Spatial GHG inventory and uncertainty analysis: A case study for electricity generation in Poland and Ukraine

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Energy Subsector: Main Activity Electricity and Heat Production

IPCC

Energy Industries

1A1a Main Activity Electricity and Heat Production

1A1b Petroleum Refining

……..

……..

1A1a i Electricity Generation

1A1a ii Combined Heat and Power Generation

1A1a iii Heat Plants

Statistical data (Poland)

Electricity and Combined (power/heat) Plants

Public (Zawodowe) — IPCC: 1A1a

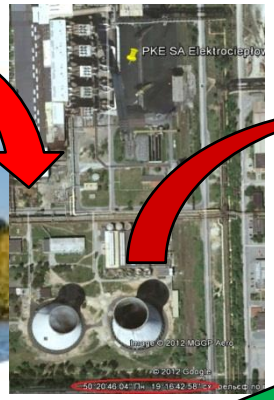
Autoproducing (Przemysłowe) — IPCC: 1A2

Essence of the approach

Statistical Data

Parameters

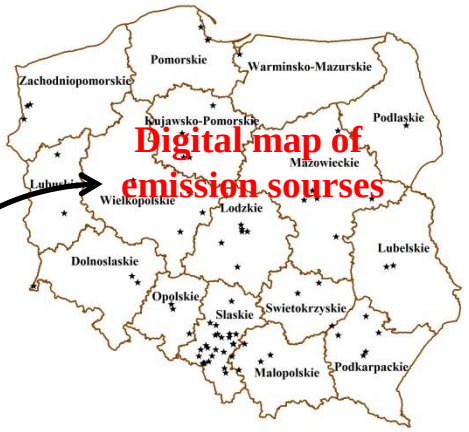
Other Information



Disaggregation algorithms and data processing

$$D_{En,f} - \sum_k D_{En,k,f}$$

$$\left(\xi_{En,n_p}\right) = \frac{D_{En,f} - \sum_k D_{En,k,f}}{\sum_{n_p} W\left(\xi_{En,i}\right) - \sum_{n_k} W\left(\xi_{En,k}\right)} W\left(\xi_{En,n_p}\right)$$



Digital map of emission sourses

ID	Name	Y		C_2010
1	Білоцерківська ТЕЦ	30,1866	49,7968	120	127,899
2	Бурштинська ТЕС	24,6349	49,1069	2 400	2 131,6
3	Вуглегірська ТЕС	38,2001	48,4639	2 800	2 984,24
4	Дарницька ТЕЦ (Київська ТЕЦ-4, «Укр-К	30,6[illegible]	50,4473	180	191,844
5	Дніпродзержинська ТЕЦ	34,6211	48,5321	61,6	65,6534

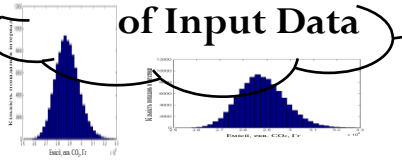
Geo-referenced database of input data

Mathematical model:

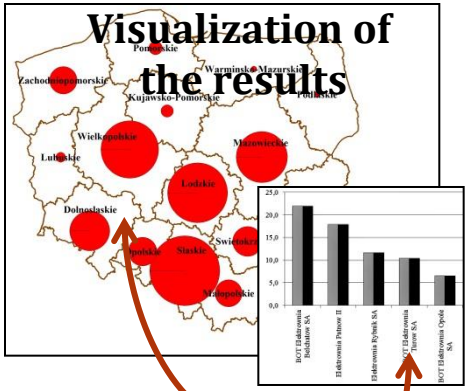
$$E_{En}^{g}\left(\xi_{En,n_p}\right) = \sum_{f \in F} Q_{En,f}\left(\xi_{En,n_p}\right) K_{En,f}^{g}\, C_f\left(\xi_{En,n_p}\right)$$

fuel types, greenhouse gases, calorific values …….

Uncertainties of Input Data



Visualization of the results



Uncertainties analysis

$$f(x;\mu,\sigma) = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left(-\frac{(\ln(x)-\mu)^2}{2\sigma^2}\right),\ x>0$$

Monte-Carlo method, 95%, ……

All plants

Geo-referenced database of results

Emission CO_2, CH_4,N_2O: ???

