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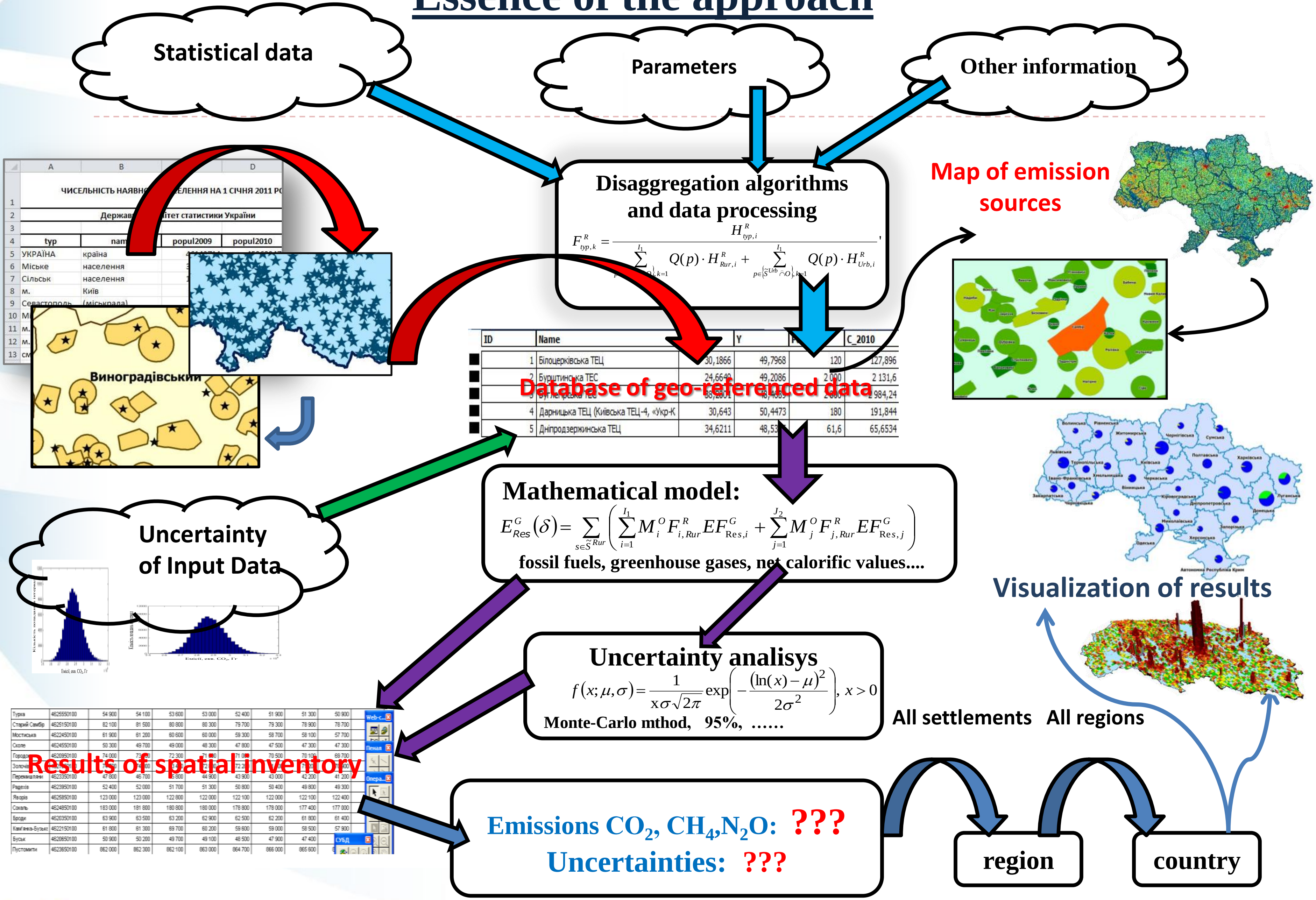
Accounting uncertainty for spatial modeling of greenhouse gas emissions in the residential sector: fuel combustion and heat production

Olha Danylo, Rostyslav Bun, Linda See, Petro Topylko, Xu Xianguang, Nadiia Charkovska, Przemysław Tymków

Agenda

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

Essence of the approach



Introduction: residential sector

IPCC -1A4b

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

Needs

1. Space heating
2. Cooking
3. Water heating

Energy sources

1. Natural gas
2. Liquefied gas
3. Coal
4. Wood
5. Other fossil fuels

Spatially

What determines?

1. HDD
2. Access to energy source
3. Population
4. Living area (LA)
5. Living conditions
6. Urban/rural areas (!!!)
7. Other indicators

