Raport Badawczy
Research Report

RB/12/2014

Information technology for spatial greenhouse gas emission inventory ready to use for any part of Poland, and any time period

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Warszawa 2014

D 1.3

Version 1
Date 30.10.2012
Author LPNU, SRI
Dissemination level PP
Document reference D 1.3

GESAPU

Geoinformation technologies, spatio-temporal approaches, and full carbon account for improving accuracy of GHG inventories

Deliverable 1.3. Information technology for spatial greenhouse gas emission inventory ready to use for any part of Poland, and any time period

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Delivery Date: M38

Project Duration 24 June 2010 – 23 June 2014 (48 Months)
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This project is supported by funding by the European Commission: FP7-PEOPLE-2009-IRSES, Project n° 247645.

Project: #247645. Call: FP7-PEOPLE-2009-IRSES, Marie Curie Actions—International Research Staff Exchange Scheme (IRSES).

Work package 1. Spatially resolved greenhouse gas inventory for Poland

Deliverable 1.3.Information technology for spatial greenhouse gas emission inventory ready to use for any part of Poland, and any time period

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2. Geoinformation technology for spatial GHG inventory: residential sector

Residential sector (RS) is one of the most promising sectors for greenhouse gas emission reduction. The emissions in this sector are caused by burning of natural and liquefied gas, as well as wood, coal, and other fossil fuels, accounting for about 10% of the total emissions (National Inventory Submissions). The data on fossil fuel consumption in this sector in Poland is available only on a regional or the country level. Therefore,a methodology for spatial inventory of greenhouse gas emissions was developed (*Figure2.1*).

Performing the inventory of GHG emissions at the level of every elementary object in the residential sector consists of the following four main steps (*Figure2.2*):

- import of statistical data;
- assessment of energy demand;
- disaggregation of the statistical data on fossil fuel consumption;
- greenhouse gas emission estimation.

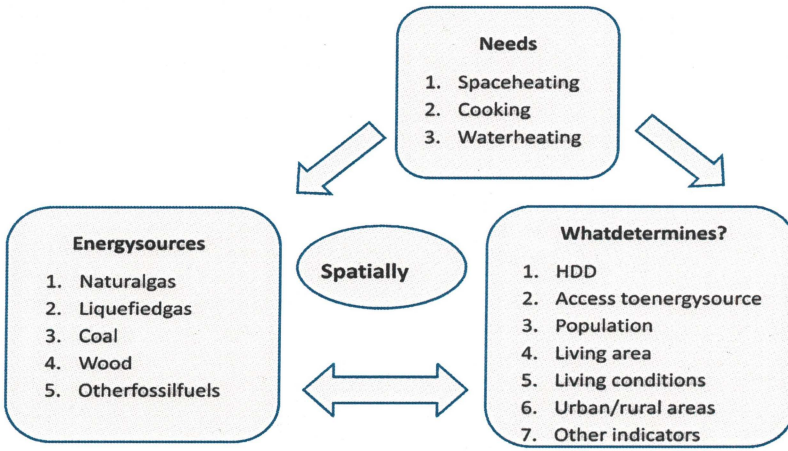

Figure 2.1. Spatial interconnection of energy needs of the households, available energy sources, and main determinants of consumers choice.

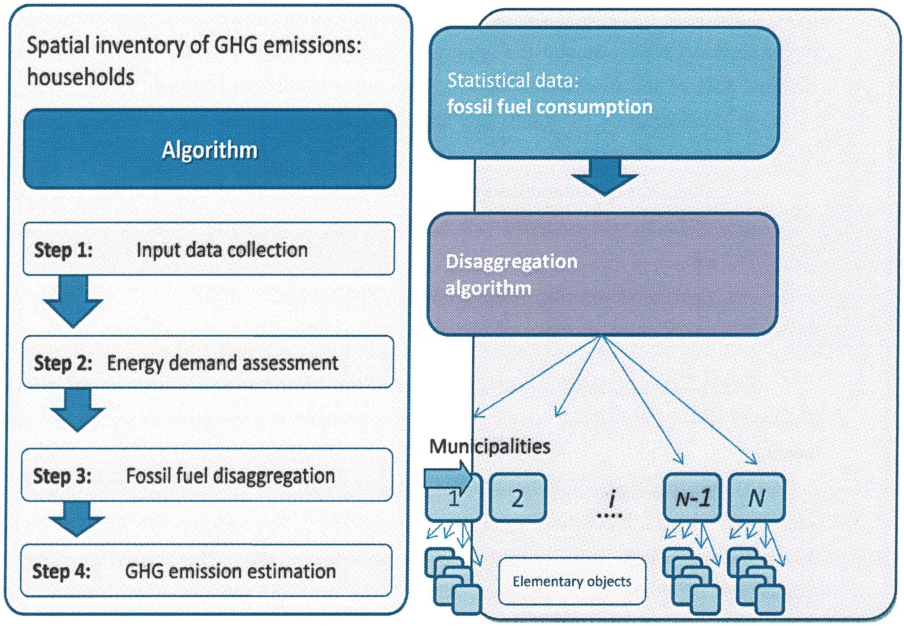

Figure 2.2. The algorithm of the spatial greenhouse gas emissions inventory in the residential sector.

The information technology has been built to apply the developed methodology. The logical structure of the algorithmis presented in *Figure2.3*. Each step of this methodology was implemented as a program module, using a geographic information system. Therefore, the information technology created consists of four program modules: Mod1preparation, Mod2energy_demand, Mod3disaggregation, and Mod4GHGemissions:

(1) Mod1preparation. The input data is given in the form of the digital maps and Excel tables with statistical data (from GUS – the Central Statistical Office of Poland),and emission factors. A population density map is used to prepare the georeferenced database with the elementary objects. In the residential sector (RS) we consider the areas, within which the population densitiesare the same as the elementary objects. The population map was created, using raster data with population density disaggregated,according to the Corine land cover 2000 (Gallego, 2010). The map was updated with the data for 2010, and additionally urban/rural characteristics were added to the map objects.

