



Accounting uncertainty for spatial modeling of greenhouse gas emissions in the residential sector: fuel combustion and heat production

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Agenda

- ▶ Introduction
- ▶ Methodology
- ▶ Inventory results: Poland and Ukraine
- ▶ Validation of approach
- ▶ Conclusions

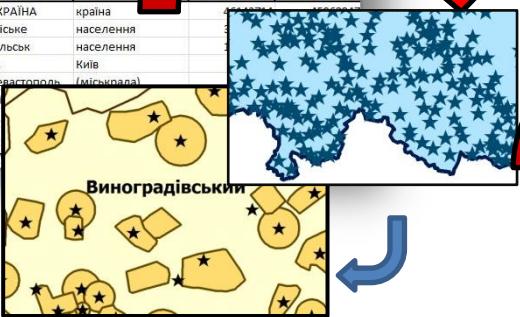
Essence of the approach

Statistical data

Parameters

Other information

A	B	C	D
ЧИСЛЕНІСТЬ НАВІЙНОГО НАСЕЛЕННЯ НА 1 СІЧНЯ 2011 РОКУ			
Державний комітет статистики України			
typ	нам	popul2009	popul2010
УКРАЇНА	країна		
Міське населення			
Сільське населення			
м.	Київ		
Севастополь (міськрада)			
м.			
см.			



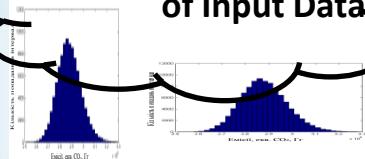
Disaggregation algorithms
and data processing

$$F_{typ,k}^R = \frac{H_{typ,i}^R}{\sum_{p \in S^{U_{typ}} \cap O_i} \sum_{k=1}^{I_1} Q(p) \cdot H_{Rur,i}^R + \sum_{p \in S^{U_{urb}} \cap O_i} \sum_{k=1}^{I_2} Q(p) \cdot H_{Urb,i}^R},$$

ID	Name	Y	C_2010
1	Білоцерківська ТЕЦ	30,1866	49,7968
2	Бориспільська ТЕС	24,6649	49,2095
3	Бориспільська ТЕС	65,2001	2,0001
4	Дарницька ТЕЦ (Київська ТЕЦ-4, «Укр-К	30,643	50,4473
5	Дніпродзержинська ТЕЦ	34,6211	48,53

Database of geo-referenced data

Uncertainty
of Input Data



Mathematical model:

$$E_{Res}^G(\delta) = \sum_{s \in S^{Rur}} \left(\sum_{i=1}^{I_1} M_i^O F_{i,Rur}^R E F_{Res,i}^G + \sum_{j=1}^{J_2} M_j^O F_{j,Rur}^R E F_{Res,j}^G \right)$$

fossil fuels, greenhouse gases, net calorific values....

Uncertainty 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%,

Тіра	4623550100	54 900	54 100	53 600	53 000	52 400	51 900	51 300	50 900
Старий Сарай	4623510000	82 100	81 500	80 800	80 300	79 700	79 300	78 900	78 700
Мостища	4623450100	61 900	61 200	60 600	60 000	59 300	58 700	58 100	57 700
Солотвино	4624450100	50 300	49 700	49 000	48 300	47 800	47 500	47 300	47 300
Городок	4623950100	74 000	73 300	72 600	71 900	70 500	70 100	69 700	69 700
Золотоноша	4623500100	72 000	71 300	70 600	70 000	69 300	68 700	68 300	68 300
Первомайськ	4623501000	47 900	46 700	45 900	44 900	43 900	43 000	42 200	41 200
Радогіт	4623950100	52 400	52 000	51 700	51 300	50 800	50 400	49 800	49 300
Ровно	4623950100	123 000	122 800	122 000	122 000	122 100	122 000	122 100	122 400
Сосниця	4623950100	183 000	181 800	180 600	178 800	178 000	177 400	177 000	177 000
Бердичів	4623950100	63 900	63 200	62 900	62 500	62 200	61 900	61 400	61 400
Київ-Бутки	4622150100	81 900	81 300	80 700	80 200	59 800	59 000	58 500	57 900
Буки	4623650100	50 900	50 200	49 700	49 100	48 500	47 900	47 400	47 400
Пустомити	4623650100	862 000	862 300	862 100	863 000	864 700	866 000	865 600	865 600

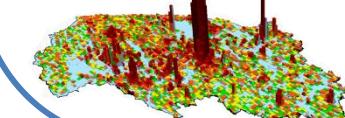
Emissions CO₂, CH₄, N₂O: ???
Uncertainties: ???

Map of emission sources



Visualization of results

All settlements All regions



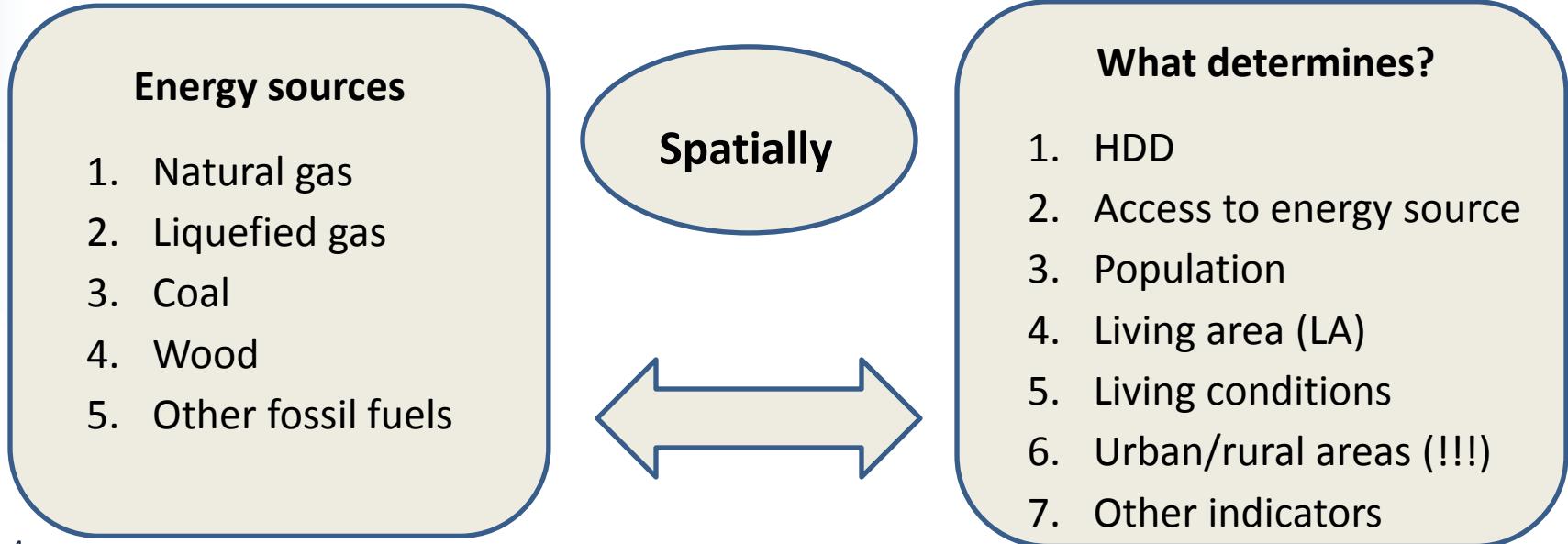
region

country

Introduction: residential sector

IPCC -1A4b

What **determines the amount** of GHG emissions in the residential sector at the level of geographical elementary objects?