Uncertainies: ???

Cadaster

Regions

Electricity Generation: input data

Statistical Data

- GUS, official statistical data
- Official web sites of associations and plants

Emission factors

- IPCC
- Individual Power Plants
- NIR, national data

Digital maps

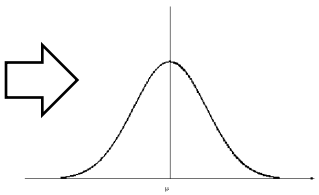
- Google Earth
- Coordinates of Power Plants

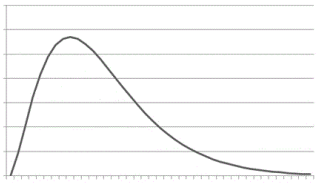
Mathematical description: “Electricity Generation” and “Combined Heat and Power Generation”

$$E^{g}_{En}\left(\xi_{En,n_p}\right)=\sum_{f\in F} Q^{R}_{En,f}\cdot F_{En,f}\left(\xi_{En,n_p}\right)\cdot K^{g}_{En,f}\cdot C_{f}\left(\xi_{En,n_p}\right)$$

$E^{g}_{En}\left(\xi_{En,n_p}\right)$	the emission of the *g*-th GHG from fuel burning of a point source;
$Q^{R}_{En,f}$	the amount of the *f*-th fuel type consumed in region *R*;
$F_{En,f}\left(\xi_{En,n_p}\right)$	dissagregation coefficient the *f*-th fuel type
$K^{g}_{En,f}$	the emission factor of the *g*-th gas from burning the *f*-th fuel type
$C_{f}\left(\xi_{En,n_p}\right)$	the calorific value of the *f*-th fuel type for point-type source

Uncertainties distributions of the model parameters:

$Q_{En,f}\left(\xi_{En,n_p}\right)$ ⇨ 

$K^{g}_{En,f}, C_{f}\left(\xi_{En,n_p}\right)$ ⇨ 

Principles of forming geo-referenced input data for modeling the emission processes

Electricity production:

Point-type sources

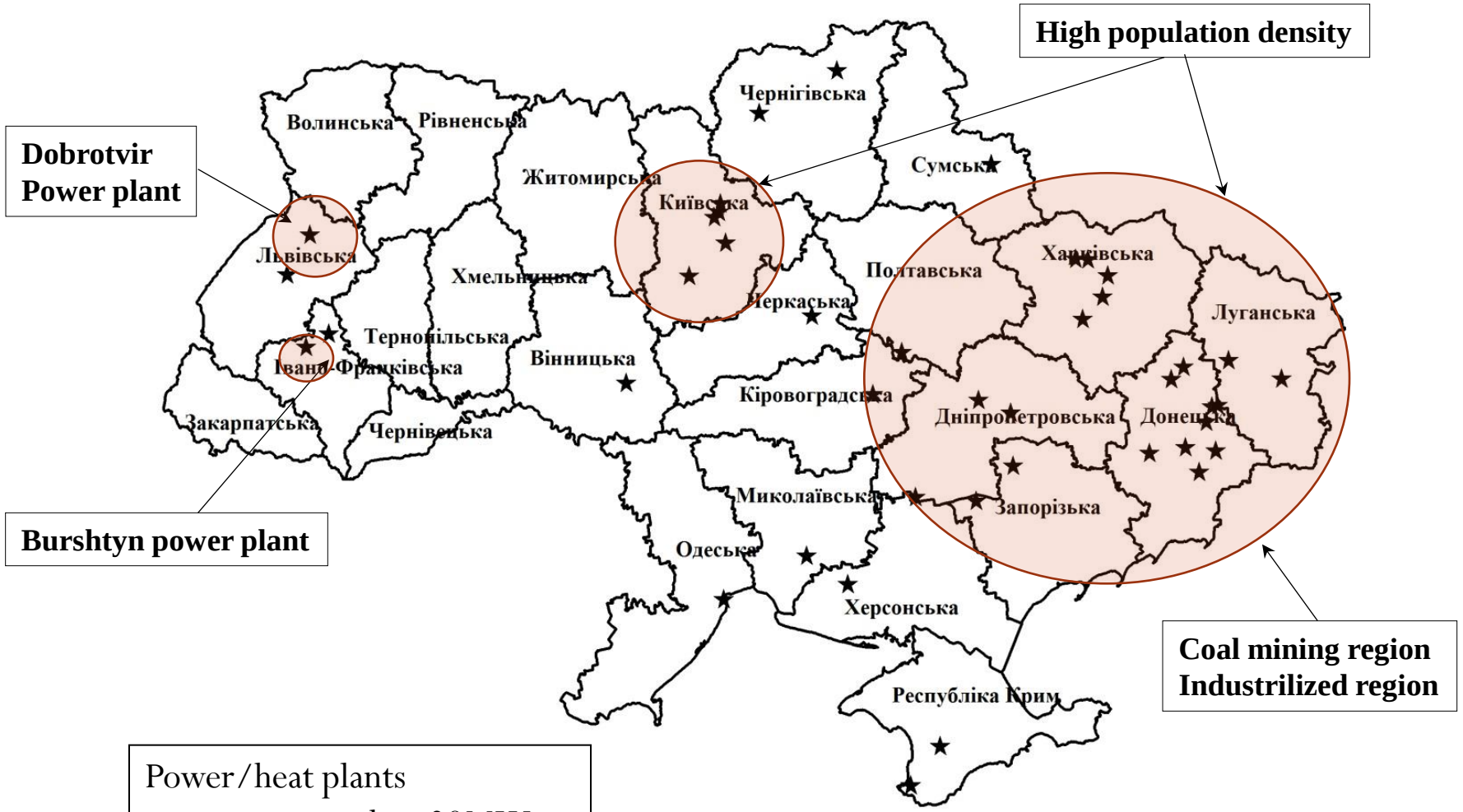
High population density

79 heat/power plants
22 – in Silesia region

Power/heat plants power is more than 20MW

Principles of forming geo-referenced input data for modeling the emission processes

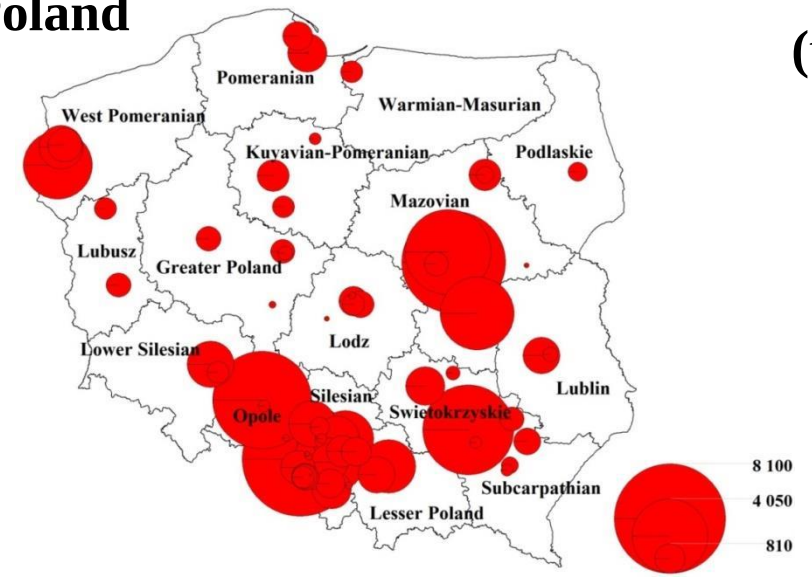
Electricity production:



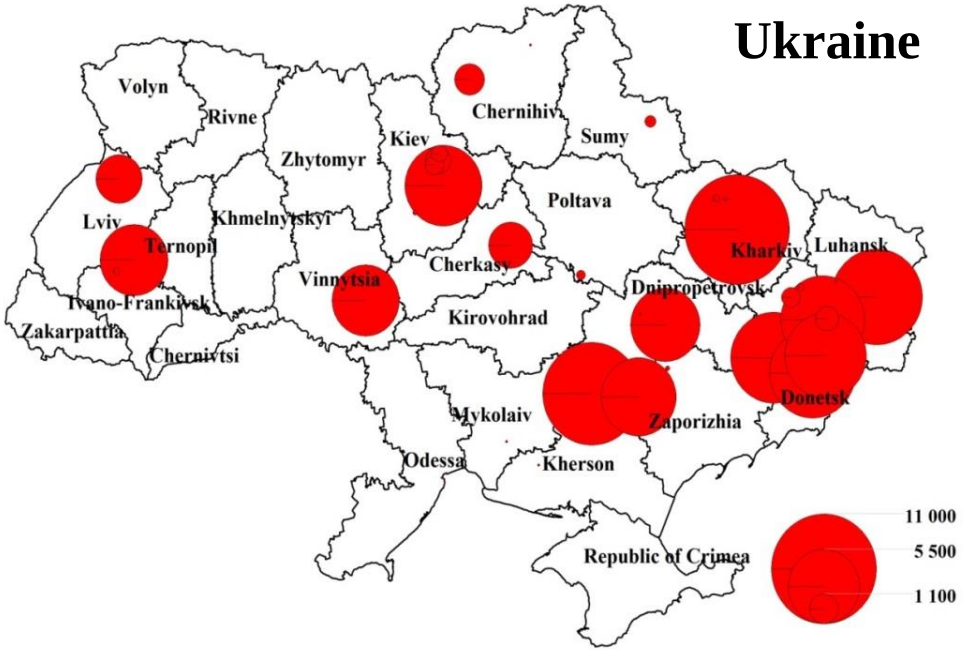
The results of spatial GHG emission modeling from electricity and combined heat and power generation

Poland

Electricity generation
(th. tones CO2-eq., 2012**):**



Ukraine

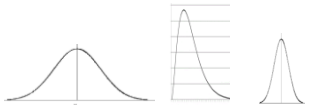


Uncertainty analysis: Monte-Carlo method

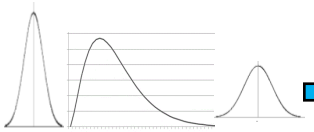
Inventory level

Plant Region Country

Power Plants

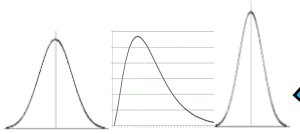


$Q_{En,f}(\xi_{En,n_p}), K^g_{En,f}, C_f$



$Q_{En,f}(\xi_{En,n_p}), K^g_{En,f}, C_f$

...

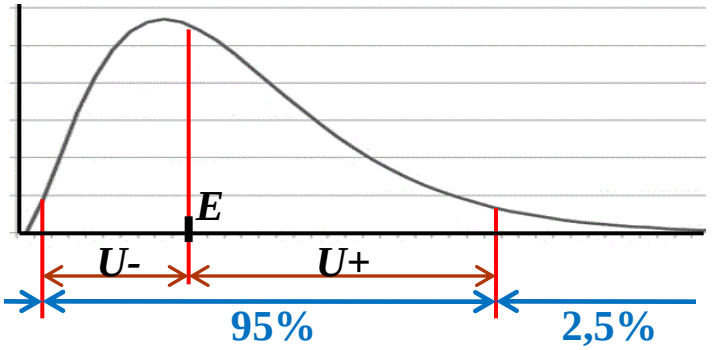


$Q_{En,f}(\xi_{En,n_p}), K^g_{En,f}, C_f$

Iterative process
- **Number of realization…**
- **Fuel types (coal, brown coal, nat. gas, oil,…)**
- **Types of GHG CO_2, CH_4, N_2O**

Result

Total emission/uncertainties: CO_2, CH_4, N_2O, CO_2-eq.