In Mod1preparation module the statistical data wasimported from Excel tables and then linked to one of the administrative maps (*Figure2.4*), based on the level of aggregation of the statistical data. The data on fossil fuel consumption was available at the regional level and was linked with the map of Polish regions. The information about the householdareas,as well as the

living conditions, was available at municipality level and was linked to the corresponding map. The imported Excel tables contain the important statistical data, which characterizesactivities in the residential sector and are essential for the greenhouse gas emission inventory. In particular:

- consumption of fossil fuel and other energy sources for individual administrative units (*Table 2.1*);
- statistical information, such as the access to centralized energy sources, the percentage of living area equipped with hot water supply, the living conditions of the households etc.;
- data on net calorific values of various fossil fuels;
- greenhouse gas emission factors.

(2) Mod2energy_demand. Energy demand in the residential sector is estimated in this module for every elementary object as the sum of the energies needed for cooking, water, and space heating.

(3) Mod3disaggregation. Fossil fuels are disaggregated from the regional level to the level of elementary objects, proportionally to the energy demands for cooking, hot water production, and space heating, which were estimated in the previous module. The access to energy sources, percentage of living areas equipped with central heating, and hot water supply, and living conditions of the households were also taken into account.

(4) Mod4GHGemissions. The greenhouse gas emissions were estimated, using the disaggregated data on fossil fuel consumption, calorific values, and emission coefficients. The calorific values of fossil fuels depend on the fuel type and its chemical characteristics, and vary by region. The burning technology in the residential sector does not differ much in different settlements, therefore it has no spatial effect on the emission factors.

Based on the statistical data for 2010, we conducted numerical experiments, using this information technology. As the result, we obtained the estimation of the greenhouse gas emissions at the level of elementary objects for 2010. The georeferenced database contains information about carbon dioxide, methane, and nitrous oxide emissions from burning every kind of fossil fuels in the residential sector, as well as the total greenhouse gas emissions in CO_2-equivalent. Every elementary object from the digital map is linked to the exact row of the georeferenced database, which contains information about greenhouse gas emissions:

- emissions of CO_2 from combustion of natural gas in RS;
- emissions of CH_4 from combustion of natural gas in RS;
- emissions of N_2O from combustion of natural gas in RS;
- emissionsfrom combustion of natural gas in RSin CO_2 -equivalent;
- emissions of CO_2 from the combustion of liquefied gas in RS;

- emissions of CH_4 from the combustion of liquefied gas in RS;
- emissions of N_2O from the combustion of liquefied gas in RS;
- emissions from the combustion of liquefied gas in RSin CO_2 -equivalent;
- emissions of CO_2 from the burning of coal in RS;
- emissions of CH_4 from the burning of coal in RS;
- emissions of N_2O from the burning of coal in RS;
- emissions from the burning of coal in RSin CO_2 -equivalent;
- emissions of CO_2 from burning wood in RS;
- emissions of CH_4 from burning wood in RS;
- emissions of N_2O from burning wood in RS;
- emissions from burning wood in RS in CO_2 -equivalent;

.....

- total emissions of CO_2 from all fossil fuels in RS;
- total emissions of CH_4 from all fossil fuels in RS;
- total emissions of N_2O from all fossil fuels in RS;
- total emissions from all fossil fuels in RS in CO_2 -equivalent.

The georeferenced database contains the results of the GHG emission inventory and consists of geographic elements and a table of the attributes:activity data, disaggregated fossil fuels consumption, and emissions of CO_2, CH_4, and N_2O from combustion of each fossil fuel. The results may be presented in the form of thematic maps using the GIS-tools. The final georeferenced database is ready to usein further research.

As an example, we presented the results of the spatial inventory of greenhouse gas emissions for one of the municipalities (Irządze) in Zawierciański district, in Silesian region (*Figure 1.5*). The map of the districts of Silesian region split by 2x2 km is presented in *Figure 1.6* (set of elementary objects of Śląskie region). The georefferenced database (*Table 1.2*) for geographic elementary objects of Zawiercianski district in Silesian region (completely or partially, within Irządze municipality, *Figure 1.7*) contains amounts of greenhouse gas emissions from burning natural gas, liquid gas, wood, coal, and other fossil fuels in the residential sector.

For correct operation of the software,the following tools areneeded:

- IBM-compatible PC;
- Windows Service Pack 2 / 2002/XP;
- MS Office (MS Excel 2003 +);
- GIS MapInfo 8,0 +;

- Module of theIPCC methodologies for MSExcel.

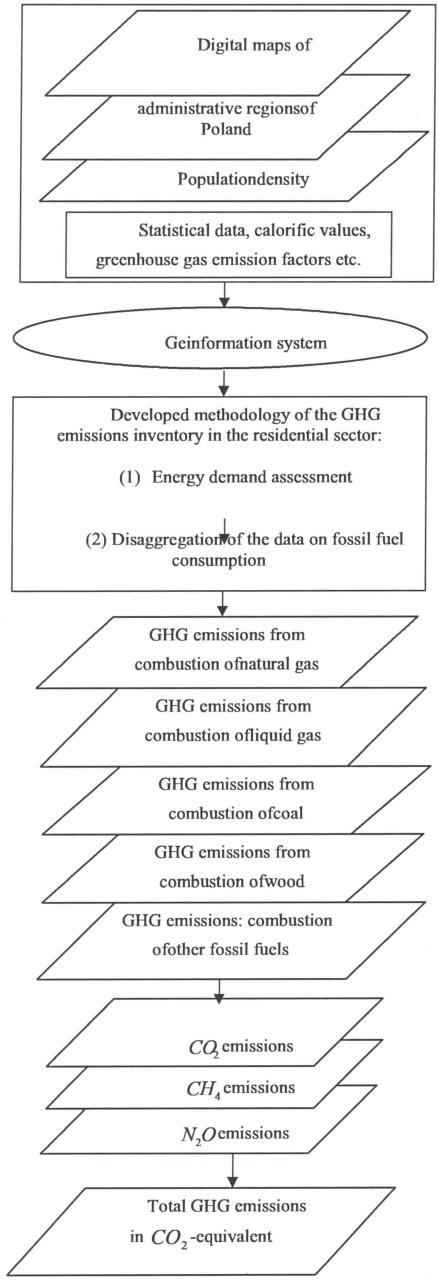

Figure 2.3. The logical structure of the software.