Methodology

Spatial inventory of GHG emissions:
households

Algorithm

Step 1: Input data collection



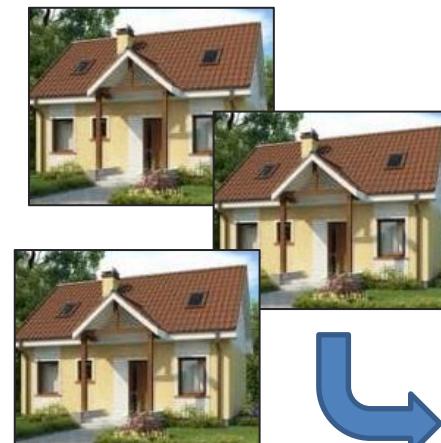
Step 2: Energy demand assessment



Step 3: Fossil fuel disaggregation



Step 4: GHG emission estimation



Step 1:

Input data collection

Energy demand assessment

Fossil fuel disaggregation

GHG emission estimation

Input data

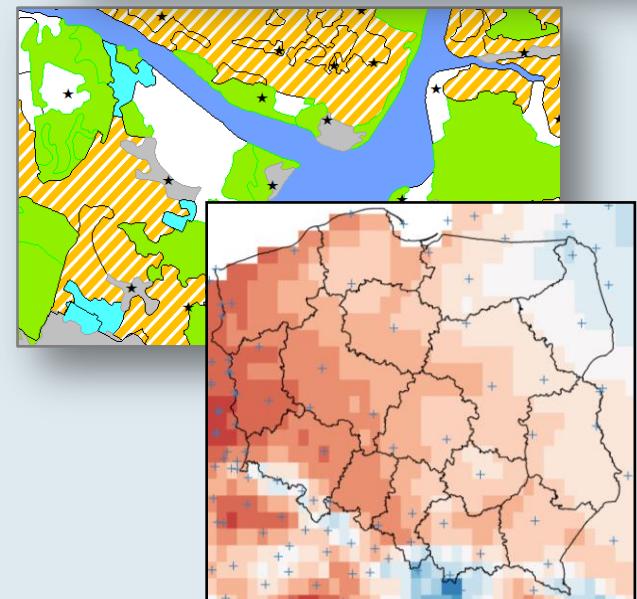
(1) official statistical information

(2) country-specific emission factors

(3) digital maps of investigated area

- population density map
raster data on population density
 disaggregated with CLC (Gallego, 2010)
 - a) update of the map (2010 data)
 - b) urban/rural characteristics were added
- Heating-Degree Days map (HDD)

1	Consumption of fossil fuels/Zużycie pal.			
	Kod	Voivodeship	Hard coal	Natura
2				
3		A	B	C
4	kod	1 Emission factors		
5	02	EFs [kg/GJ]		
6	04	applied for fuels in the years 1988-2009 for stationary sources in 1A		
7	06	IPCC 2006]		
8	08			
9	10			
10	12			
3		Fuels		CO2 E
4			fuel	[kg/GJ]
5	Hard coal	coal	94	
6	natural gas	ngas	55	
7	liquid petroleum gas (LPG)	lgas	62	
8	Lignite (węgiel brunatny)	l	107	
9	hard coal briquettes (patent fuels)	coalBr	92	
10	brown coal briquettes	brownCoalBr	92	



Input data collection

Step 2:

Energy demand assessment

Energy demand assessment

$$Q = Q_c + Q_w + Q_h$$

Cooking:

$$Q_c = Q_{c,rs} + Q_{c,agri}$$

The average energy demand for :

- cooking per person,
- feed cooking,
- water heating for drinking and sanitary per 1 head of cattle.

Water heating:

$$Q_w = Q_w^{summ} + Q_w^{wint}$$

Average hot water consumption (norms):

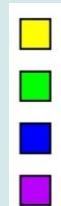
- 48 dm³ – dwelling,
- 35 dm³ - detached house (55°C per person).

Space heating:

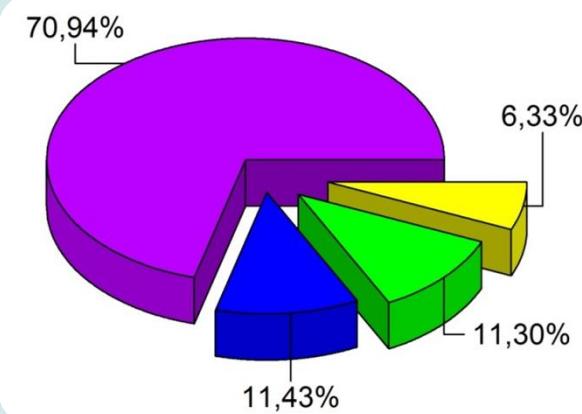
$$Q_h = k_{HDD} \cdot f(Q_{h,sqm}, LA, \varepsilon)$$

- relative change of HDD
- living area (LA) per person
- energy demand per sq m of LA
- characteristics of living area
- efficiency coefficient