Methodology

Spatial inventory of GHG emissions: households

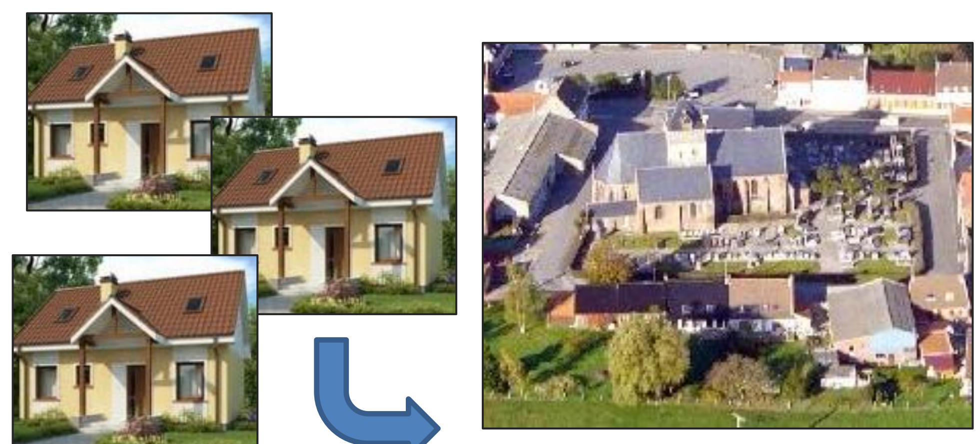
Algorithm

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

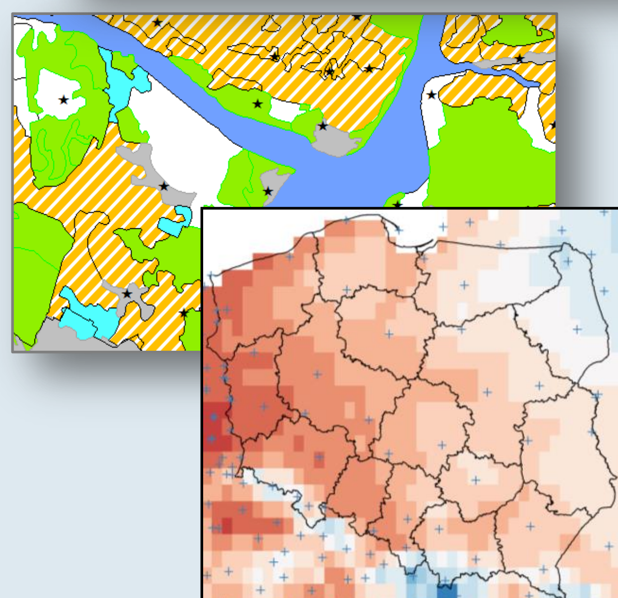
1	Consumption of fossil fuels/Zużycie pal			
2	Kod	Voivodeship	Hard coal	Natur
3				
4	kod			
5	02			
6	04			
7	06			
8	08			
9	10			

	A	B	C
1	Emission factors		
2	EFs [kg/GJ] applied for fuels in the years 1988-2009 for stationary sources in 1A IPCC 2006]		
3	Fuels		CO2 E [kg/G
4		fuel	CO2E
5	Hard coal	coal	94
6	natural gas	ngas	55
7	liquid petroleum gas (LPG)	lgas	62
8	Lignite (wegel brunatny)	l	107
9	hard coal briquettes (patent fuels)	coalBr	92
10	brown coal briquettes	brownCoalBr	92

(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)



Input data collection

↓

Step 2:

Energy demand assessment

↓

Fossil fuel disaggregation

↓

GHG emission estimation

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):

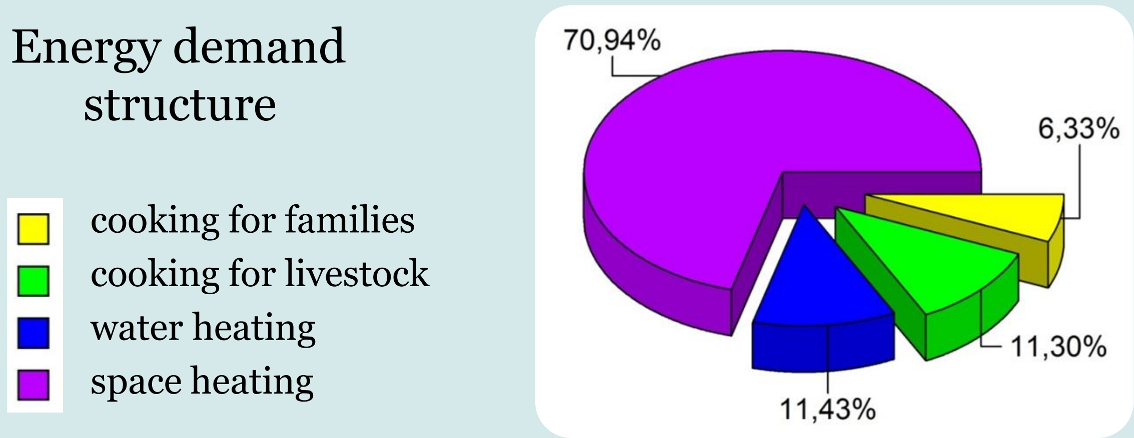
- 48 dm3 – dwelling,
- 35 dm3 - detached house (55°C per person).

Space heating:

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

- 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



Input data collection

Energy demand assessment

Step 3:

Fossil fuel disaggregation

GHG emission estimation

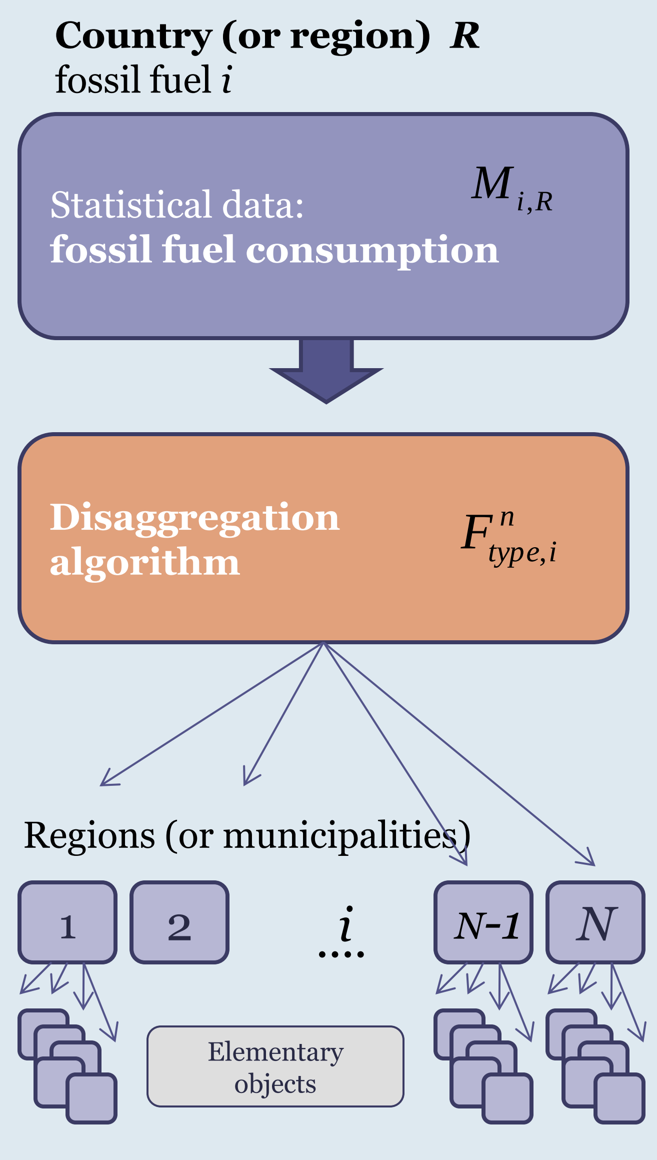
Disaggregation algorithm

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

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

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

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



Input data collection

↓

Energy demand assessment

↓

Fossil fuel disaggregation

↓

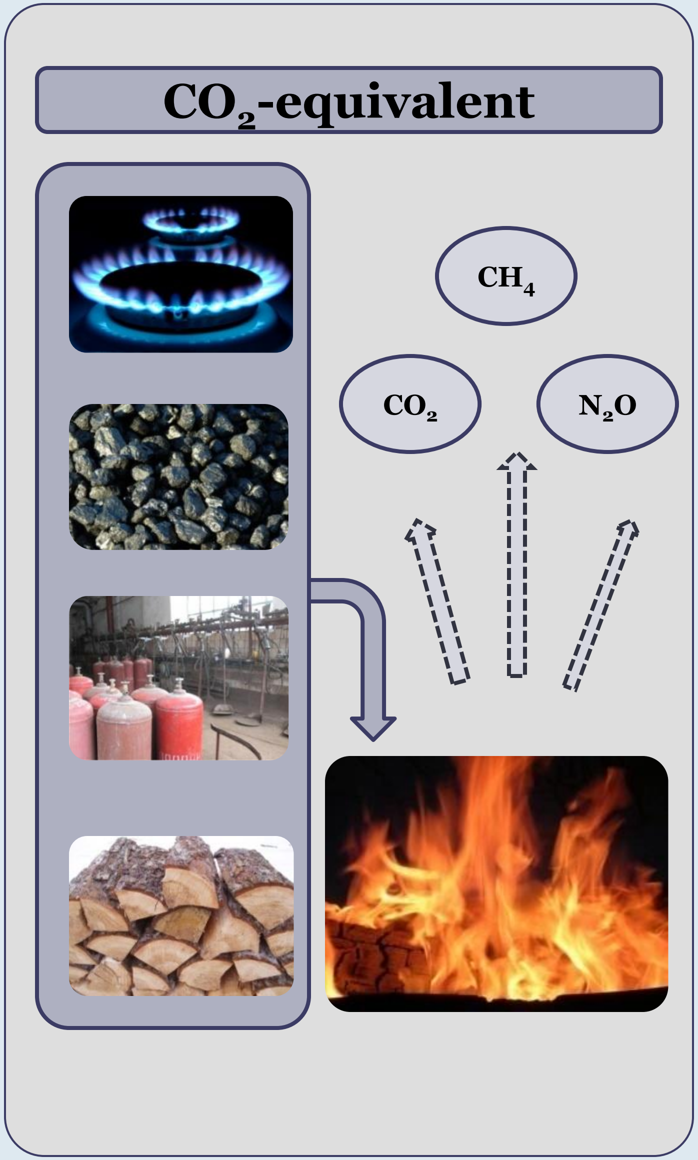
Step 4:

GHG emission estimation

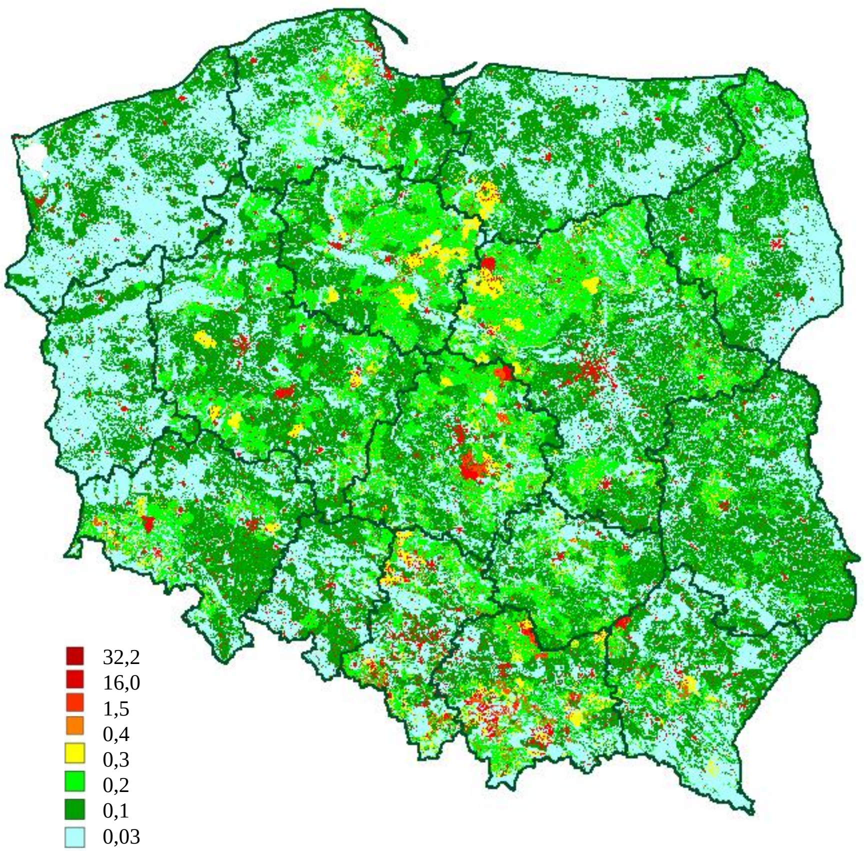
GHG emission estimation

$$E^{G}_{i,n} = M_{i,n} \cdot EF^{G}_{i,n}, n = \overline{1, N},$$

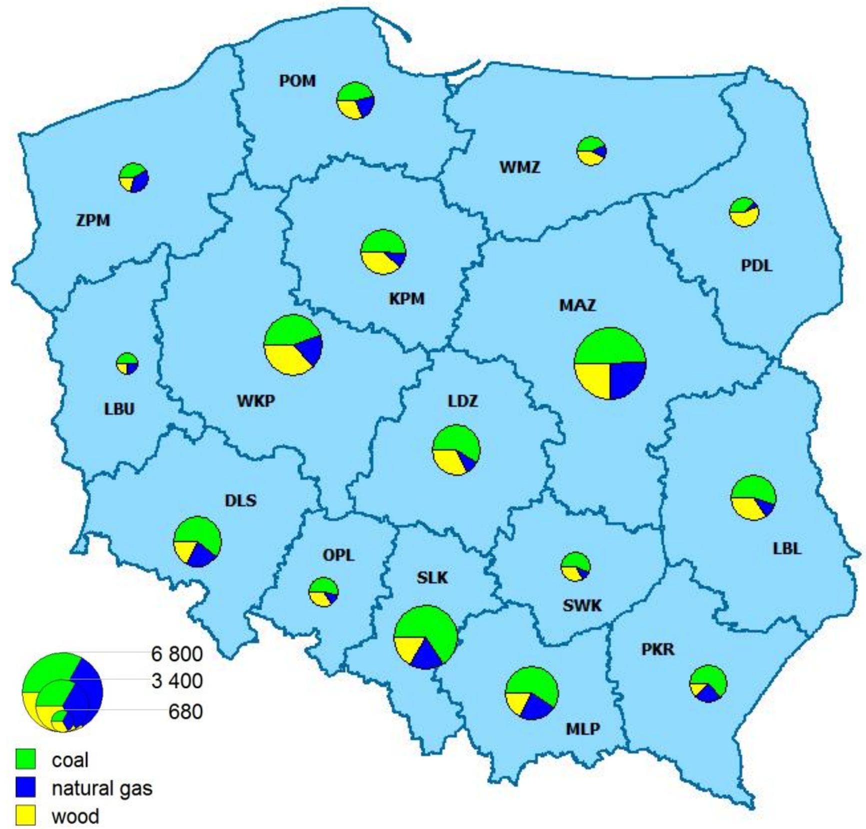
$EF^{G}_{i,n}$ - emission factor of greenhouse gas G



Inventory results: Poland

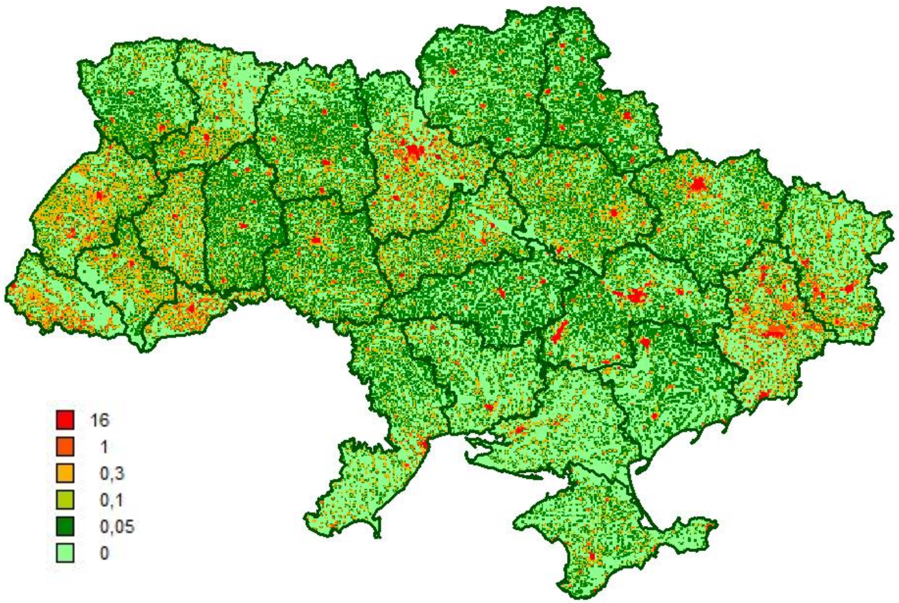


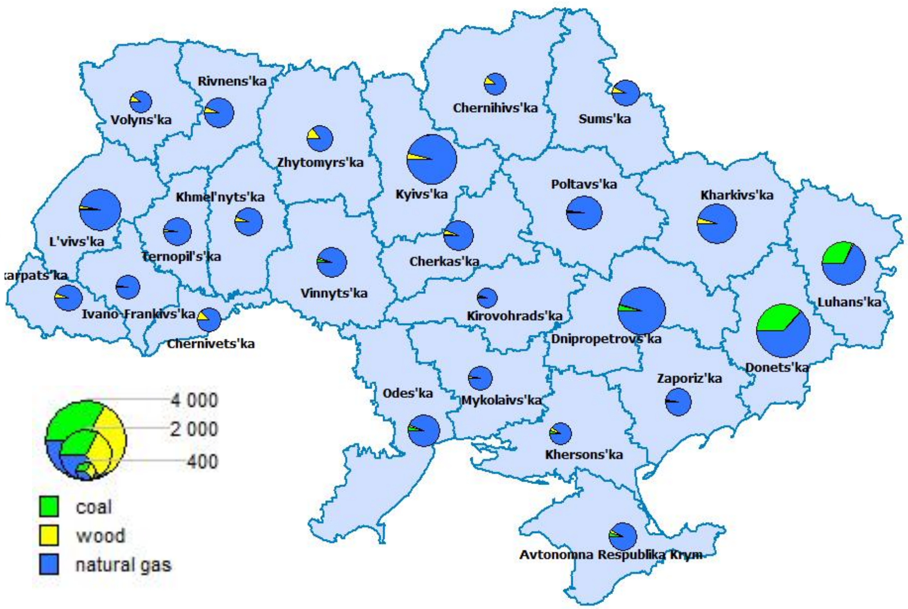
Specific GHG emissions in residential sector (mln kg/sq.km., CO2-eq., Poland, 2010)