Table 2.1. Part of the input database at the regional level.

Kod	Voivodeship	Hard coal	Natural gas	Liquid gas	Light fuel oil
		thous. ton, 2010	TJ, 2010	thous. ton, 2010	thous. ton, 2010
kod	name	coal	ngas	lgas	
02	dolnośląskie	775	12498	26	7
04	kujawsko-pomorskie	576	5033	26	7
06	lubelskie	649	5905	32	6
08	lubuskie	188	3875	11	2
10	łódzkie	838	5628	42	10
12	małopolskie	895	15536	25	6
14	mazowieckie	1306	29645	59	18
16	opolskie	295	2576	14	3
18	podkarpackie	561	9234	9	3
20	podlaskie	248	1665	24	4
22	pomorskie	393	8244	25	7
24	śląskie	1448	17518	46	11
26	świętokrzyskie	366	3012	20	3
28	warmińsko-mazurskie	266	3408	24	5
30	wielkopolskie	848	15324	41	8
32	zachodniopomorskie	248	9326	16	5
Total		9900	148427	440	105

Figure 2.4. Administrative regions in Poland.

Figure 2.5. District Zawierciański, and one of the municipalities within the distric (Irządze).

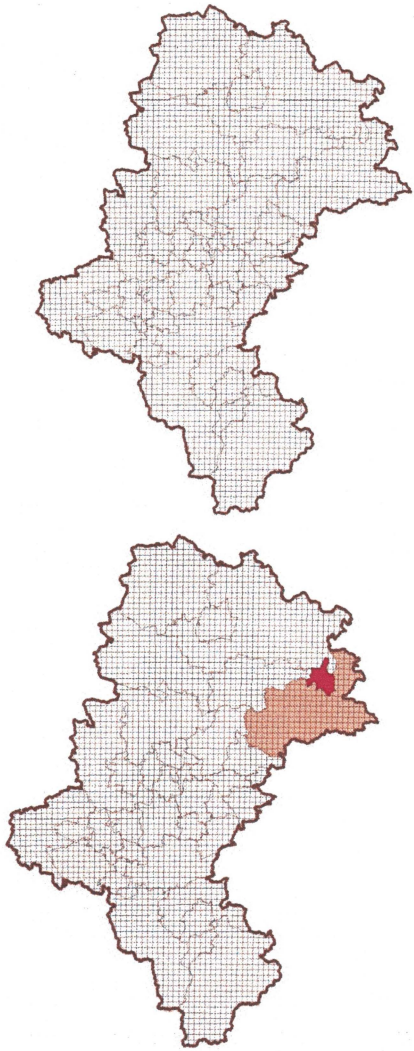

Figure 2.6. Map of the districts of Silesian region, split by 2x2 km (set of elementary objects of Silesian region).

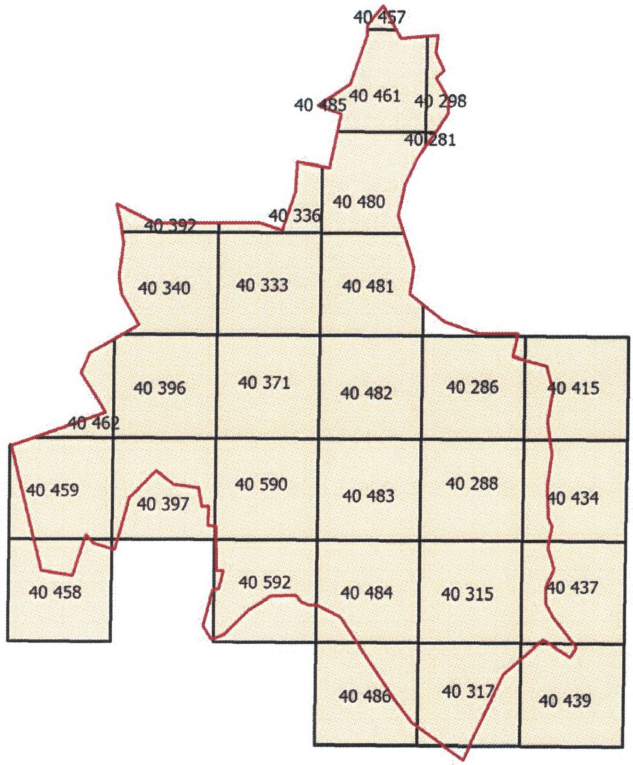

Figure 2.7. Geographic elementary objects of Zawierciański district in Silesian region(completely or partially, within Irządze municipality).