Energy demand structure

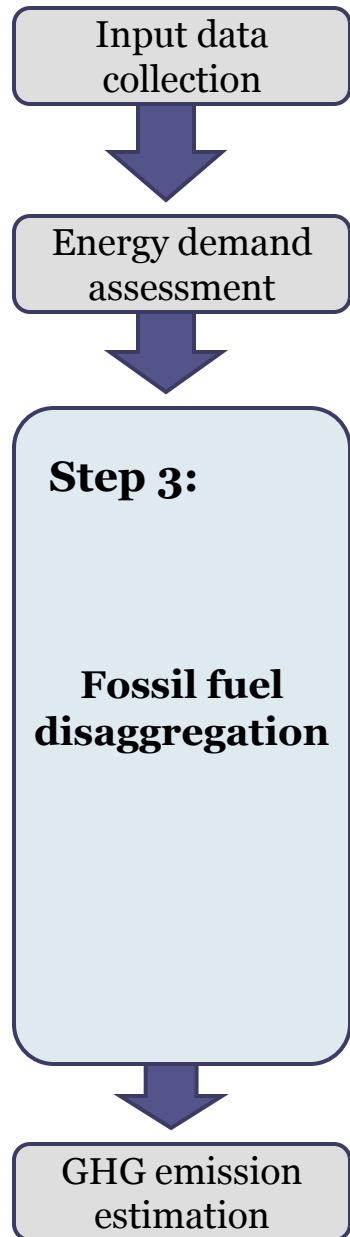


- cooking for families
- cooking for livestock
- water heating
- space heating



Fossil fuel disaggregation

GHG emission estimation



Disaggregation algorithm

$$M_{i,n} = M_{i,R} \cdot F_{type,i}^n, n = \overline{1, N},$$

$M_{i,R}$ - consumed fossil fuel i in region R ,

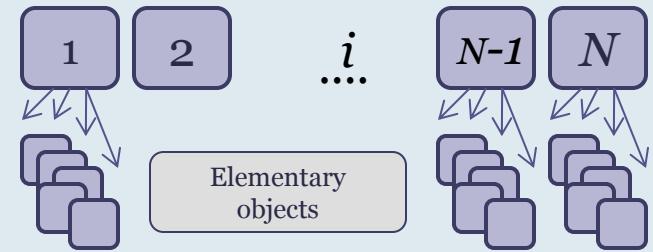
$type$ - characterizes affiliation of elementary object to urban or rural area,

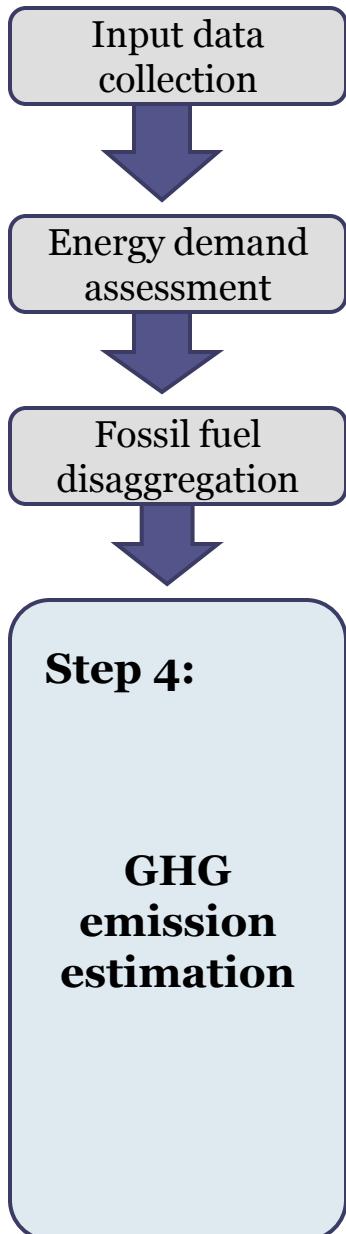
$F_{type,i}^n$ - disaggregation coefficient.

Country (or region) R
fossil fuel i



Regions (or municipalities)



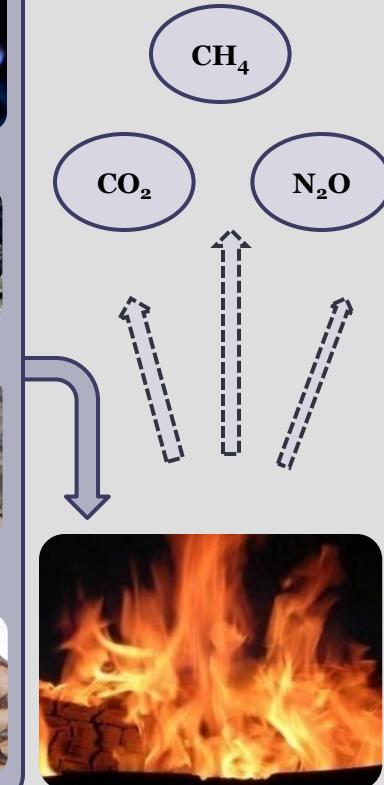


GHG emission estimation

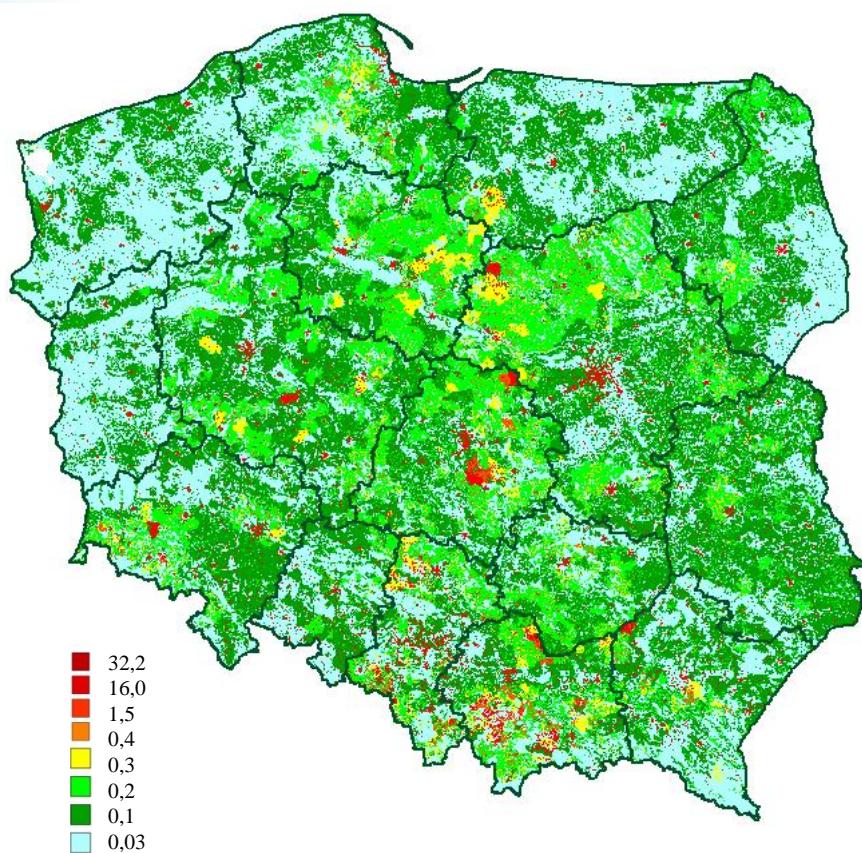
$$E_{i,n}^G = M_{i,n} \cdot EF_{i,n}^G, n = \overline{1, N},$$