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

Inventory results: Ukraine

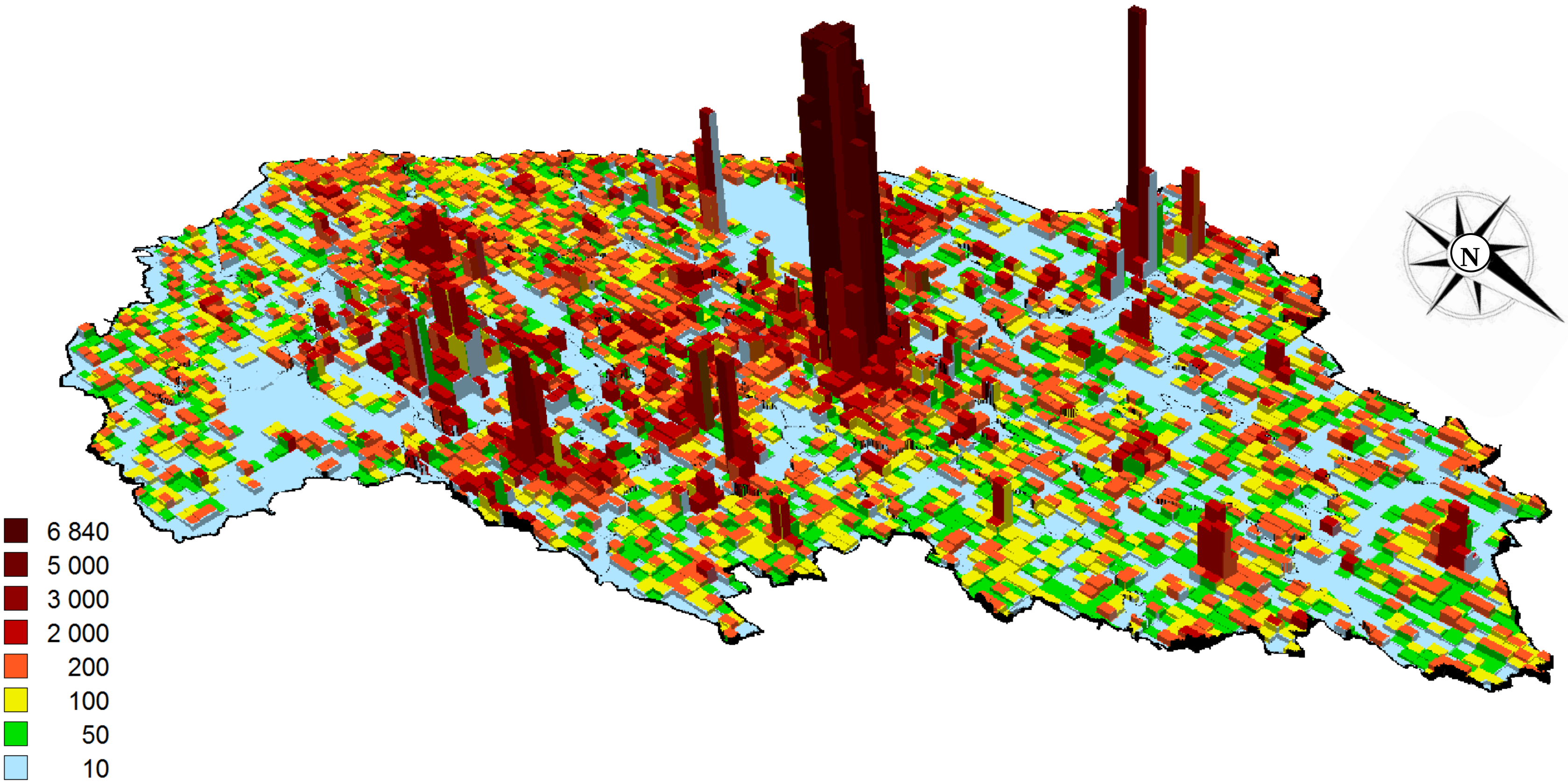




Specific GHG emissions in residential sector (mln kg/sq.km., CO2-eq., Ukraine, 2010)

