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## Biogas role for smart municipalities – a step-wise dynamic assessment framework

BioEcon Management Committee Meeting, Pulawy, 26/09/2017

# Outline

**1) Context**

**2) Step-wise method and results**

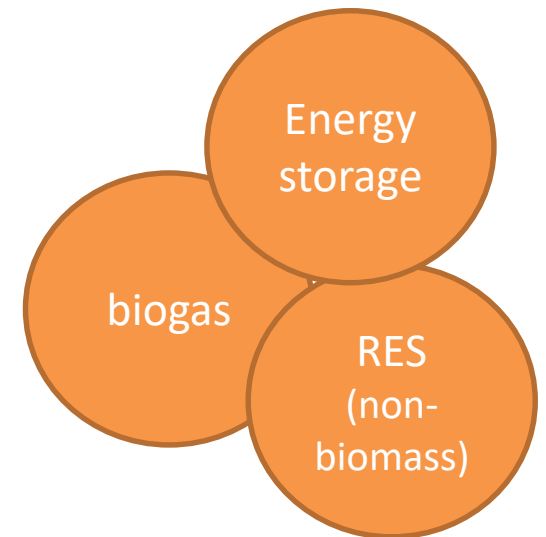
**3) Conclusions**



# Context

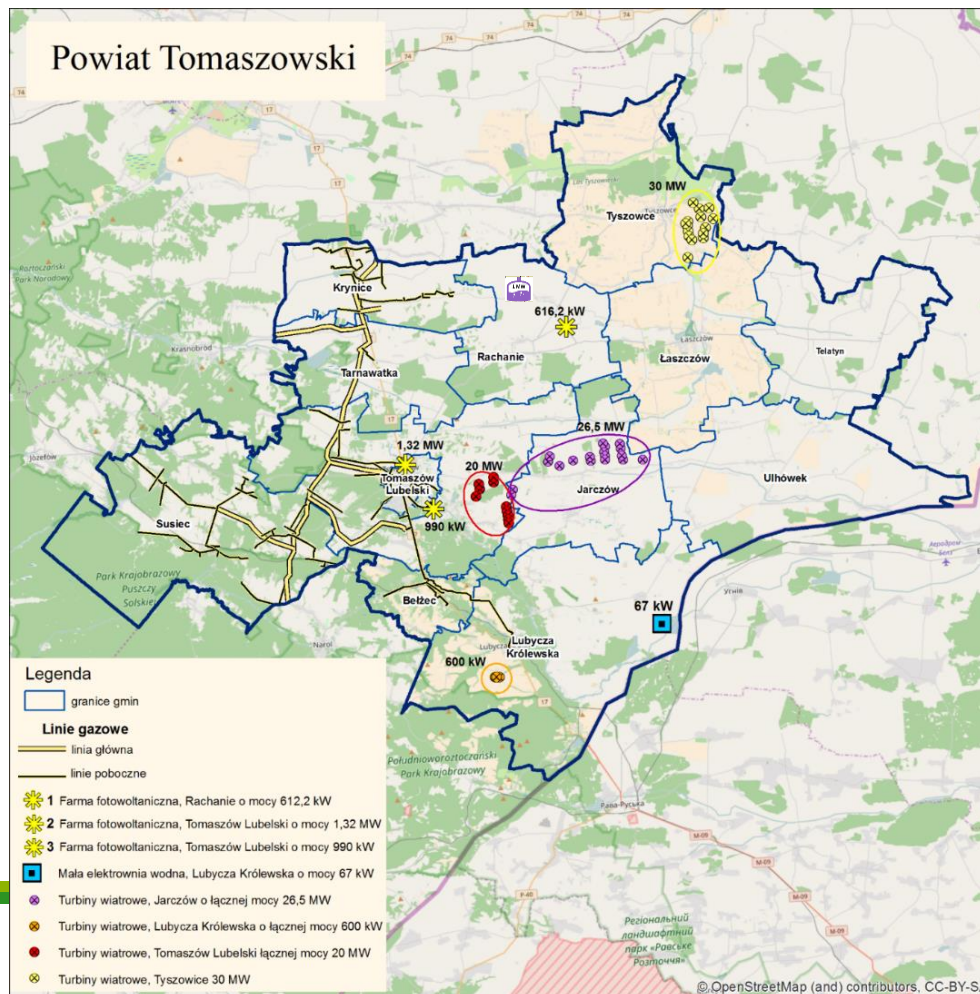
# Context

- **How can the “powiat” be as self-sufficient as possible in energy?**
- **What investments to make?**
- **Expressed preferences**
  - **Local solutions**
  - **“Simple”**
  - **Cheap**