Table 2.2. Part of the georeferenced database with the results of the spatial inventory of greenhouse gas emissions in the residential sector (Silesian region, Zawierciański district, and Irządze municipality).

id	District	Id_pow	Location	Voivodeship	Area,ha	Voiv.ID	Distr.ID	popul_CLC	coal	ngas	lgas	id
40281	Zawierciański	2416	Zawiercie	Śląskie	2.75352	24	16	0.123186	0.00022173	0	1.37175e-005	40281
40286	Zawierciański	2416	Zawiercie	Śląskie	400.959	24	16	131.189	0.235179	0	0.0145145	40286
40288	Zawierciański	2416	Zawiercie	Śląskie	400.962	24	16	105.856	0.190539	0	0.0117877	40288
40298	Zawiercianski	2416	Zawiercie	Śląskie	55.3748	24	16	2.81359	0.00506443	0	0.000313311	40298
40315	Zawiercianski	2416	Zawiercie	Śląskie	400.964	24	16	27.3296	0.0491929	0	0.00304332	40315
40317	Zawierciański	2416	Zawiercie	Śląskie	400.966	24	16	43.0047	0.0665425	0	0.00372426	40317
40333	Zawiercianski	2416	Zawiercie	Śląskie	400.965	24	16	122.225	0.220003	0	0.0136105	40333
40336	Zawiercianski	2416	Zawiercie	Śląskie	100.464	24	16	26.4941	0.0476891	0	0.00295028	40336
40340	Zawiercianski	2416	Zawiercie	Śląskie	363.37	24	16	104.874	0.188772	0	0.0116784	40340
40371	Zawiercianski	2416	Zawiercie	Śląskie	400.964	24	16	126.092	0.226964	0	0.0140411	40371
40392	Zawiercianski	2416	Zawiercie	Śląskie	46.6113	24	16	5.85124	0.0105322	0	0.000651571	40392
40396	Zawiercianski	2416	Zawiercie	Śląskie	400.265	24	16	145.02	0.261034	0	0.0161489	40396
40397	Zawiercianski	2416	Zawiercie	Śląskie	400.968	24	16	120.376	0.174399	0	0.00936488	40397
40415	Zawiercianski	2416	Zawiercie	Śląskie	400.957	24	16	109.845	0.158163	0	0.00834836	40415
40434	Zawiercianski	2416	Zawiercie	Śląskie	400.96	24	16	87.3371	0.128403	0	0.00689771	40434
40437	Zawiercianski	2416	Zawiercie	Śląskie	400.962	24	16	84.9228	0.122399	0	0.0064661	40437
40439	Zawiercianski	2416	Zawiercie	Śląskie	400.964	24	16	84.1243	0.114974	0	0.00578928	40439
40457	Zawiercianski	2416	Zawiercie	Śląskie	14.4061	24	16	0.573647	0.00103256	0	6.3879e-005	40457
40458	Zawiercianski	2416	Zawiercie	Śląskie	400.971	24	16	77.2153	0.0909407	0	0.0040073	40458
40459	Zawiercianski	2416	Zawiercie	Śląskie	396.981	24	16	112.302	0.191279	0	0.0114674	40459
40461	Zawiercianski	2416	Zawiercie	Śląskie	297.299	24	16	28.5477	0.0513855	0	0.00317896	40461
40462	Zawiercianski	2416	Zawiercie	Śląskie	100.012	24	16	33.5417	0.0603743	0	0.00373504	40462
40480	Zawiercianski	2416	Zawiercie	Śląskie	326.183	24	16	150.88	0.271582	0	0.0168014	40480
40481	Zawiercianski	2416	Zawiercie	Śląskie	366.835	24	16	1231.97	2.21753	0	0.137187	40481
40482	Zawiercianski	2416	Zawiercie	Śląskie	400.961	24	16	131.962	0.237529	0	0.0146947	40482
40483	Zawierciański	2416	Zawiercie	Śląskie	400.964	24	16	118.653	0.213573	0	0.0132127	40483
40484	Zawierciański	2416	Zawiercie	Śląskie	400.966	24	16	21.3786	0.0372712	0	0.00226501	40484
40485	Zawierciański	2416	Zawiercie	Śląskie	0.65363	24	16	0.173794	0.00031282	0	1.9353e-005	40485
40486	Zawierciański	2416	Zawiercie	Śląskie	400.968	24	16	15.9651	0.0194703	0	0.000892325	40486
40590	Zawierciański	2416	Zawiercie	Śląskie	400.968	24	16	129.488	0.232925	0	0.0144047	40590
40592	Zawierciański	2416	Zawiercie	Śląskie	400.97	24	16	69.5922	0.107046	0	0.00600855	40592

Table 2.2(Continuation 1). Part of the georeferenced database with the results of the spatial inventory of greenhouse gas emissions in the residential sector (Silesian region, Zawierciański district, and Irządze municipality).