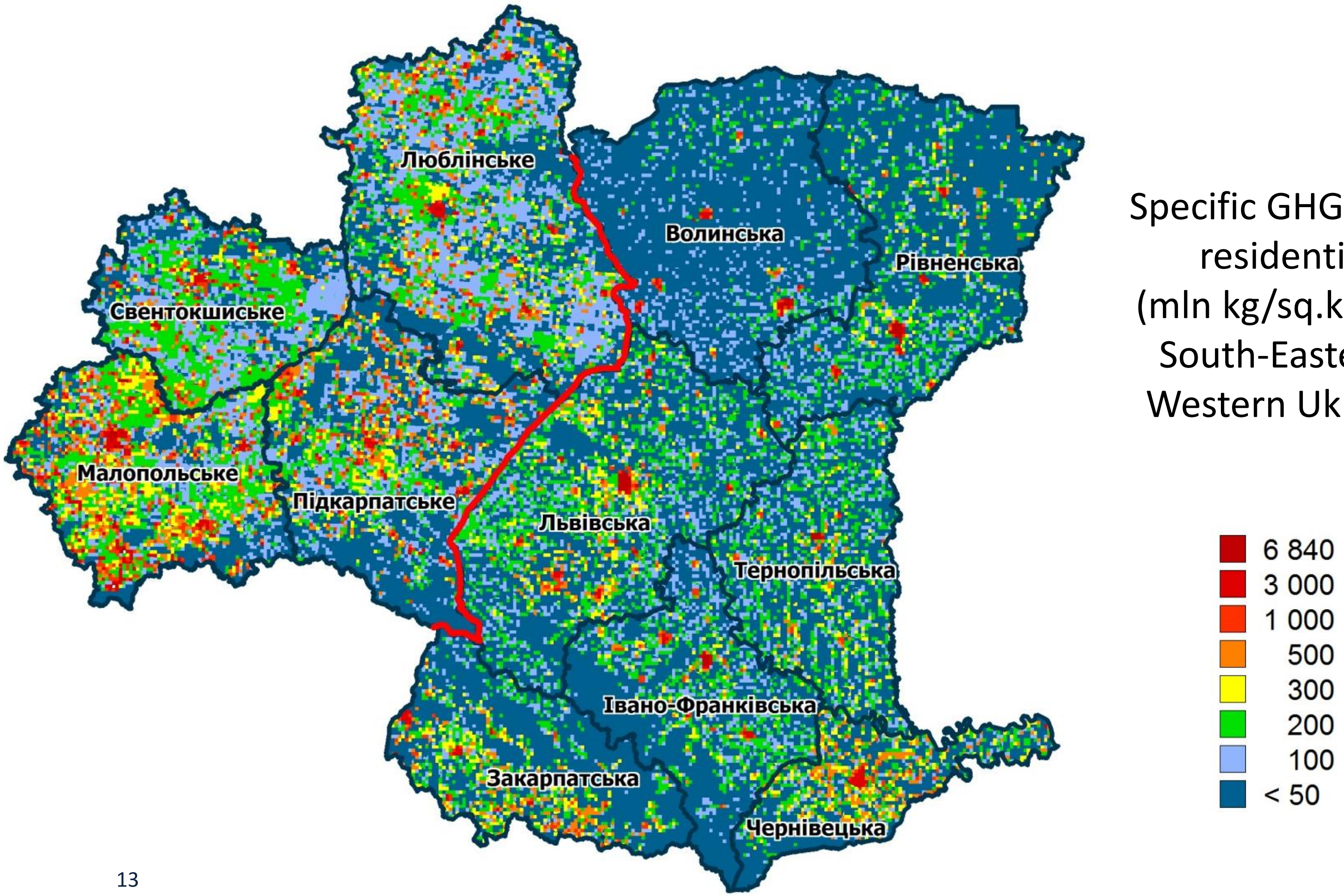
Structure of GHG emissions by type of fossil fuel for administrative regions (mln kg, CO2-eq., Ukraine, 2010)

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)

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

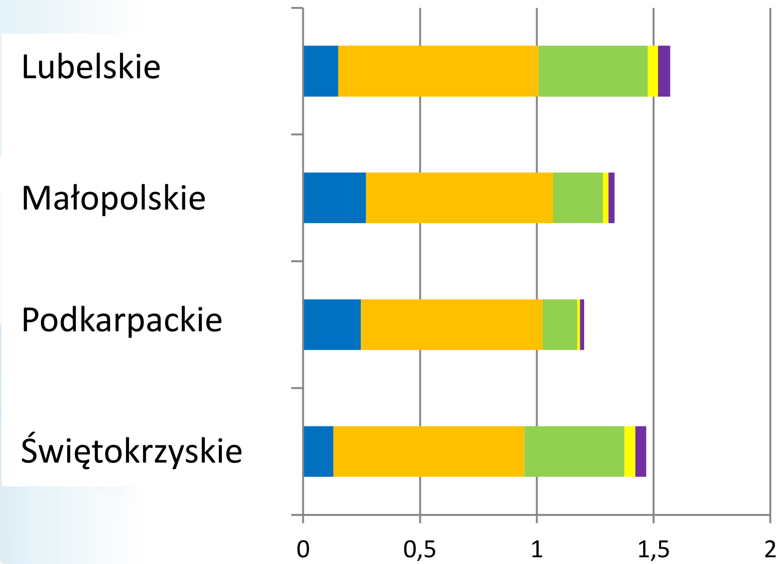


Fig. 1. Structure of GHG emissions per capita by type of fossil fuel (thousands kg per capita, CO_2–eq., South-Eastern Poland, 2010)