$EF_{i,n}^G$ - emission factor of greenhouse gas G

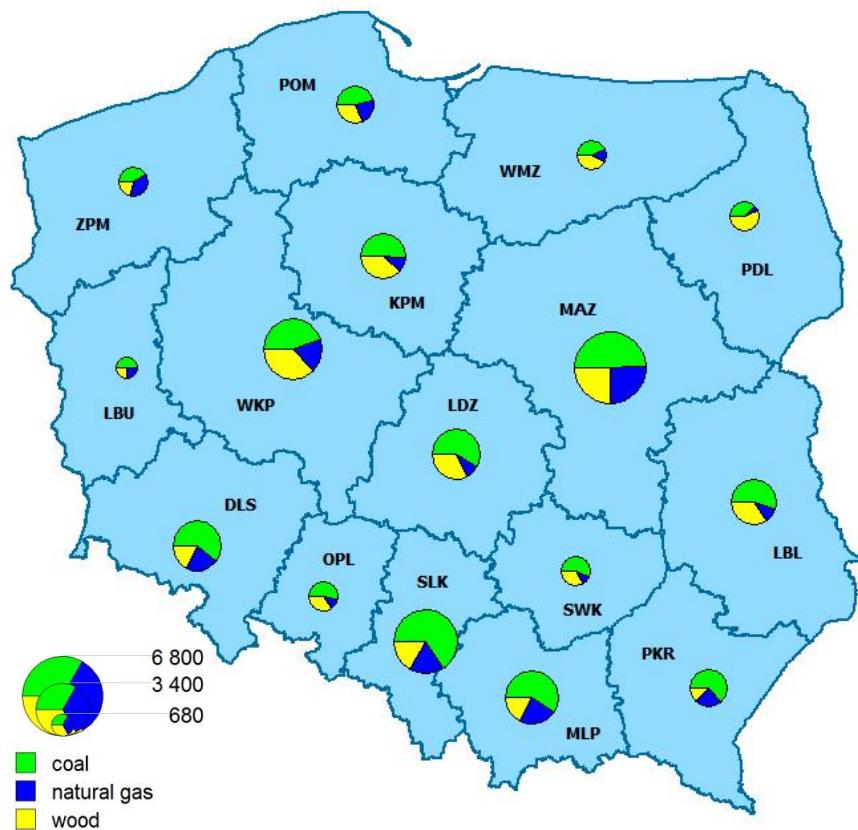
CO₂-equivalent



Inventory results: Poland

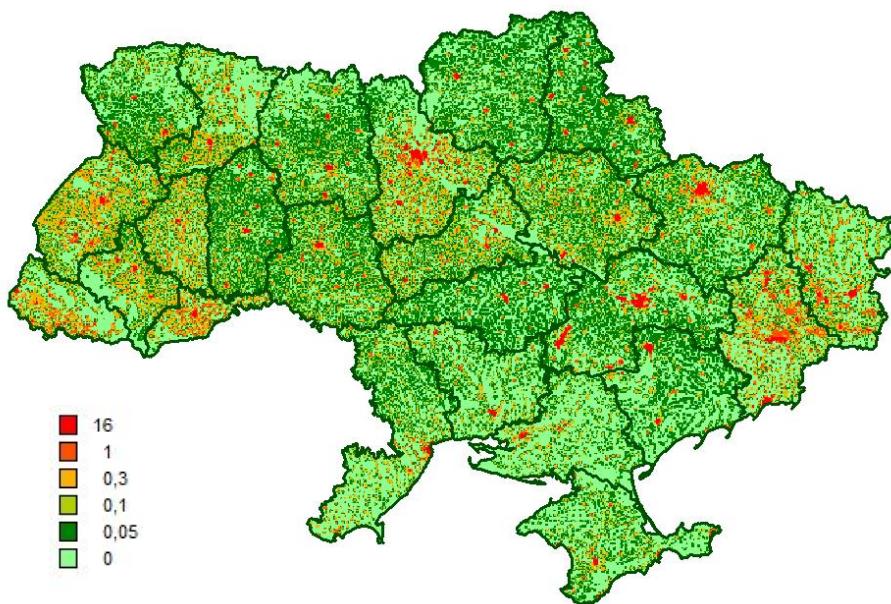


Specific GHG emissions in residential sector (mln kg/sq.km., CO₂-eq., Poland, 2010)

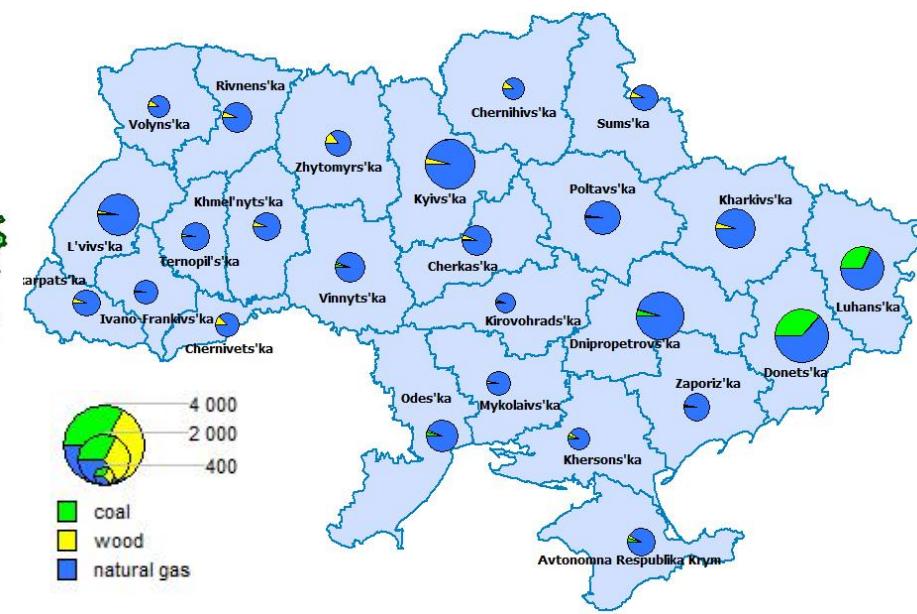


Structure of GHG emissions by type of fossil fuel for administrative regions (mln kg, CO₂-eq., Ukraine, 2010)