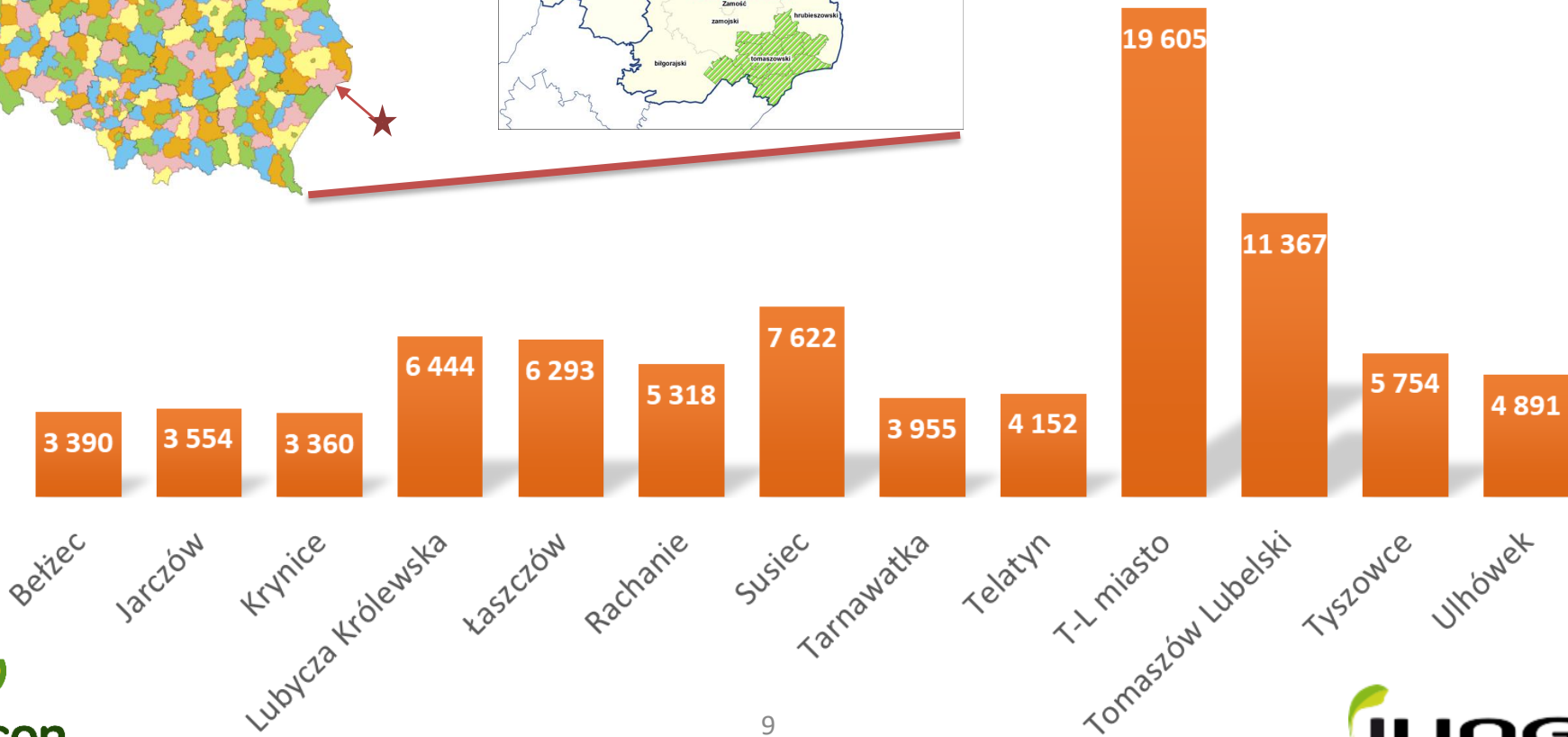
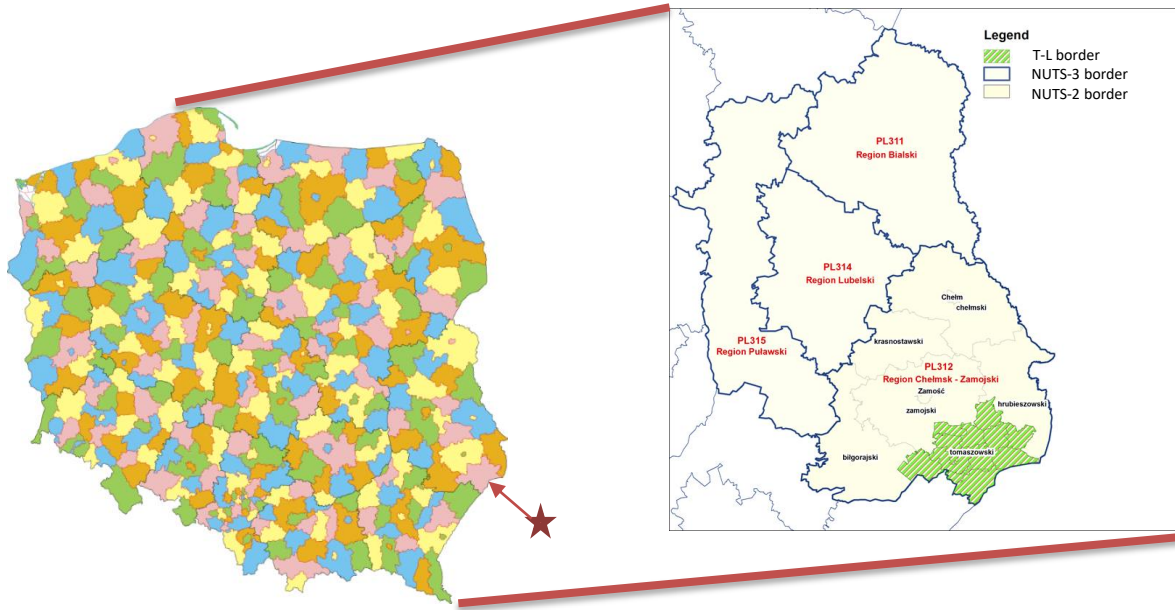