id	oil	coke	wood	Lignite	coalCO2	coalCH4	coalN2O	woodCO2
40281	3.28026e-006	2.5525e-006	0.000132284	5.3948e-006	0.598223	0.00191738	9.58691e-006	0.137935
40286	0.00347086	0.00270728	0.140306	0.00572194	634.5	2.03365	0.0101683	146.3
40288	0.00281879	0.0021934	0.113674	0.00463584	514.063	1.64764	0.00823819	118.53
40298	7.49221e-005	5.82997e-005	0.0030214	0.000123219	13.6636	0.0437935	0.000218968	3.15048
40315	0.00072775	0.00056629	0.0293482	0.00119687	132.72	0.425385	0.00212692	30.6019
40317	0.000890585	0.000766012	0.0396988	0.00161899	179.528	0.575412	0.00287706	41.3947
40333	0.00325469	0.00253259	0.131252	0.00535273	593.558	1.90243	0.00951215	136.86
40336	0.000705502	0.000548978	0.0284509	0.00116028	128.663	0.41238	0.0020619	29.6664
40340	0.00279266	0.00217307	0.11262	0.00459287	509.298	1.63237	0.00816183	117.431
40371	0.00335765	0.00261272	0.135405	0.00552207	612.336	1.96262	0.00981308	141.189
40392	0.00015581	0.000121242	0.0062834	0.000256249	28.4152	0.0910744	0.000455372	6.55183
40396	0.00386169	0.00300492	0.155731	0.00635102	704.257	2.25724	0.0112862	162.384
40397	0.00223943	0.00200762	0.104045	0.00424317	470.52	1.50808	0.00754039	108.49
40415	0.00199635	0.00182071	0.094359	0.00384814	426.716	1.36768	0.0068384	98.3901
40434	0.00164945	0.00147812	0.0766042	0.00312407	346.424	1.11033	0.00555167	79.8767
40437	0.00154624	0.00140901	0.0730226	0.002978	330.227	1.05842	0.0052921	76.1421
40439	0.00138439	0.00132353	0.0685926	0.00279734	310.194	0.994211	0.00497106	71.5229
40457	1.52754e-005	1.18864e-005	0.000616016	2.51223e-005	2.78579	0.0089288	4.4644e-005	0.642332
40458	0.000958267	0.00104687	0.0542546	0.00221261	245.353	0.786389	0.00393195	56.5723
40459	0.00274221	0.00220192	0.114115	0.00465385	516.06	1.65404	0.00827019	118.99
40461	0.000760187	0.00059153	0.0306562	0.00125022	138.636	0.444345	0.00222172	31.9659
40462	0.000893162	0.000695005	0.0360189	0.00146892	162.887	0.522073	0.00261037	37.5576
40480	0.00401773	0.00312635	0.162024	0.00660765	732.715	2.34845	0.0117422	168.946
40481	0.0328056	0.0255273	1.32296	0.0539529	5982.77	19.1756	0.0958778	1379.48
40482	0.00351395	0.00273434	0.141708	0.00577912	640.841	2.05398	0.0102699	147.762
40483	0.00315955	0.00245857	0.127416	0.00519628	576.209	1.84682	0.00923412	132.859
40484	0.000541634	0.000429051	0.0222357	0.000906816	100.556	0.322294	0.00161147	23.1856
40485	4.62789e-006	3.60113e-006	0.00018663	7.61113e-006	0.84399	0.0027051	1.35255e-005	0.194603
40486	0.000213382	0.000224135	0.0116159	0.000473718	52.53	0.168365	0.000841827	12.1121
40590	0.00344461	0.00268134	0.138961	0.0056671	628.419	2.01416	0.0100708	144.898
40592	0.00143683	0.00123227	0.0638627	0.00260445	288.804	0.925654	0.00462827	66.591

Table 2.2(Continuation 2). Part of the georeferenced database with the results of the spatial inventory of greenhouse gas emissions in the residential sector (Silesian region, Zawierciański district, and Irządze municipality).

id	ngasCO2	lgasCO2	cokeCO2	oilCO2	ligniteCO2	woodCH4	ngasCH4	lgasCH4	cokeCH4
40281	0	0.0405219	0.00762993	0.0109898	0.00491406	0.000377009	0	3.24487e-006	2.15941e-005
40286	0	42.8763	8.09261	11.6283	5.21205	0.399872	0	0.0034334	0.0229036
40288	0	34.8212	6.55652	9.44368	4.22273	0.323971	0	0.00278837	0.0185562
40298	0	0.925531	0.17427	0.251009	0.112238	0.00861099	0	7.41136e-005	0.000493216
40315	0	8.99007	1.69275	2.43816	1.09022	0.0836422	0	0.000719897	0.00479081
40317	0	11.0016	2.28976	2.9837	1.47472	0.113142	0	0.000880975	0.00648046
40333	0	40.2059	7.57043	10.9041	4.87574	0.37407	0	0.00321956	0.0214257
40336	0	8.71524	1.641	2.36362	1.05689	0.0810852	0	0.000697889	0.00464435
40340	0	34.4984	6.49575	9.35615	4.18359	0.320968	0	0.00276252	0.0183842
40371	0	41.4779	7.80993	11.249	5.02999	0.385904	0	0.00332142	0.0221036
40392	0	1.92476	0.362416	0.522006	0.233414	0.0179077	0	0.000154129	0.00102571
40396	0	47.7044	8.98232	12.9377	5.78507	0.443834	0	0.00382002	0.0254217
40397	0	27.6642	6.00116	7.50267	3.86505	0.296529	0	0.00221526	0.0169844
40415	0	24.6614	5.44247	6.68829	3.50523	0.268923	0	0.00197481	0.0154032
40434	0	20.3761	4.41841	5.5261	2.84568	0.218322	0	0.00163165	0.0125049
40437	0	19.1011	4.21182	5.18032	2.71263	0.208114	0	0.00152956	0.0119203
40439	0	17.1017	3.95631	4.63808	2.54806	0.195489	0	0.00136945	0.0111971
40457	0	0.188701	0.0355308	0.0511767	0.0228836	0.00175564	0	1.51106e-005	0.000100559
40458	0	11.8377	3.12931	3.21045	2.01544	0.154626	0	0.000947926	0.00885655
40459	0	33.8752	6.58199	9.18714	4.23913	0.325229	0	0.00271262	0.0186283
40461	0	9.39077	1.7682	2.54683	1.13881	0.0873703	0	0.000751984	0.00500434
40462	0	11.0334	2.07751	2.99233	1.33802	0.102654	0	0.000883524	0.00587975
40480	0	49.632	9.34528	13.4605	6.01883	0.461769	0	0.00397438	0.0264489
40481	0	405.256	76.3062	109.908	49.145	3.77044	0	0.0324516	0.215961
40482	0	43.4087	8.17348	11.7727	5.26413	0.403868	0	0.00347603	0.0231325
40483	0	39.0307	7.34915	10.5853	4.73322	0.363136	0	0.00312546	0.0207995
40484	0	6.69093	1.28252	1.81462	0.826008	0.0633718	0	0.000535789	0.00362977
40485	0	0.0571694	0.0107645	0.0155047	0.00693289	0.000531895	0	4.57795e-006	3.04656e-005
40486	0	2.63596	0.669984	0.714887	0.431504	0.0331052	0	0.00021108	0.00189618
40590	0	42.5521	8.01505	11.5403	5.1621	0.396039	0	0.00340744	0.0226841
40592	0	17.7495	3.6835	4.81375	2.37236	0.182009	0	0.00142132	0.010425