Inventory results: Ukraine

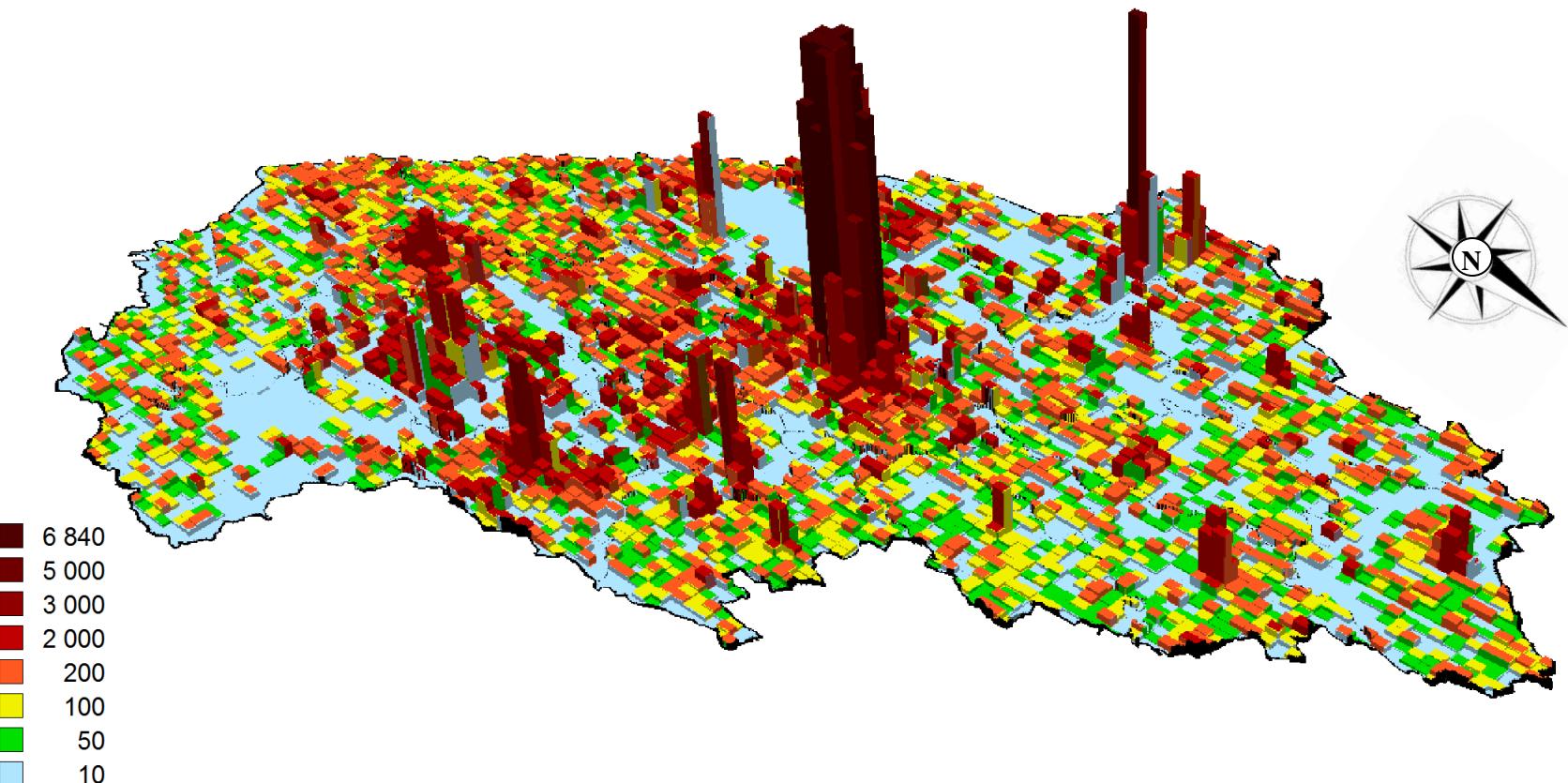


Specific GHG emissions in residential sector
(mln kg/sq.km., CO₂-eq., Ukraine, 2010)



Structure of GHG emissions by type of fossil fuel for
administrative regions
(mln kg, CO₂-eq., Ukraine, 2010)

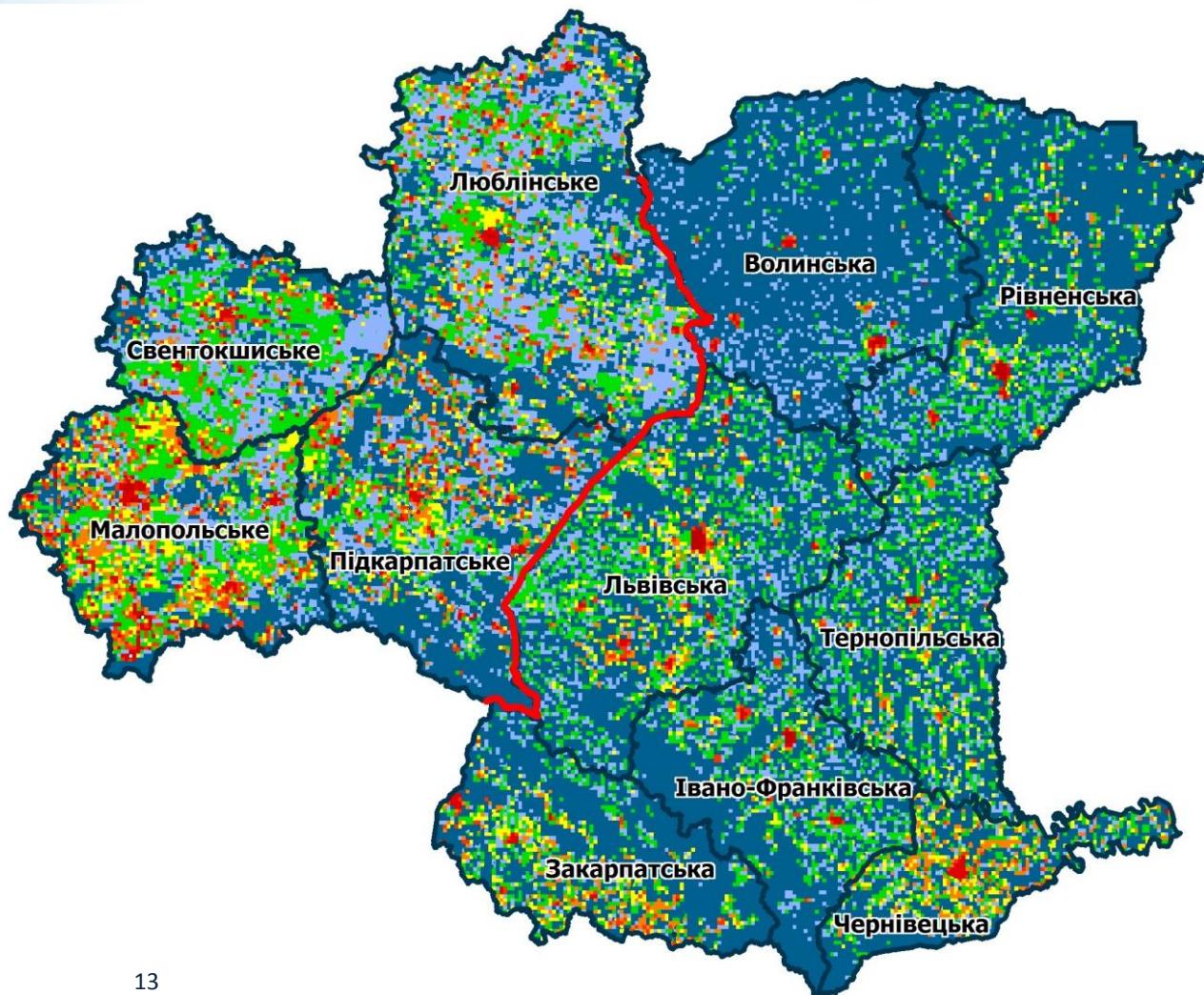
Inventory results: Ukraine (Lviv region)



Prosm-map of specific GHG emissions in residential sector
(mln kg/sq.km., CO₂-eq., Lviv region, Ukraine, 2010)