# Context

## Why a cluster in T-L “powiat”?



# The case study area



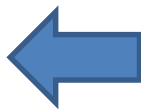
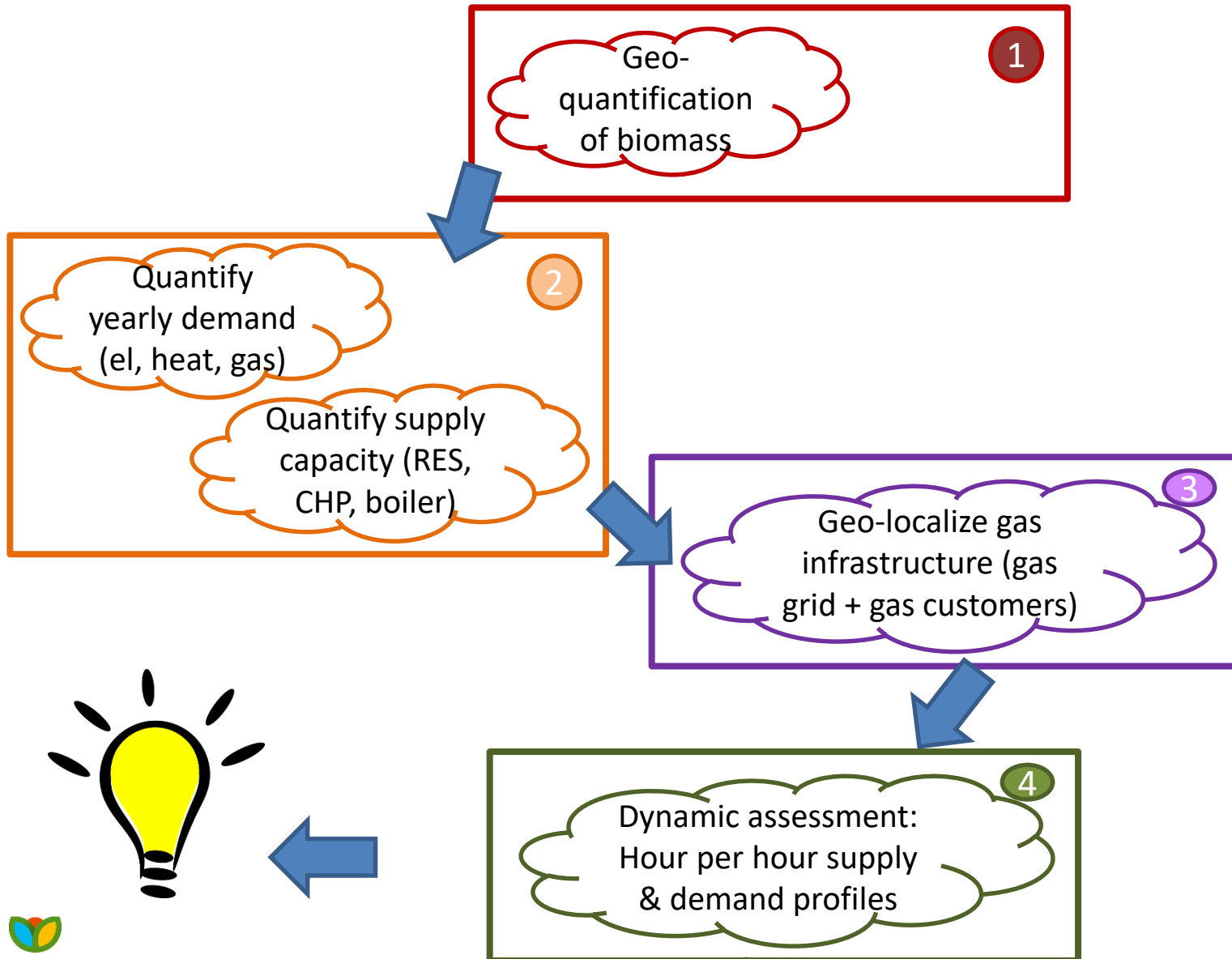
# Why biogas? How biogas?

- **Biogas does make sense for Poland**
- **Residues only**
  - **Agricultural (straw and manure)**
  - **Grass from unused grasslands**



# Methodology

# Step-wise methodology



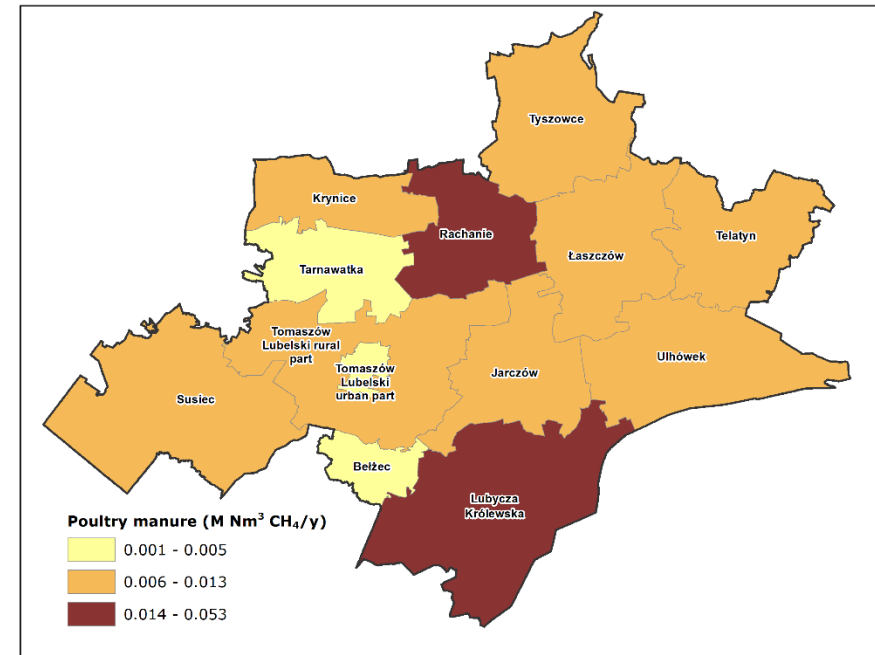
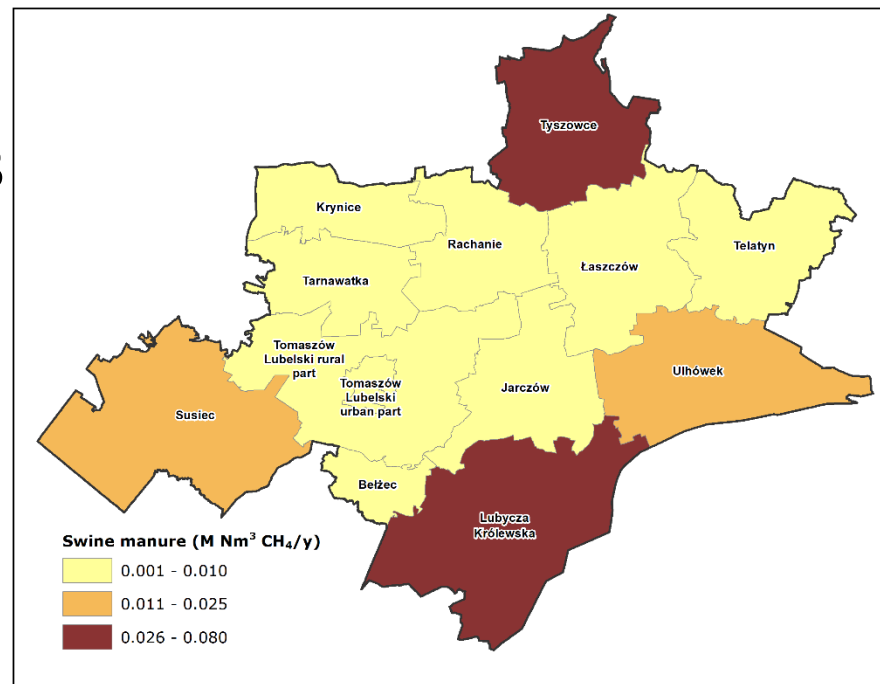
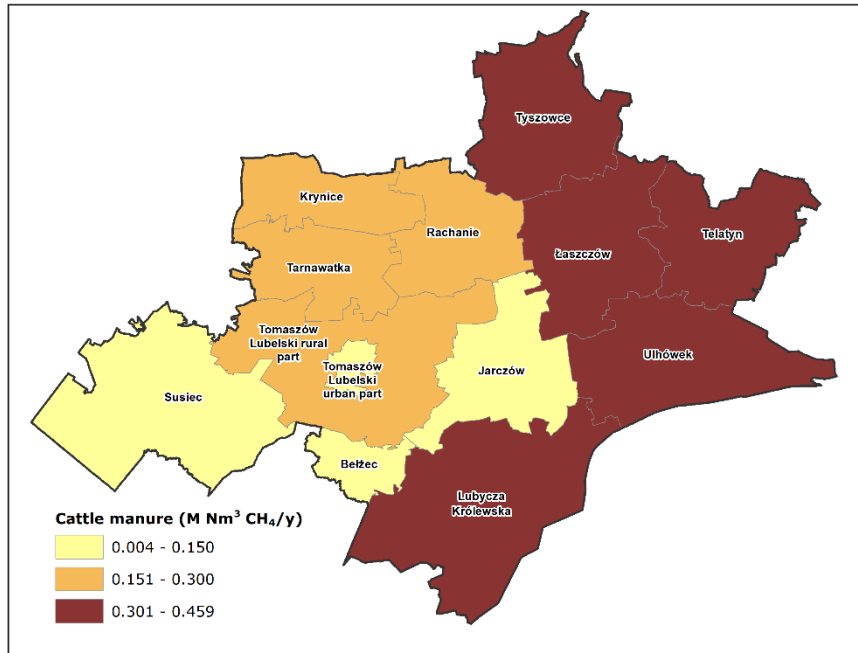
# Step 1. Geo-quantification of resources