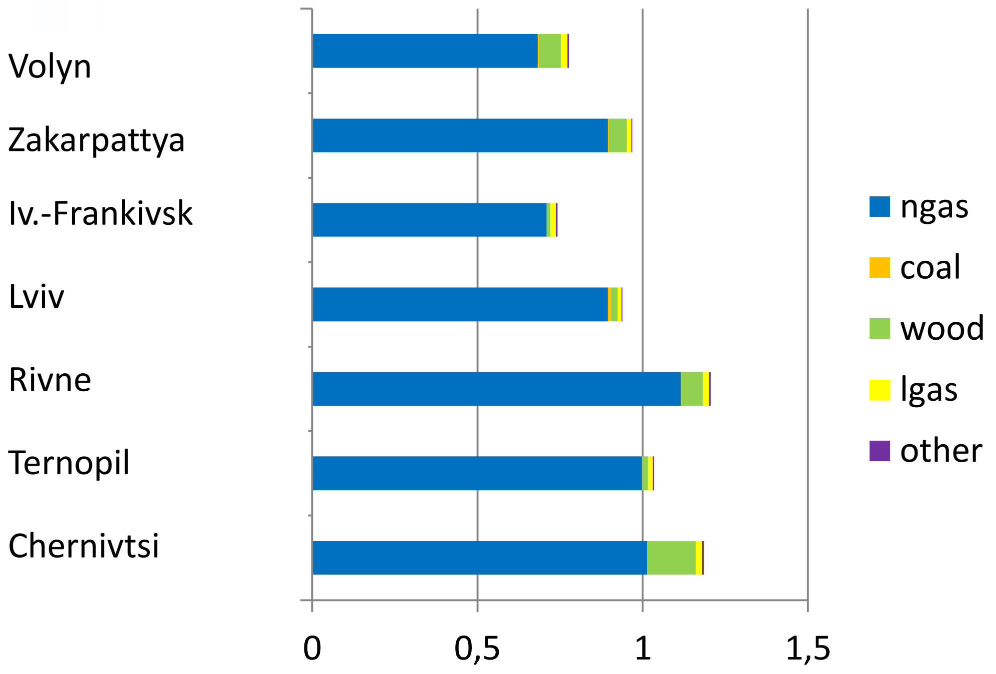
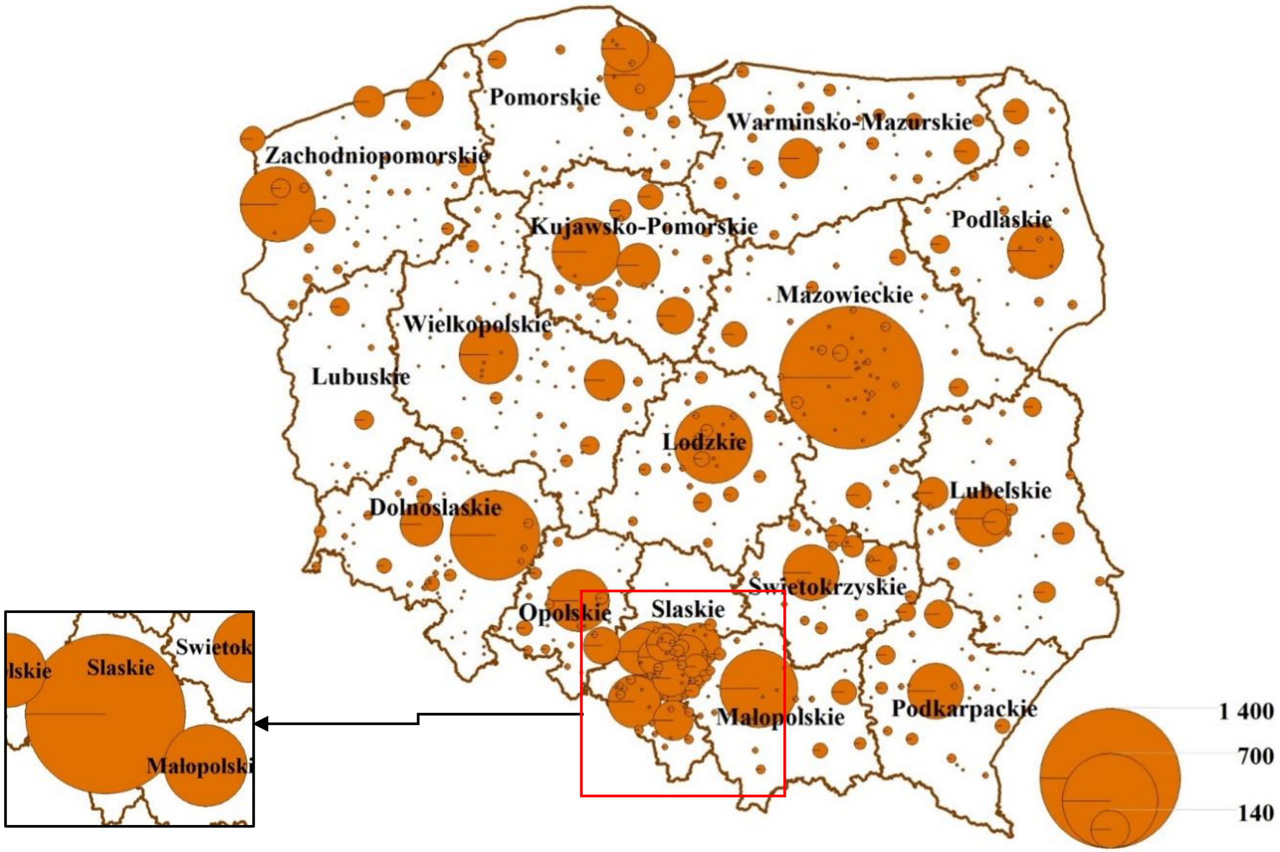


Fig. 2. Structure of GHG emissions per capita by type of fossil fuel (thousands kg per capita, CO_2–eq., Western Ukraine, 2010)

GHG emissions from the heat production



Greenhouse gas emissions from heat production in Poland
(thousands tons, CO_2-equivalent, 2010)

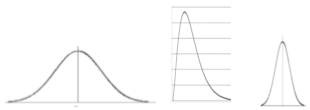
Uncertainty analysis: Monte-Carlo method