Comparison of GHG inventory results: South-Eastern Poland and Western Ukraine



Specific GHG emissions in
residential sector
(mln kg/sq.km., CO₂-eq.,
South-Eastern Poland,
Western Ukraine, 2010)

6 840
3 000
1 000
500
300
200
100
< 50

Comparison of GHG inventory results: South-Eastern Poland and Western Ukraine

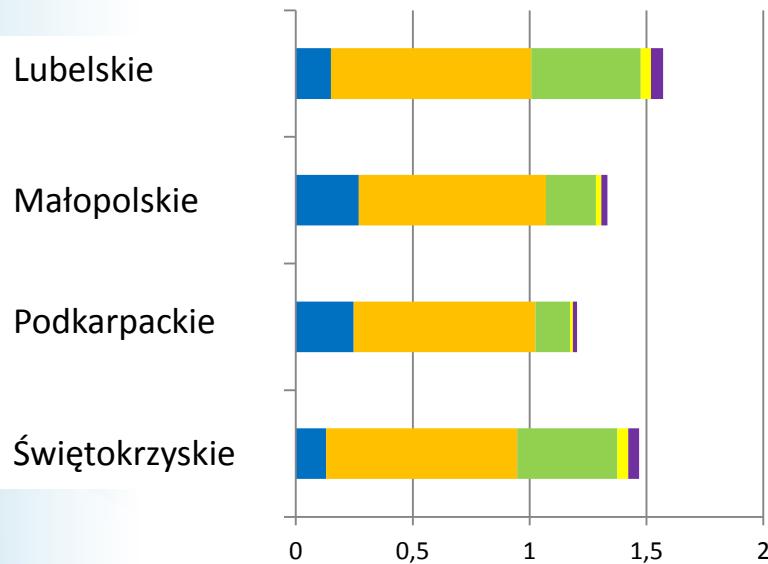


Fig. 1. Structure of GHG emissions per capita by type of fossil fuel (thousands kg per capita, CO₂-eq., South-Eastern Poland, 2010)

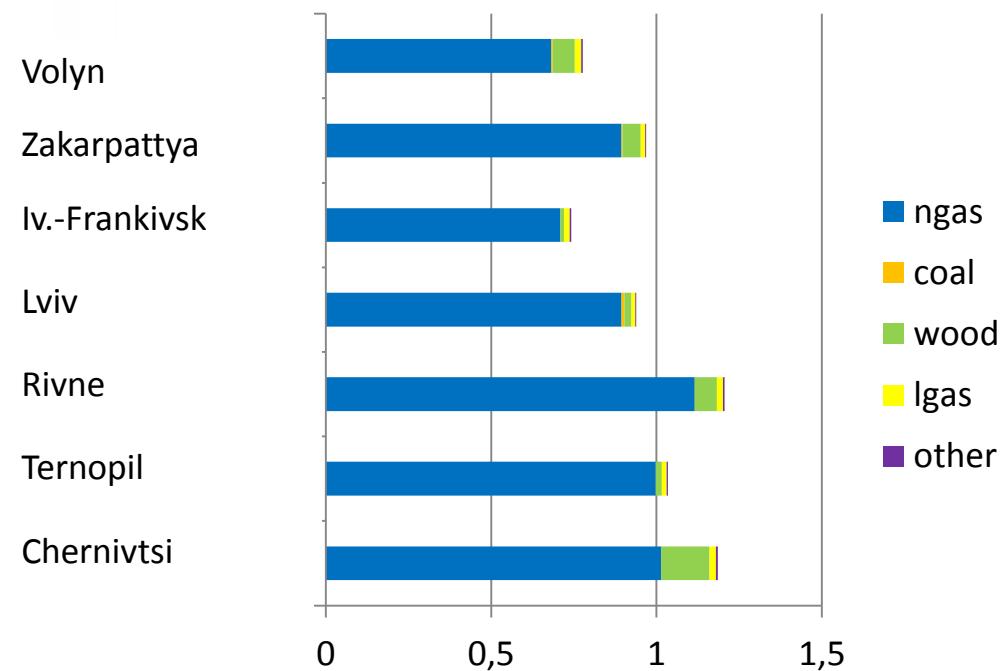
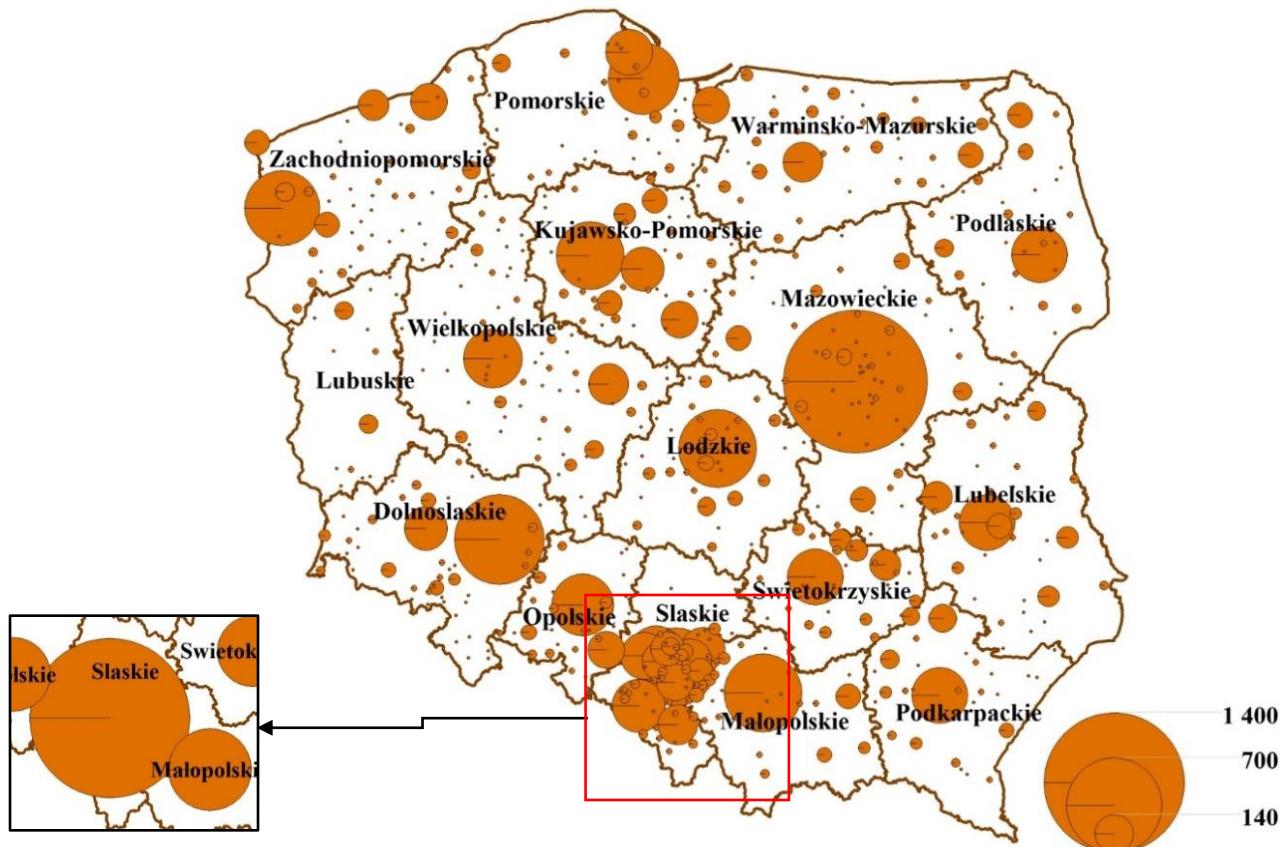