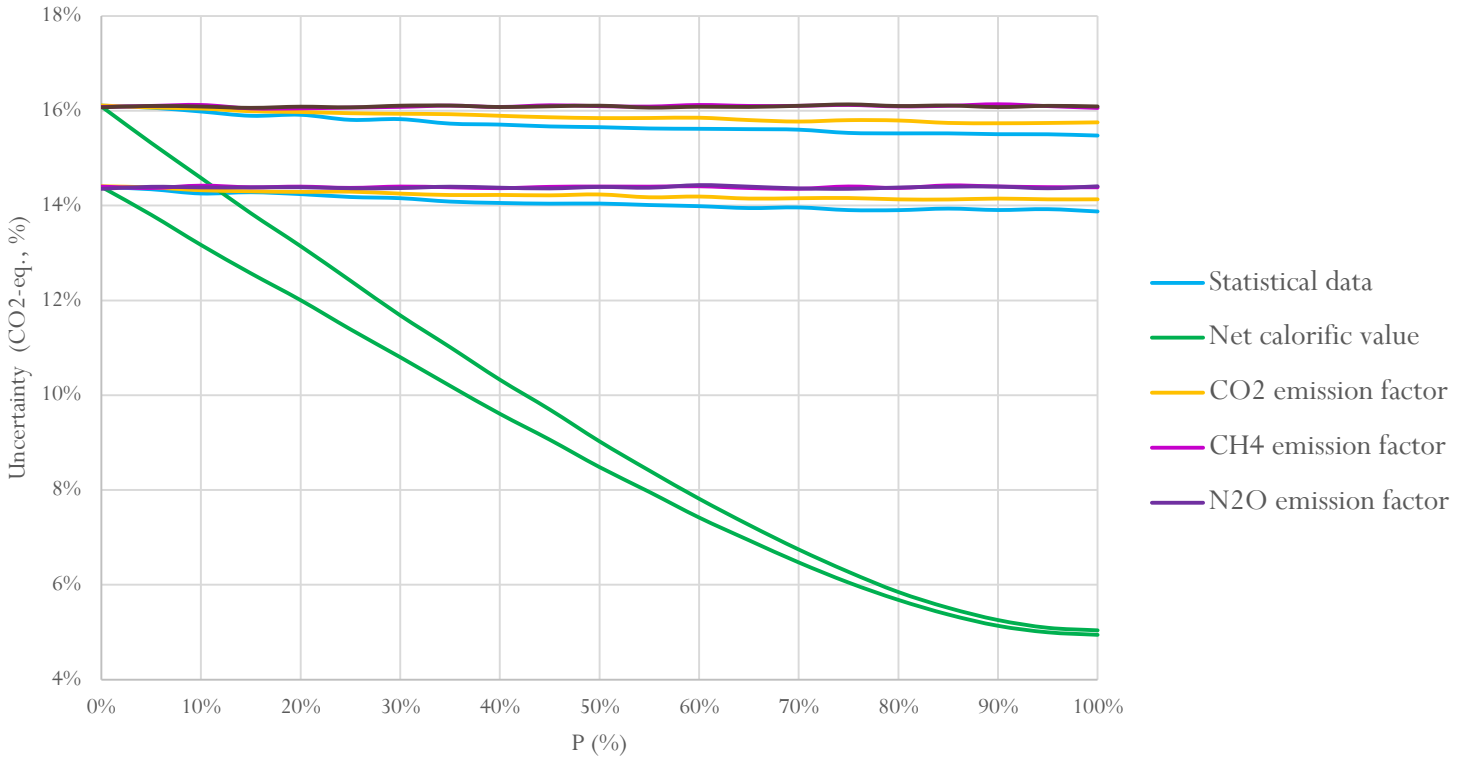


Uncertainty estimates: Poland

Power/heat plant	CO_2, th. t (uncertainty, %)	CH_4, th. t (uncertainty, %)	N_2O, th. t (uncertainty, %)	Total emissions, th. t (uncertainty, %)
Elektrownia Patnów II	28624,0 (-13,8: +15,3)	0,26 (-18,0: +20,8)	0,39 (-17,1: +19,5)	28747,4 (-13,8: +15,3)
BOT Elektrownia Bełchatów SA	17535,9 (-13,8: +15,3)	0,16 (-18,1: +20,8)	0,24 (-17,1: +19,5)	17611,5 (-13,8: +15,3)
BOT Elektrownia Turów SA	8317,4 (-13,8: +15,3)	0,07 (-18,0: +20,8)	0,11 (-17,1: +19,5)	8353,3 (-13,8: +15,3)
Elektrownia Rybnik SA	7862,2 (-17,6: +20,2)	0,08 (-21,0: +24,8)	0,12 (-20,1: +23,7)	7901,8 (-17,6: +20,2)
BOT Elektrownia Opole SA	6012,1 (-17,6: +20,2)	0,06 (-21,0: +24,8)	0,10 (-20,1: +23,7)	6042,4 (-17,6: +20,2)
Elektrownia Polaniec	5271,9 (-17,6: +20,2)	0,06 (-21,0: +24,8)	0,08 (-20,1: +23,7)	5298,5 (-17,6: +20,2)
...	...	...	...	..