Table 2.2(Continuation3). Part of the georeferenced database with the results of the spatial inventory of greenhouse gas emissions in the residential sector (Silesian region, Zawierciański district, and Irządze municipality).

id	oilCH4	ligniteCH4	ngasN2O	lgasN2O	cokeN2O	oilN2O	ligniteN2O	woodN2O
40281	1.43488e-006	1.34056e-005	0	6.48974e-008	1.07971e-007	8.60929e-008	6.70281e-008	5.02679e-006
40286	0.00151825	0.0142186	0	6.8668e-005	0.000114518	9.10951e-005	7.10928e-005	0.00533162
40288	0.00123302	0.0115197	0	5.57674e-005	9.2781e-005	7.39811e-005	5.75984e-005	0.00431961
40298	3.27731e-005	0.000306188	0	1.48227e-006	2.46608e-006	1.96638e-006	1.53094e-006	0.000114813
40315	0.000318339	0.00297413	0	1.43979e-005	2.39541e-005	1.91003e-005	1.48707e-005	0.00111523
40317	0.000389567	0.00402307	0	1.76195e-005	3.24023e-005	2.3374e-005	2.01153e-005	0.00150855
40333	0.00142369	0.0133011	0	6.43913e-005	0.000107129	8.54215e-005	6.65055e-005	0.00498759
40336	0.000308607	0.00288321	0	1.39578e-005	2.32218e-005	1.85164e-005	1.44161e-005	0.00108114
40340	0.00122159	0.0114129	0	5.52505e-005	9.1921e-005	7.32953e-005	5.70645e-005	0.00427957
40371	0.00146873	0.0137219	0	6.64284e-005	0.000110518	8.8124e-005	6.86094e-005	0.00514538
40392	6.81559e-005	0.000636759	0	3.08258e-006	5.12853e-006	4.08936e-006	3.18379e-006	0.000238769
40396	0.00168921	0.0157818	0	7.64003e-005	0.000127108	0.000101353	7.89088e-005	0.00591779
40397	0.000979589	0.0105439	0	4.43052e-005	8.49221e-005	5.87754e-005	5.27196e-005	0.00395372
40415	0.00087326	0.00956232	0	3.94961e-005	7.70161e-005	5.23956e-005	4.78116e-005	0.00358564
40434	0.000721518	0.00776305	0	3.26331e-005	6.25246e-005	4.32911e-005	3.88153e-005	0.00291096
40437	0.00067637	0.00740009	0	3.05911e-005	5.96013e-005	4.05822e-005	3.70004e-005	0.00277486
40439	0.000605573	0.00695116	0	2.73891e-005	5.59855e-005	3.63344e-005	3.47558e-005	0.00260652
40457	6.68191e-006	6.24269e-005	0	3.02212e-007	5.02794e-007	4.00914e-007	3.12134e-007	2.34086e-005
40458	0.000419173	0.00549814	0	1.89585e-005	4.42828e-005	2.51504e-005	2.74907e-005	0.00206167
40459	0.00119952	0.0115644	0	5.42524e-005	9.31414e-005	7.19713e-005	5.78221e-005	0.00433639
40461	0.000332527	0.0031067	0	1.50397e-005	2.50217e-005	1.99516e-005	1.55335e-005	0.00116494
40462	0.000390695	0.00365014	0	1.76705e-005	2.93987e-005	2.34417e-005	1.82507e-005	0.00136872
40480	0.00175747	0.0164195	0	7.94875e-005	0.000132245	0.000105448	8.20974e-005	0.00615691
40481	0.0143501	0.134068	0	0.000649032	0.0010798	0.000861007	0.000670342	0.0502725
40482	0.0015371	0.0143606	0	6.95207e-005	0.000115662	9.22262e-005	7.18032e-005	0.0053849
40483	0.00138208	0.0129123	0	6.25092e-005	0.000103997	8.29248e-005	6.45616e-005	0.00484181
40484	0.000236926	0.00225336	0	1.07158e-005	1.81489e-005	1.42156e-005	1.12668e-005	0.000844958
40485	2.02437e-006	1.8913e-005	0	9.1559e-008	1.52328e-007	1.21462e-007	9.45652e-008	7.09194e-006
40486	9.33394e-005	0.00117715	0	4.22159e-006	9.48091e-006	5.60037e-006	5.88574e-006	0.000441403
40590	0.00150677	0.0140823	0	6.81487e-005	0.000113421	9.04062e-005	7.04114e-005	0.00528052
40592	0.000628509	0.00647183	0	2.84264e-005	5.2125e-005	3.77105e-005	3.23592e-005	0.00242678

Table 2.2(Continuation 4). Part of the georeferenced database with the results of the spatial inventory of greenhouse gas emissions in the residentialsector (Silesian region, Zawierciański district, and Irządze municipality).