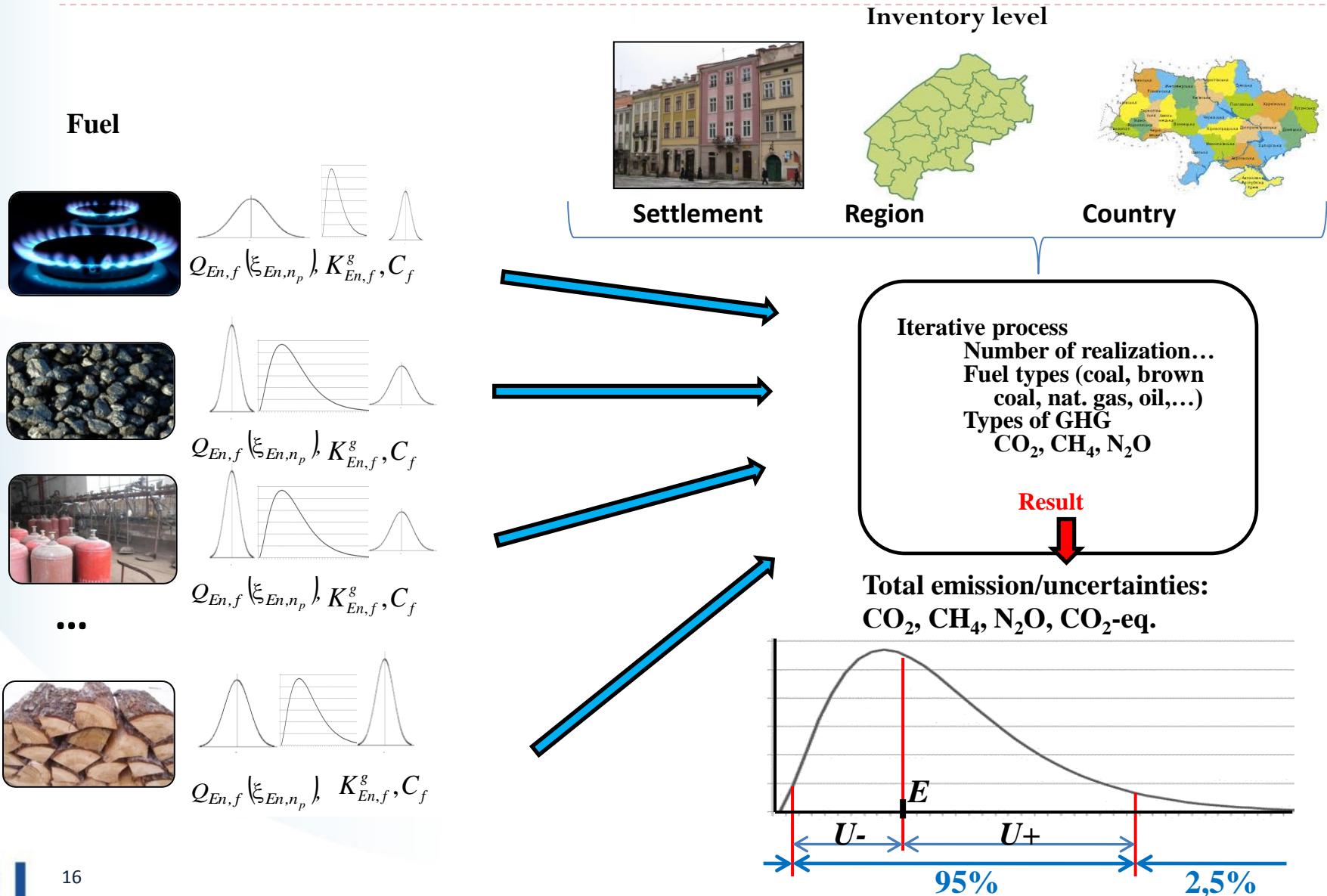
Fig. 2. Structure of GHG emissions per capita by type of fossil fuel (thousands kg per capita, CO₂-eq., Western Ukraine, 2010)

GHG emissions from the heat production



Greenhouse gas emissions from heat production in Poland
(thousands tons, CO₂-equivalent, 2010)

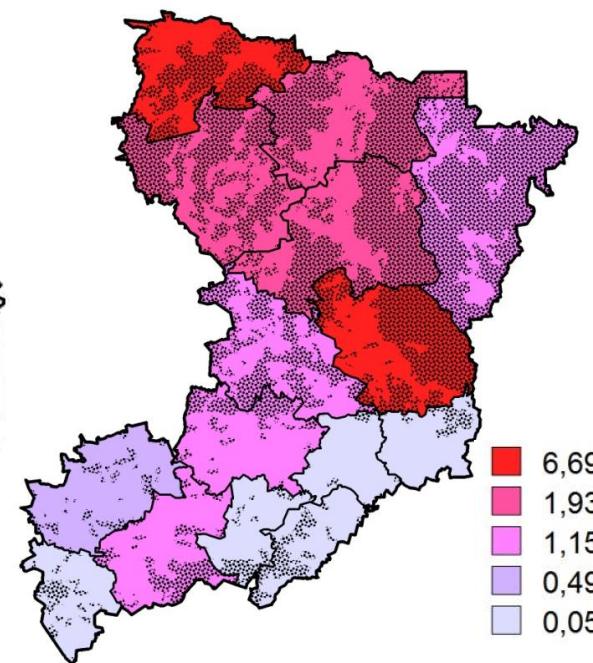
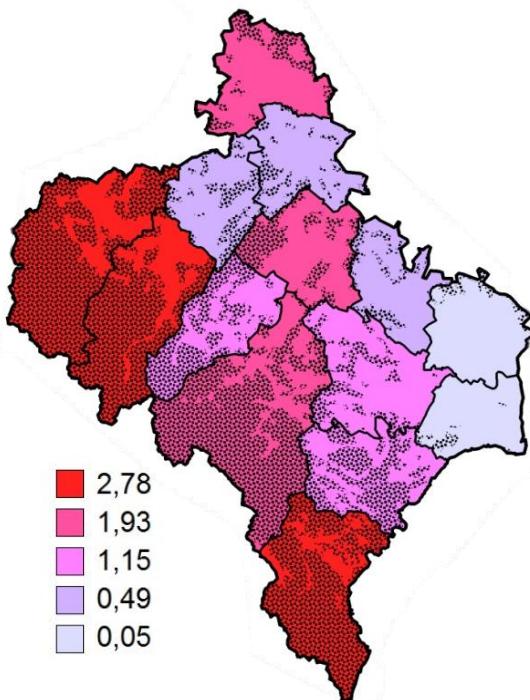
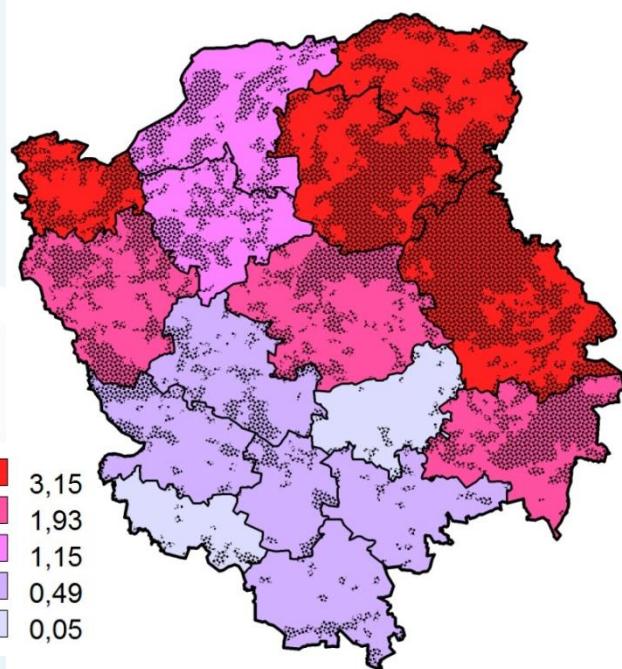
Uncertainty analysis: Monte-Carlo method