# Role of biogas – step 1.

## Geo-quantification of resources

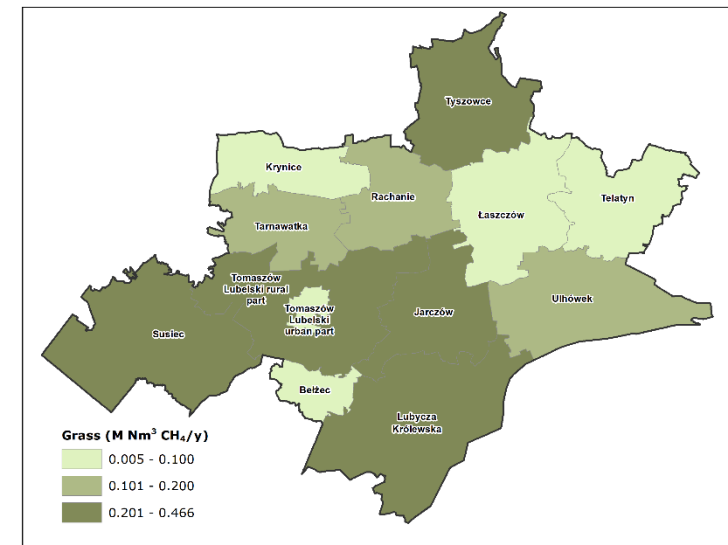
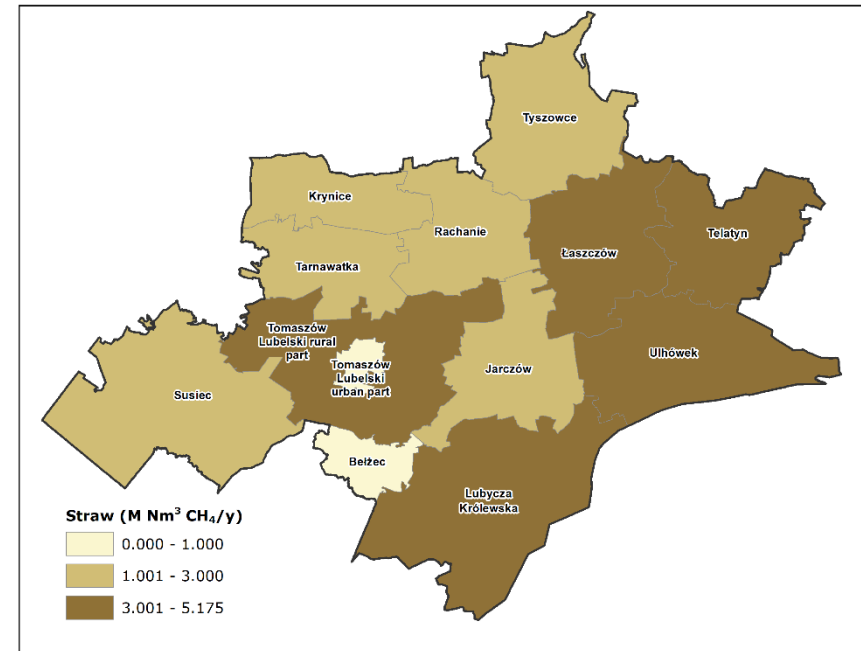
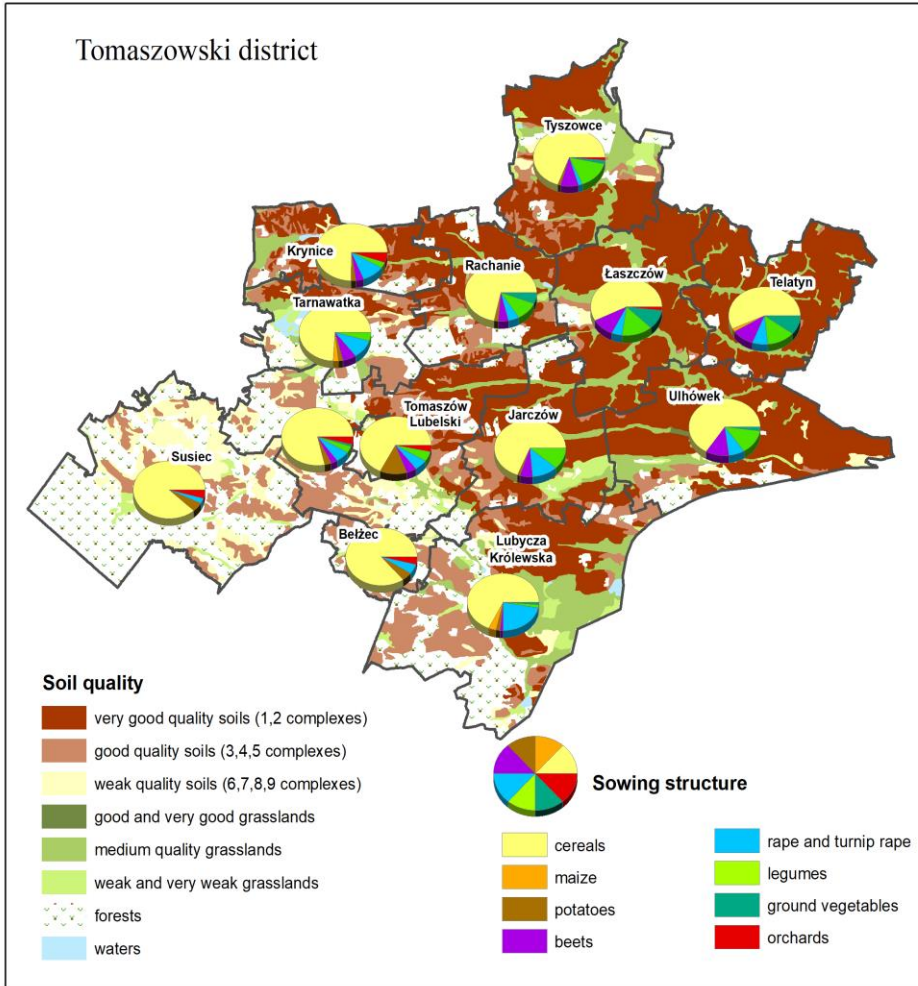
- Manure . Max potential after excretion on pastures.