id	ngasCO2eq	lgasCO2eq	woodCO2eq	oilCO2eq	ligniteCO2eq	cokeCO2eq	coalCO2eq	CO2
40281	0	0.0406102	0.147411	0.0110466	0.00521635	0.00811687	0.64146	0.800214
40286	0	42.9697	156.35	11.6884	5.53268	8.60909	680.359	848.609
40288	0	34.897	126.673	9.49251	4.4825	6.97497	551.217	687.637
40298	0	0.927547	3.3669	0.252307	0.119143	0.185392	14.6511	18.2771
40315	0	9.00966	32.7041	2.45076	1.15729	1.80079	142.312	177.533
40317	0	11.0256	44.2384	2.99912	1.56544	2.4359	192.504	238.673
40333	0	40.2935	146.261	10.9604	5.17568	8.05358	636.458	793.974
40336	0	8.73422	31.7043	2.37584	1.12191	1.74573	137.962	172.106
40340	0	34.5735	125.498	9.40452	4.44095	6.91031	546.108	681.264
40371	0	41.5682	150.888	11.3072	5.33942	8.30836	656.593	819.092
40392	0	1.92896	7.00191	0.524705	0.247773	0.385546	30.4689	38.0096
40396	0	47.8083	173.539	13.0046	6.14095	9.55558	755.158	942.051
40397	0	27.7244	115.943	7.54147	4.10282	6.38416	504.528	624.044
40415	0	24.7151	105.149	6.72288	3.72086	5.78982	457.558	565.404
40434	0	20.4205	85.3639	5.55468	3.02073	4.70039	371.462	459.467
40437	0	19.1427	81.3727	5.2071	2.8795	4.48062	354.095	437.575
40439	0	17.139	76.4362	4.66206	2.70481	4.2088	332.613	409.961
40457	0	0.189112	0.686457	0.0514413	0.0242913	0.0377984	2.98713	3.72641
40458	0	11.8635	60.4586	3.22705	2.13942	3.32903	263.087	322.119
40459	0	33.949	127.165	9.23464	4.49991	7.00206	553.359	688.934
40461	0	9.41123	34.1618	2.56	1.20887	1.88105	148.656	185.446
40462	0	11.0575	40.1376	3.0078	1.42033	2.2101	174.66	217.886
40480	0	49.7401	180.551	13.5301	6.38909	9.9417	785.673	980.118
40481	0	406.139	1474.24	110.476	52.1683	81.1761	6415.18	8002.87
40482	0	43.5032	157.912	11.8335	5.58797	8.69512	687.158	857.221
40483	0	39.1158	141.986	10.6401	5.0244	7.81818	617.855	770.767
40484	0	6.70551	24.7784	1.824	0.876821	1.36437	107.824	134.356
40485	0	0.057294	0.207971	0.0155848	0.00735938	0.0114515	0.90499	1.12896
40486	0	2.6417	12.9441	0.718583	0.458048	0.712743	56.3266	69.0944
40590	0	42.6448	154.851	11.6	5.47965	8.52658	673.838	840.586
40592	0	17.7881	71.1654	4.83864	2.5183	3.91858	309.678	384.014

Table 2.2(Continuation 5). Part of the georeferenced database with the results of the spatial inventory of greenhouse gas emissions in the residential sector (Silesian region, Zawierciański district, and Irządze municipality).

id	CH4	N2O	CO2	CO2eq
40281	0.00233407	1.49397e-005	0.800214	0.853861
40286	2.4756	0.0158453	848.609	905.508
40288	2.00571	0.0128379	687.637	733.737
40298	0.0533108	0.000341226	18.2771	19.5024
40315	0.51783	0.00331448	177.533	189.435
40317	0.700327	0.00447912	238.673	254.768
40333	2.31587	0.0148232	793.974	847.202
40336	0.502	0.00321315	172.106	183.644
40340	1.98712	0.0127189	681.264	726.936
40371	2.38914	0.0152921	819.092	874.005
40392	0.110867	0.000709625	38.0096	40.5578
40396	2.74778	0.0175877	942.051	1005.21
40397	1.83533	0.0117348	624.044	666.223
40415	1.66442	0.0106408	565.404	603.655
40434	1.35128	0.0086399	459.467	490.523
40437	1.28806	0.00823474	437.575	467.177
40439	1.20982	0.00773204	409.961	437.764
40457	0.0108692	6.95706e-005	3.72641	3.97623
40458	0.956737	0.0061095	322.119	344.104
40459	2.01337	0.0128838	688.934	735.209
40461	0.540911	0.00346221	185.446	197.878
40462	0.635531	0.00406785	217.886	232.493
40480	2.85882	0.0182984	980.118	1045.83
40481	23.3428	0.14941	8002.87	8539.38
40482	2.50035	0.016004	857.221	914.69
40483	2.24818	0.0143899	770.767	822.44
40484	0.392322	0.00251078	134.356	143.373
40485	0.00329297	2.10773e-005	1.12896	1.20465
40486	0.204848	0.00130842	69.0944	73.8019
40590	2.45188	0.0156937	840.586	896.941
40592	1.12661	0.00720568	384.014	409.907

Table 2.3. Explanation of columns of the attribute in Table 2.2.

Column name	Explanation
Id	elementary object ID
Powiat	name of the district
Id_pow	district ID
Siedziba	name of the district center
Wojewodztwo	name of the region
Pow_ha	area of elementary object (ha)
Woj	region ID
Pow	district ID
popul_CLC	Population
Coal	amount of the coal consumed in the residential sector (thousand ton)
Ngas	amount of the natural gas consumed in the residential sector (TJ)
Lgas	amount of the liquid gas consumed in the residential sector (thousand ton)
Oil	amount of the oil consumed in the residential sector (thousand ton)
Coke	amount of the coke consumed in the residential sector (thousand ton)
wood	amount of the wood consumed in the residential sector (thousand ton)
lignite	amount of the lignite consumed in the residential sector (thousand ton)
coalCO2	CO_2 emissions from burning coal (kg)
coalCH4	CH_4 emissions from burning coal (kg)
coalN2O	N_2O emissions from burning coal (kg)
woodCO2	CO_2 emissions from burning wood (kg)
ngasCO2	CO_2 emissions from burning natural gas (kg)
lgasCO2	CO_2 emissions from burning liquid gas (kg)
cokeCO2	CO_2 emissions from burning coke (kg)
oilCO2	CO_2 emissions from burning oil (kg)
ligniteCO2	CO_2 emissions from burning lignite (kg)
woodCH4	CH_4 emissions from burning wood (kg)
ngasCH4	CH_4 emissions from burning natural gas (kg)
lgasCH4	CH_4 emissions from burning liquid gas (kg)
cokeCH4	CH_4 emissions from burning coke (kg)
oilCH4	CH_4 emissions from burning oil (kg)
ligniteCH4	CH_4 emissions from burning lignite (kg)
ngasN2O	N_2O emissions from burning natural gas (kg)
lgasN2O	N_2O emissions from burning liquid gas (kg)
cokeN2O	N_2O emissions from burning coke (kg)
oilN2O	N_2O emissions from burning oil (kg)
ligniteN2O	N_2O emissions from burning lignite (kg)
woodN2O	N_2O emissions from burning wood (kg)
ngasCO2eq	greenhouse gas emissions from burning natural gas in CO_2-equivalent (kg)
lgasCO2eq	greenhouse gas emissions from burning natural gas in CO_2-equivalent (kg)
woodCO2eq	greenhouse gas emissions from burning natural gas in CO_2-equivalent (kg)
oilCO2eq	greenhouse gas emissions from burning natural gas in CO_2-equivalent (kg)