Uncertainty analysis: Monte-Carlo method

Voivodeship	CO ₂ , Gg (uncertainty, %)	CH ₄ , Gg (uncertainty, %)	N ₂ O, Gg (uncertainty, %)	Total emission Gg (uncertainty, %)
Lower Silesian	2635,8 (-12,9 : +14,9)	5,4 (-21,4 : +25,5)	0,03 (-19,7 : +23,2)	2780,50 (-13,2 : +15,2)
Kuyavian-Pomeranian	1741,5 (-14,5 : +16,7)	4,0 (-21,5 : +25,5)	0,02 (-19,9 : +23,4)	1848,54 (-14,7 : +16,9)
Lublin	1982,9 (-14,3 : +16,5)	4,5 (-21,5 : +25,6)	0,03 (-19,8 : +23,4)	2103,56 (-14,5 : +16,8)
Lubusz	700,4 (-11,8 : +13,6)	1,3 (-21,3 : +25,4)	0,01 (-19,3 : +22,7)	735,77 (-12,1 : +14,0)
Łódź	2451,2 (-15,0 : +17,3)	5,8 (-21,6 : +25,6)	0,03 (-20,0 : +23,6)	2606,73 (-15,2 : +17,5)
Lesser Poland	3091,0 (-12,7 : +14,7)	6,3 (-21,4 : +25,5)	0,04 (-19,7 : +23,3)	3258,20 (-13,0 : +15,0)
.....
.....
Warmian-Masurian	900,1 (-13,0 : +15,0)	1,9 (-21,4 : +25,5)	0,01 (-19,5 : +23,0)	949,97 (-13,2 : +15,3)
Greater Poland	3013,4 (-12,4 : +14,3)	5,9 (-21,3 : +25,4)	0,04 (-19,5 : +22,9)	3172,27 (-12,7 : +14,6)
West Pomeranian	1163,7 (-9,6 : +11,0)	1,8 (-21,0 : +25,1)	0,01 (-18,6 : +21,9)	1210,98 (-9,9 : +11,3)

Validation of the approach: Ukraine, wood combustion

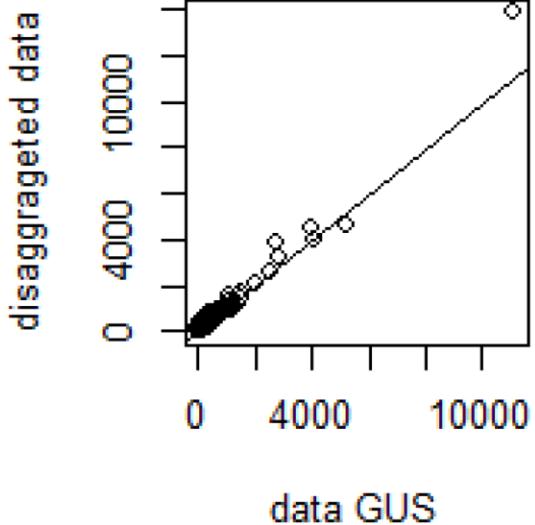


Statistical data devided by disaggregated data
(black dots – forest cover)

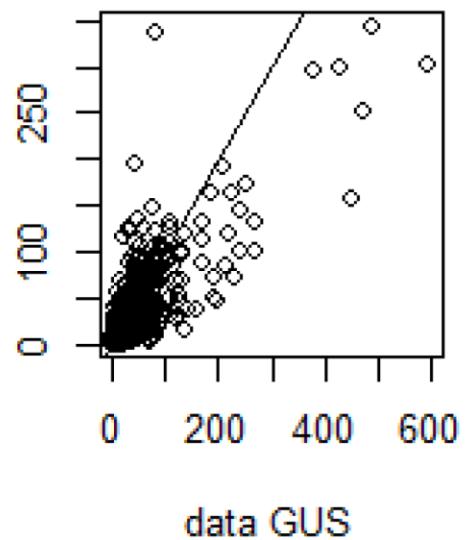
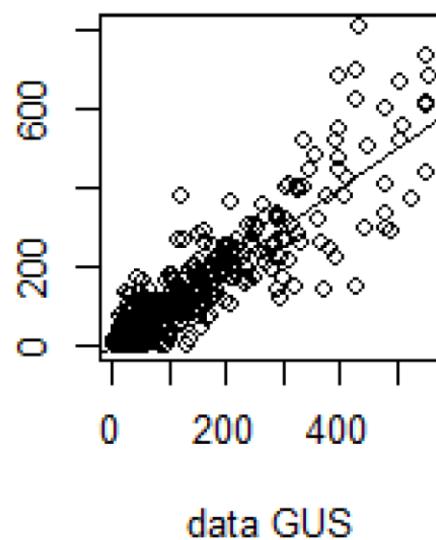
Validation of the approach: Poland, natural gas

Natural gas combustion at the level of municipalities

Urban areas



Rural areas



Conclusions

- ▶ A new understanding of the residential sector
- ▶ Lack of detailed data on FF combustion -> disaggregation -> spatial uncertainty
- ▶ Validation and uncertainty analysis are important components of spatial inventory

Thank you for your attention!

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