# Role of biogas – step 1.

## Geo-quantification of resources

- *Straw and grass . Max potential.*

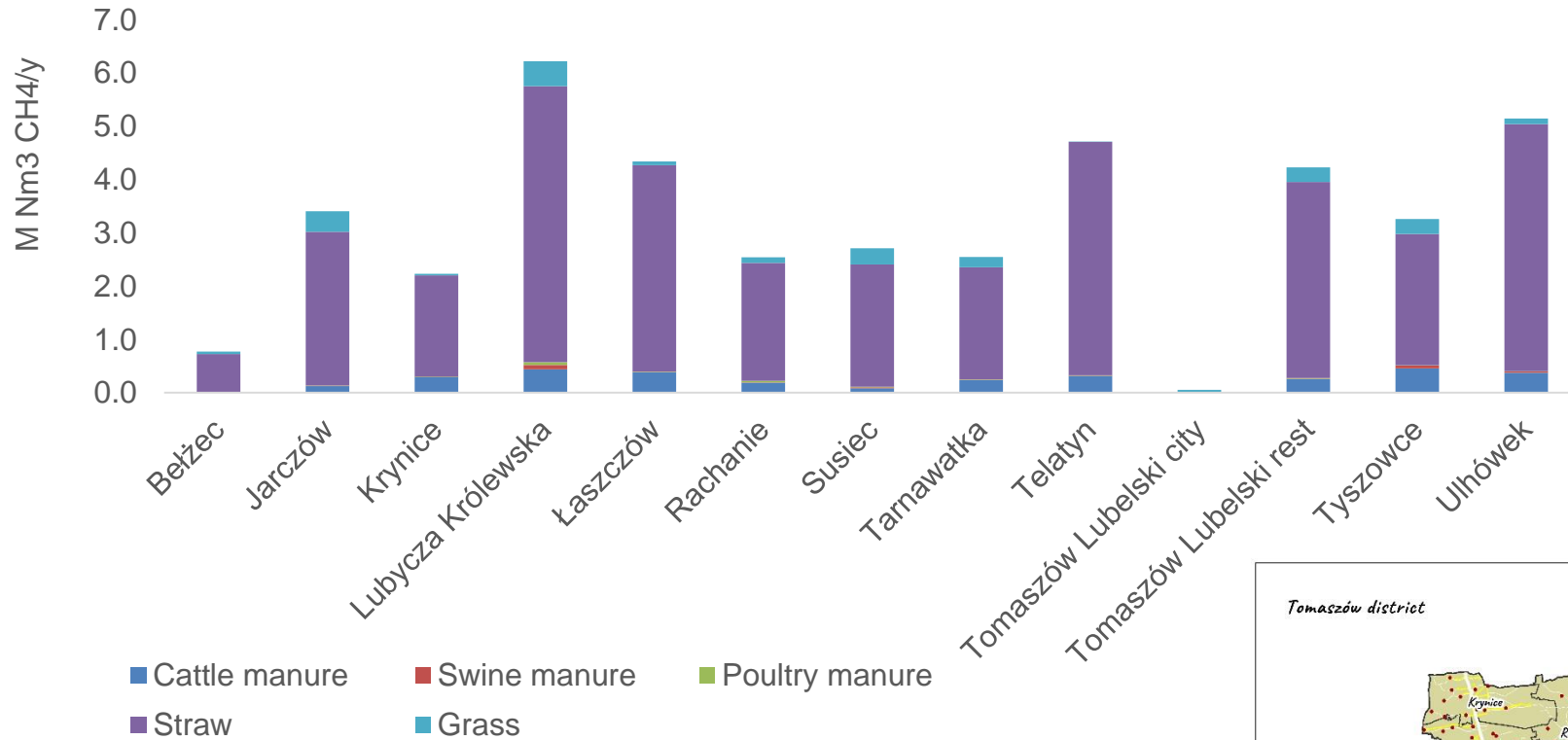


Data: Central Statistical Office of Poland (GUS) for yield and area; Ratio product to residues (algorithms function of the yield); Polish soil geo-database. Straw from wheat, rye, barley, oat, triticale, rape, mixed cereals, maize