- 79 power/heat plants in Poland
- 6 power plants emitted over 52% of total emissions (in CO_2-eq) in this sector (2012)

Sensitivity analysis: Elektrownia Patnów II (Poland)



Dependence of total uncertainty of emission estimates for Elektrownia Patnów II to changes of uncertainty (on P %) of input parameters (the upper and lower limits of 95% confidence interval)

Conclusions

- Reducing uncertainty of net calorific values can recude overall uncertainty on power/heat plants level
- Decreased uncertainty of the location of point sources reduces spatial uncertainty

Further steps

- Uncertainty due to disaggragation – still to be analyzed

References

1. Danylo O. (2012) Spatial inventory of greenhouse gas emissions in the residential sector: a case-study for Poland and Ukraine, World with Reach: from Science to Policy: IIASA 40th Anniversary Conference, 24-26 October 2012, Vienna, Austria, Available online at: http://conference2012.iiasa.ac.at/poster_session.html
2. Hamal K., R. Bun, N. Shpak, O. Yaremchyshyn (2010) Spatial cadastres of GHG emissions: Accounting for uncertainty, The 3rd Intern. Workshop on Uncertainty in Greenhouse Gas Inventories : Proceedings, Lviv, LPNU, 81-90.
3. Horynski M., Pietrzyk W., Boguta A. (2012) A model of an energy efficient building automation system, Econtechmod, 1(1), 41-46.
4. Lesiv M., Bun A., Jonas M. (2014) Analysis of change in relative uncertainty in GHG emissions from stationary sources for the EU 15, Climatic Change. Springer, 124(3), 505-518.
5. Lesiv M., Bun R., Shpak N., Danylo O., Topylko P. (2012) Spatial analysis of GHG emissions in Eastern Polish regions: energy production and residential sector, Ekontechmod, 1(2), 17-23.
6. Lesiv M., Bun R., Topylko P. (2011) Geoinformation technologies and models for spatial analysis of GHC emissions: energy production in eastern Polish regions, Proceedings of the International Workshop "Methods and Applications of Artificial Intelligence", 22-23 September 2011, Bielsko-Biała, CIM, 38-48.
7. Poland's National Inventory report 2012: Greenhouse Gas Inventory for 1988-2010, Warszawa, National Centre for Emission Management at the Institute of Environmental Protection - National Research Institute, 2012. Available at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/6598.php.
8. Poland's National Inventory report 2014: Greenhouse Gas Inventory for 1988-2012, Warszawa, National Centre for Emission Management at the Institute of Environmental Protection - National Research Institute, 2014, Available at: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php.
9. Stan środowiska w województwie śląskim w 2012 roku. Available online at: http://www.katowice.wios.gov.pl/ monitoring/raporty/ 2012/raport2012.pdf.
10. State statistics service of Ukraine. Available at: http://www.ukrstat.gov.ua
11. Topylko P., Bun R. (2013) Geoinformation technology for inventory of emissions of greenhouse gases in the electricity production sector of Ukraine, Artificial intelligence (Donetsk), 4, 432-440.
12. Topylko P., Bun R., Striamets O., Danylo O. (2013) Uncertainty of greenhouse gases spatial inventory: power and heat production, Proceedings of the 8th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT'2013), November 11-16, 2013, Lviv, 15-16.
13. Topylko P., Lesiv M., Bun R., Nahorski Z., Horabik J. (2013) Geoinformation technology for spatial inventory of greenhouse gas emissions: electricity and heat generation in Poland, Econtechmod, 2(2), 51-58.
14. Zużycie paliw i nośnikow energii w 2012 r., Główny Urząd Statystyczny, Warszawa, 2013. Available at: http://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2012-r-,6,7.html
15. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, H. S. Eggleston, L. Buendia, K. Miwa, T. Ngara, K. Tanabe, eds., IPCC, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan, 2006, 5 volumes. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.
16. 2014 IPCC, ClimateChange 2014: Synthesis Report of the Intergovernmental Panel on Climate Change. Available at: http://www.ipcc.ch/report/ar5/syr/

Thank You for Attention!