Inventory level

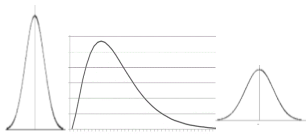


Settlement **Region** **Country**

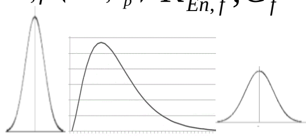
Fuel

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

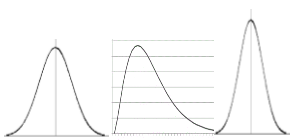



$Q_{En,f}(\xi_{En,n_p}), K^{g}_{En,f}, C_f$

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

…

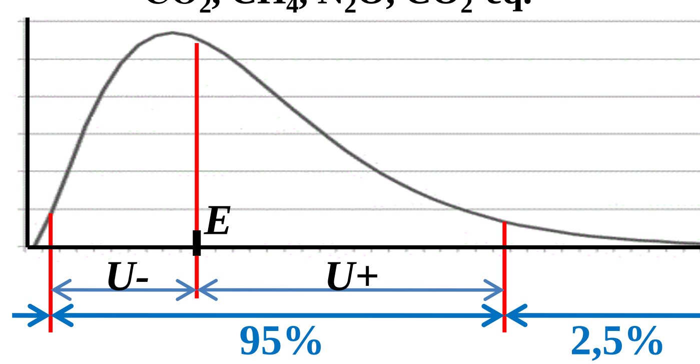



$Q_{En,f}(\xi_{En,n_p}), K^{g}_{En,f}, C_f$

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

Result

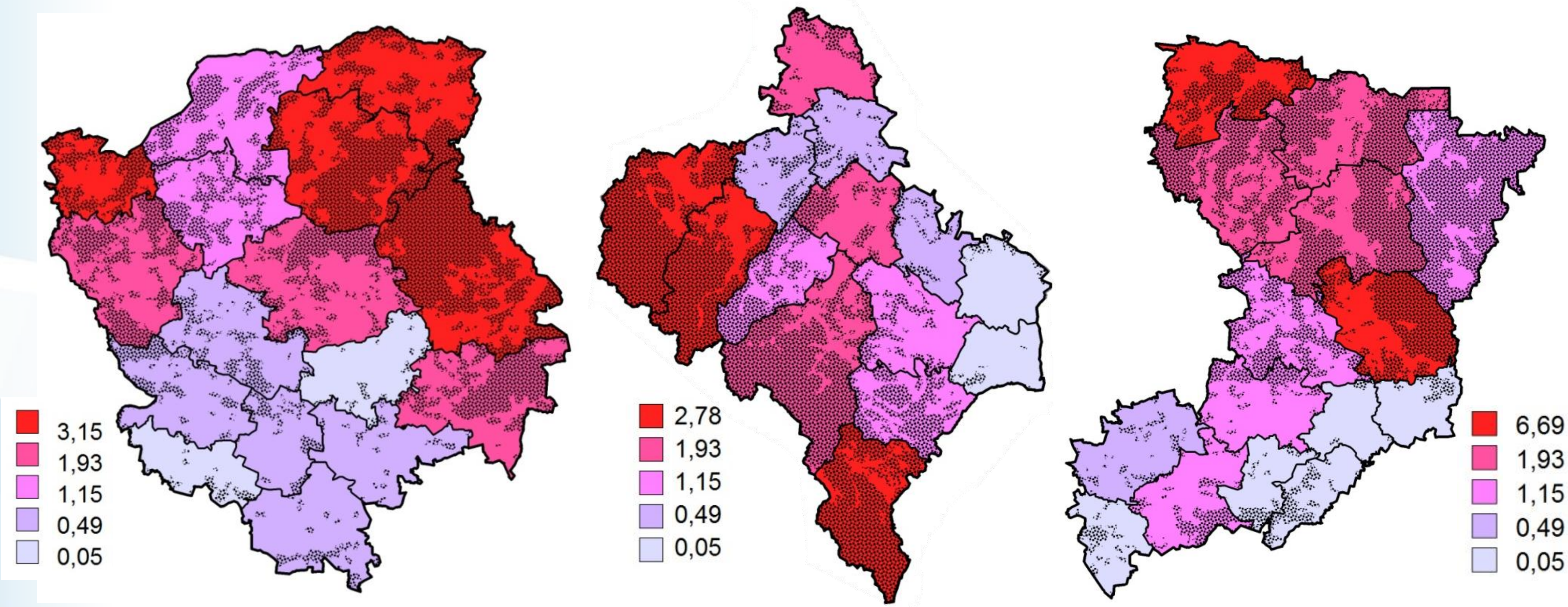
Total emission/uncertainties:
CO_2, CH_4, N_2O, CO_2-eq.



Uncertainty analysis: Monte-Carlo method

Voivodeship	CO_2, Gg (uncertainty, %)	CH_4, Gg (uncertainty, %)	N_2O, 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

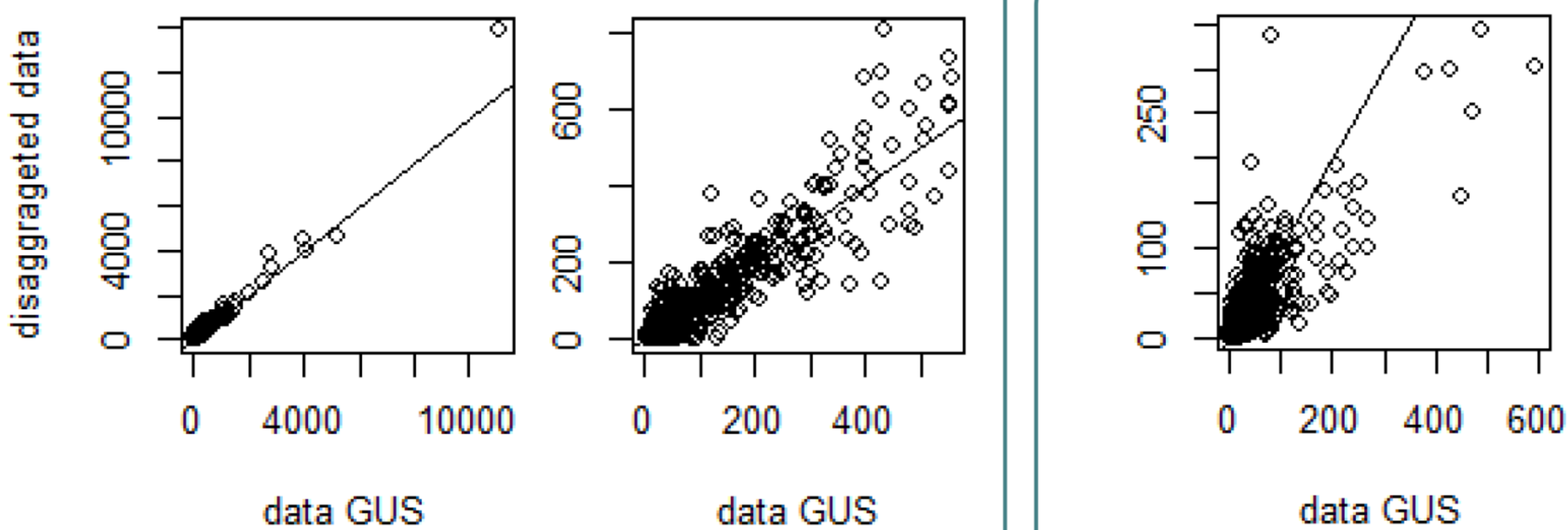


Statistical data devided by disaggragated data
(black dots – forest cover)

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 -> dissagregation -> spatial uncertainty
- Validation and uncertainty analysis are important components of spatial inventory

Thank you for your attention!

Olha Danylo
Interntional Institute for Applied Systems Analysis
email: olha.danylo@gmail.com
danylo@iiasa.ac.at