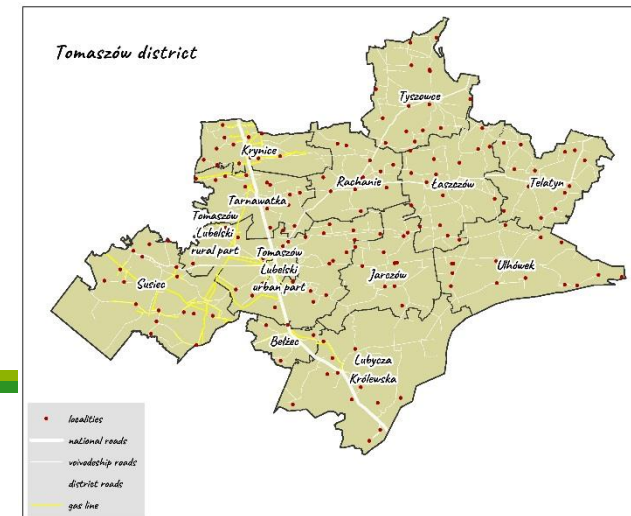
# Role of biogas – step 1.

## Geo-quantification of resources

- Straw and grass . Max potential. After fermentation losses (1%) but before combustion engine.



Data:  
Compilation for BMP, VS, and DM of all substrates. Fugitive losses during anaerobic digestion assumed as 1% of the brutto CH<sub>4</sub> produced.



## Step 2 – Geo-quantification of energy demand and supply (electricity and heat)

# Role of biogas – step 2.

## Geo-quantification of customers (demand)

### - Electricity

LP	Gmina	Total (GWh/y)	Industry (MWh/y)	Public Inst. (MWh/y)	Street light (MWh/y)	Houses (MWh/y)
1	Bełżec	2,297	x	227	73	2,000
2	Jarczów	2,297	x	100	100	2,097
3	Krynice	3,735	1,516	152	84	1,983
4	Lubyc. Królewska	4,070	x	194	73	3,803
5	Łaszczów	12,297	7,533	348	702	3,714
6	Rachanie	3,368	x	168	61	3,138
7	Susiec	4,892	x	279	116	4,498
8	Tarnawatka	4,420	1,841	176	69	2,334
9	Telatyn	3,037	x	547	40	2,450
10	T-L city	38,572	23,063	2,442	1,498	11,569
11	T-L rural	7,417	x	142	567	6,708
12	Tyszowce	3,672	x	120	157	3,395
13	Ulhówek	3,282	x	326	69	2,886
<b>Total</b>		<b>91,057</b>	<b>33,953</b>	<b>5,221</b>	<b>3,609</b>	<b>50,574</b>

Source: Municipalities (cluster members) + Municipal Low Emission Plans

# Role of biogas – step 2.

## Geo-quantification of customers (demand)

- Heat

LP	Gmina	Total (GJ/y)	Industry (GJ/y)	Public Inst. (GJ/y)	Houses (GJ/y)
1	Bełżec		X		
2	Jarczów		X		
3	Krynice	123,467	11,703	5,657	106,107
4	Lubyc. Królewska		X		
5	Łaszczów				
6	Rachanie		X		
7	Susiec		X		
8	Tarnawatka				
9	Telatyn	108,746	X	4,787	103,959
10	T-L city	526,487	101,988	26,889	397,610
11	T-L rural		X		
12	Tyszowce	20,725	X	4,309	16,416
13	Ułhówek		x		
<b>Total</b>		<b>779,424</b>	<b>113,691</b>	<b>41,641</b>	<b>624,092</b>

Source: Municipalities (cluster members) + Municipal Low Emission Plans

# Role of biogas – step 2.

## Geo-quantification of supply capacity

LP	Gmina	Boiler plant (heat) (GJ)	Wind (el) (MW)	Solar thermal (GJ)	PV (el) (MW)	Hydro & biogas (el) (MW)
1	Bełżec					
2	Jarczów		27	65		
3	Krynice	100,183		209		
4	Lubyc. Królewska					0.067
5	Łaszczów					
6	Rachanie				0.6	1.0
7	Susiec					
8	Tarnawatka	1,445				
9	Telatyn					
10	T-L city	29,318			1.3	
11	T-L rural		20		1.0	
12	Tyszowce		30			
13	Ulhówek					
<b>Total</b>		<b>130,946</b>	<b>77</b>	<b>275</b>	<b>3.0</b>	<b>1.07</b>

Source: Municipalities (cluster members) + Municipal Low Emission Plans

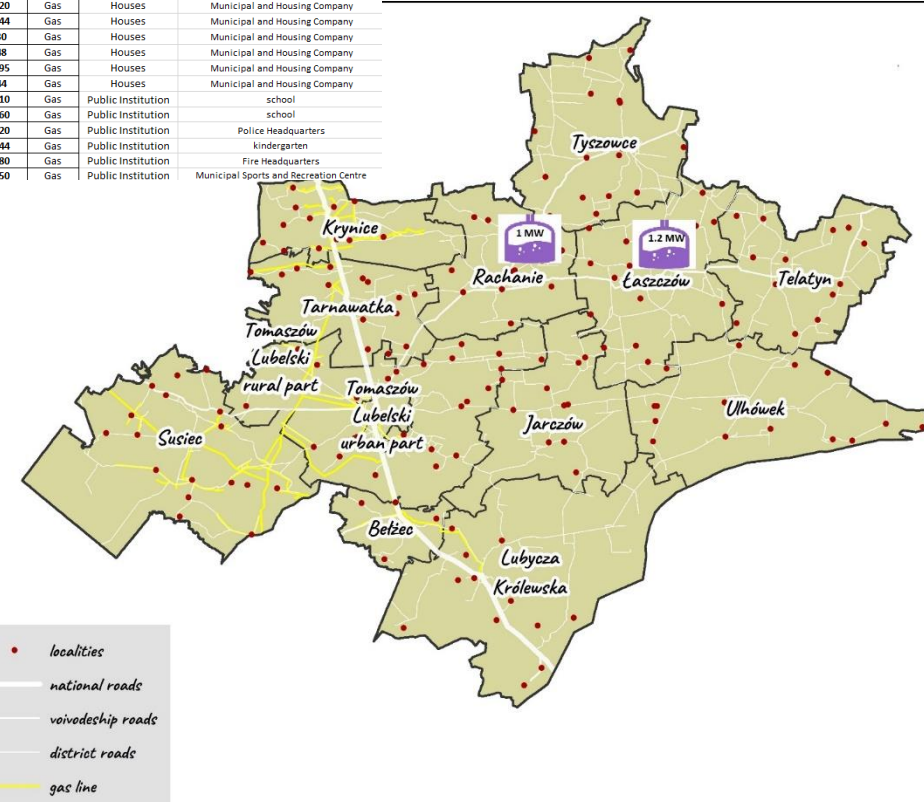
# Step 3. Geo-localization of infrastructure in place