ligniteCO2eq	greenhouse gas emissions from burning natural gas in CO_2-equivalent (kg)
cokeCO2eq	greenhouse gas emissions from burning natural gas in CO_2-equivalent (kg)
coalCO2eq	greenhouse gas emissions from burning natural gas in CO_2-equivalent (kg)
CO2	CO_2 emissions in the residential sector (kg)
CH4	CH_4 emissions in the residential sector (kg)
N2O	N_2O emissions in the residential sector (kg)
CO2eq	greenhouse gas emissions in the residential sector in CO_2-equivalent (kg)

3. Geoinformation technology for spatial GHG inventory: transport sector

Based on the IPCC classification, the road transport subcategory includes GHG emissions from fuel combustion and evaporation from the motor transport, which consists of passenger cars, light and heavy duty vehicles, buses, tractors, motorcycles, and mopeds. According to the Poland's National Inventory Report to the United Nations Framework on Climate Change, the transport sector is responsible for 14,5% of all the GHG emissions in Poland in 2010 (NIR, 2011).

On a scale of the whole country, the distribution of GHG emission sources in road transport is very irregular — automobile transport is highly dense in large cities, when compared to low emissions in villages and uninhabited areas. In order to adequately grasp this diversity, the territory of Poland is split into cells using the 2 x 2 km grid and the administrative borders of municipalities. The spatial inventory of GHG emissions consists of carrying out bottom-up inventory for each grid cell, and then summing up the inventory results for all the fuel and vehicle types.

The GHG emission from the road transport in a grid cell is in turn a sum of emissions from all the emission sources, which are fully or partially located within its borders (Hamal, 2008). In order to build the spatial cadastre of certain gas emissions, it is necessary to calculate its territorially distributed specific emissions. Such specific emission values are calculated, using the parameters and data, which describe emission process for a selected activity, and which also take into account geographic location of the emission sources. That is, the specific GHG emission is a function of: (i) the activity intensity parameters in a certain territory and a period of time, (ii) the proper emission coefficients, as well as (iii) the geographic coordinates of the territory under investigation.

In the road transport sector, motor vehicles operating on roads are the sources of GHG emissions. For practical implementation of spatially distributed inventory, motorways and highways are interpreted as line GHG emission sources in this sector. Urban road networksare treated as area sources, due to a very high density, and only main urban roads are separately treated as line sources.

In general, the level of GHG emissions in a grid cell depends on the amount of fuel consumed by transport within this cell borders. That is, the amount of fossil fuel used by transport is disaggregated to specific emission sources before the spatial GHG emission inventory from road transport is attempted. The obtained fuel quantity is multiplied by the corresponding emission factors to calculate emissions for a certain GHG. For the road transport, the emission sources are as follows:

- the automobile roads of all types, including main roads that, cross settlements;
- the territories of settlements, which are the area sources of emissions from the fuel combustion in transport on the internal road network of a settlement (on the roads and streets of settlements that ,are within its administrative borders).

Thefollowingsteps are taken to disaggregate the regional fuel combustion data to individual roads and settlements.

1. The fuel used for road transport in an administrative unit is disaggregated by settlements and suburban areas for large cities within the unit. If exact information on fuel consumption on road transport sector is available for some cities, it is directly located to the territory of the city and suburban areas around it. For small cities, disaggregation of transport fuel is proportional to the population density.
2. The fuel used in road transport sector in a certain administrative unit (district – in Polish 'powiat' – or voivodeship) is disaggregated to the automobile roads of the unit according to the developed algorithms (including main roads within settlements). This step takes into account the length and width of each road segment, its capacity, and current state. The amount of fuel used in suburban territories, which were found in p.1, is disaggregated to road segments located within their borders.
3. For each emission source, which is fully or partially located within a grid cell, the total amount of fuel used by a certain road transport category is calculated taking into account either the area of emission source – for area emission sources, or the length of an object – for line sources. In this approach the following assumptions are taken: (a) a part of the fuel that, was bought in a settlement for the road transport purposes is used (burnt) within its borders (for the needs of internal urban transport), (b) a large part of the fuel is used on automobile roads in suburban territories that, are located within a certain distance from the administrative borders of the settlement, and (c) the rest of the fuel is used outside the settlements and located to the road segments according to the road maps.

The territory of a smaller settlement is treated as one zone (n=1 below), while two level buffer zones are built around administrative borders of each city with population over 20,000 people. The first one (n=2 below) has the width of a half of the radius of the city area, and the second one (n=3 below) the width of one radius:

$$\widetilde{Z} = \begin{cases} Z_{1,i}, \text{ the territory of settlement } i; \\ Z_{2,i}, \text{ the zone radius} = \dfrac{1}{2}\sqrt{S(i)/\pi}; \\ Z_{3,i}, \text{ the zone radius} = \sqrt{S(i)/\pi}, \end{cases} \tag{3.1}$$

where:

$Z_{n,i}$ is the n-th buffer zone around the$i$-th settlement,

$S(i)$ is the settlement's area.

The reason for building the zones, is to identify suburban roads and road segments with a very dense traffic (*Figure 3.1*).

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