# Role of biogas – step 3.

## Geo-localization of current infrastructure

### - Natural gas infrastructure and localization of demand

Coordinate wgs_84	Coordinate wgs_84	Gmina	Spec	Address	plot number	SUM Capacity (kW)	Fuel	Type	translation
50.452347	23.416258	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		335	600	Gas	Houses	housing cooperative
50.448578	23.414510	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		163/11	2240	Gas	Houses	housing cooperative
50.44903	23.412867	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		139/23	4200	Gas	Houses	housing cooperative
50.451629	23.419117	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		308/1	100	Gas	Houses	housing cooperative
50.449284	23.417987	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		251/44	400	Gas	Houses	housing cooperative
50.448073	23.417193	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		251/49	240	Gas	Houses	housing cooperative
50.442386	23.427353	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		65/3	100	Gas	Houses	housing cooperative
50.447359	23.4181	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		240/2	300	Gas	Houses	housing cooperative
50.446599	23.418012	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		240/5	300	Gas	Houses	housing cooperative
50.447204	23.416589	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		240/3	300	Gas	Houses	housing cooperative
50.451907	23.416996	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		345	1000	Gas	Houses	housing cooperative
50.452701	23.408711	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		353	1000	Gas	Houses	housing cooperative
50.450667	23.41004	Tomaszów Lubelski urban part	Spółdzielnia Mieszkaniowa w Tomaszowie Lub.		244	150	Gas	Houses	housing cooperative
50.439051	23.414791	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Składowskiej 48B	78	384	Gas	Houses	Municipal and Housing Company
50.452597	23.420052	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Kościelna 1	2/1	35	Gas	Houses	Municipal and Housing Company
50.43789	23.424334	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Rolnicza 15	34/9	84	Gas	Houses	Municipal and Housing Company
50.457725	23.420909	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Zamojska 27	172	48	Gas	Houses	Municipal and Housing Company
50.453798	23.41794	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Piłsudskiego 2	293	25	Gas	Houses	Municipal and Housing Company
50.434005	23.423572	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Rejlana 7	20/7	120	Gas	Houses	Municipal and Housing Company
50.432551	23.418486	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Rolnicza 28	11.12	144	Gas	Houses	Municipal and Housing Company
50.430732	23.39889	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Rynek 26	4	30	Gas	Houses	Municipal and Housing Company
50.430732	23.39889	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	ujście wody, Brygady 1	1/1	48	Gas	Houses	Municipal and Housing Company
50.443894	23.430594	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Oczyszczalnia ścieków, Petera 63	36	195	Gas	Houses	Municipal and Housing Company
50.449849	23.418016	Tomaszów Lubelski urban part	Przedsiębiorstwo Gospodarki Komunalnej i Mieszkaniowej w Tomaszowie Lub.	Baza PGKM Lwowska 37A	160/3	44	Gas	Houses	Municipal and Housing Company
50.453208	23.403175	Tomaszów Lubelski urban part	Szkoła Podstawowa Nr 2 im. J. Piłsudskiego, gimnazjum	Żołnierzy Września 1	84/2	810	Gas	Public Institution	school
50.448685	23.405595	Tomaszów Lubelski urban part	Specjalny Ośrodek Szkolno – Wychowawczy im. Janusza Korczaka	Wesoła 1	12/2	260	Gas	Public Institution	school
50.445311	23.421989	Tomaszów Lubelski urban part	Komenda Powiatowa Policji	Zeromskiego 4	93/31, 200/18	420	Gas	Public Institution	Police Headquarters
50.452903	23.413328	Tomaszów Lubelski urban part	Przedszkole Samorządowe Nr 1 im. Jana Brzechwy	Chocińska 17	117	344	Gas	Public Institution	kindergarten
50.444138	23.423278	Tomaszów Lubelski urban part	Komenda Powiatowa Państwowej Straży Pożarnej	Petera 7	96/3	280	Gas	Public Institution	Fire Headquarters
50.44865	23.420941	Tomaszów Lubelski urban part	OSIR Tomaszovia	Al. Sportowa 8	2	450	Gas	Public Institution	Municipal Sports and Recreation Centre



IEA (2017)

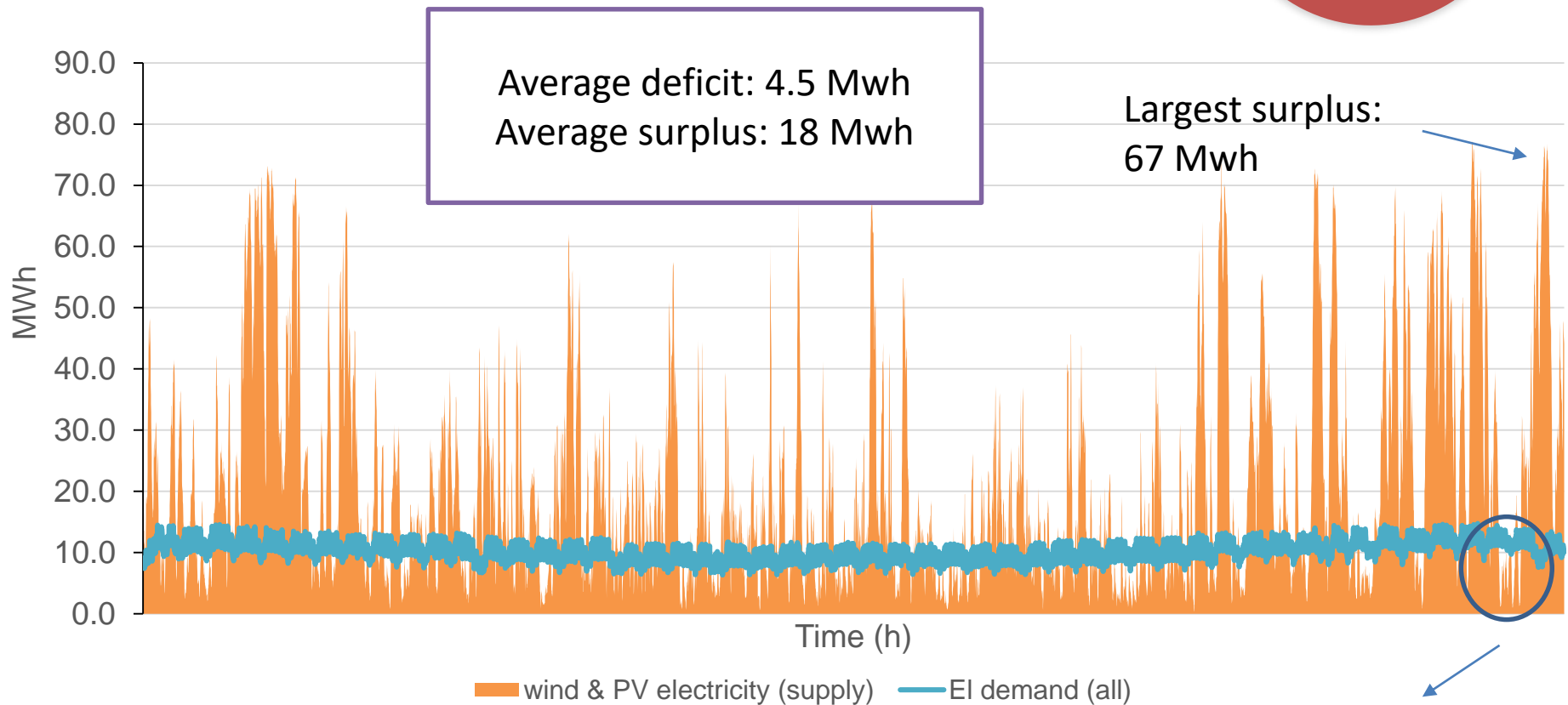
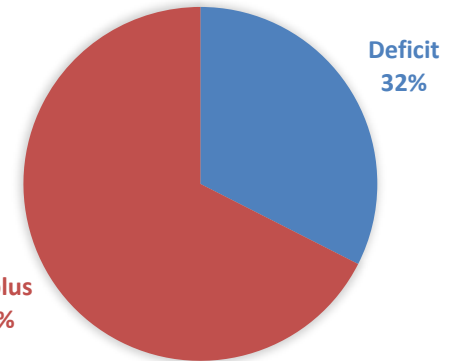
# Step 4 – Dynamic analysis

Gmina	Julian date	supply PV el generated (MWh)	supply wind el (MWh)	supply wind + sun el (MWh)	Demand el for street lightning (MWh)	Demand el rest (MWh)	Demand total el (MWh)	Heat demand (MJ)	Gas demand for heat (MJ)	Non-heat industrial gas demand (MJ)	Biogas EL supply, (el only, MAX resources) (MWh)	Biogas EL supply, MAX (MJ)	Biogas el + PV (MWh)	Biogas el + other RES (MWh)	Biogas HEAT supply (heat only, max resources) (MJ)	Biogas EL supply, MIN resources (MWh)	Biogas el + PV (MWh)	Biogas el + other RES (MWh)	Biogas HEAT supply (MJ)	Price of el (PLN/MWh)
Tomaszów Lubelski, urban part	01/01/2016 01:00	0.000	21.060	21.060	0.88717	8.16	9.04	191713	87957	2271	20.913	75286.8852	20.913	41.973	75286.8852	10.760	10.760	31.820	38734.4	122.0
Tomaszów Lubelski, urban part	01/01/2016 02:00	0.000	19.675	19.675	0.88717	7.80	8.69	191713	87957	2271	20.913	75286.8852	20.913	40.588	75286.8852	10.760	10.760	30.435	38734.4	105.7
Tomaszów Lubelski, urban part	01/01/2016 03:00	0.000	18.589	18.589	0.88717	7.49	8.38	191713	87957	2271	20.913	75286.8852	20.913	39.502	75286.8852	10.760	10.760	29.348	38734.4	96.0
Tomaszów Lubelski, urban part	01/01/2016 04:00	0.000	15.913	15.913	0.88717	7.26	8.15	191713	87957	2271	20.913	75286.8852	20.913	36.826	75286.8852	10.760	10.760	26.673	38734.4	88.0
Tomaszów Lubelski, urban part	01/01/2016 05:00	0.000	13.536	13.536	0.88717	7.21	8.10	191713	87957	2271	20.913	75286.8852	20.913	34.449	75286.8852	10.760	10.760	24.296	38734.4	117.0
Tomaszów Lubelski, urban part	01/01/2016 06:00	0.000	13.615	13.615	0.88717	7.36	8.25	191713	87957	2271	20.913	75286.8852	20.913	34.528	75286.8852	10.760	10.760	24.375	38734.4	120.2
Tomaszów Lubelski, urban part	01/01/2016 07:00	0.000	11.884	11.884	0.88717	7.47	8.36	191713	87957	2271	20.913	75286.8852	20.913	32.797	75286.8852	10.760	10.760	22.643	38734.4	127.8
Tomaszów Lubelski, urban part	01/01/2016 08:00	0.001	11.254	11.255	0	7.44	7.44	191713	87957	2271	20.913	75286.8852	20.914	32.168	75286.8852	10.760	10.760	22.014	38734.4	71.7
Tomaszów Lubelski, urban part	01/01/2016 09:00	0.237	11.569	11.806	0	7.54	7.54	191713	87957	2271	20.913	75286.8852	21.150	32.719	75286.8852	10.760	10.996	22.565	38734.4	75.0
Tomaszów Lubelski, urban part	01/01/2016 10:00	0.536	10.071	11.007	0	7.73	7.73	191713	87957	2271	20.913	75286.8852	21.480	32.110	75286.8852	10.760	11.205	22.256	38734.4	96.7

# Role of biogas – step 4.

## Dynamic analysis

### Incidences of excess and deficit power -whole "powiat"

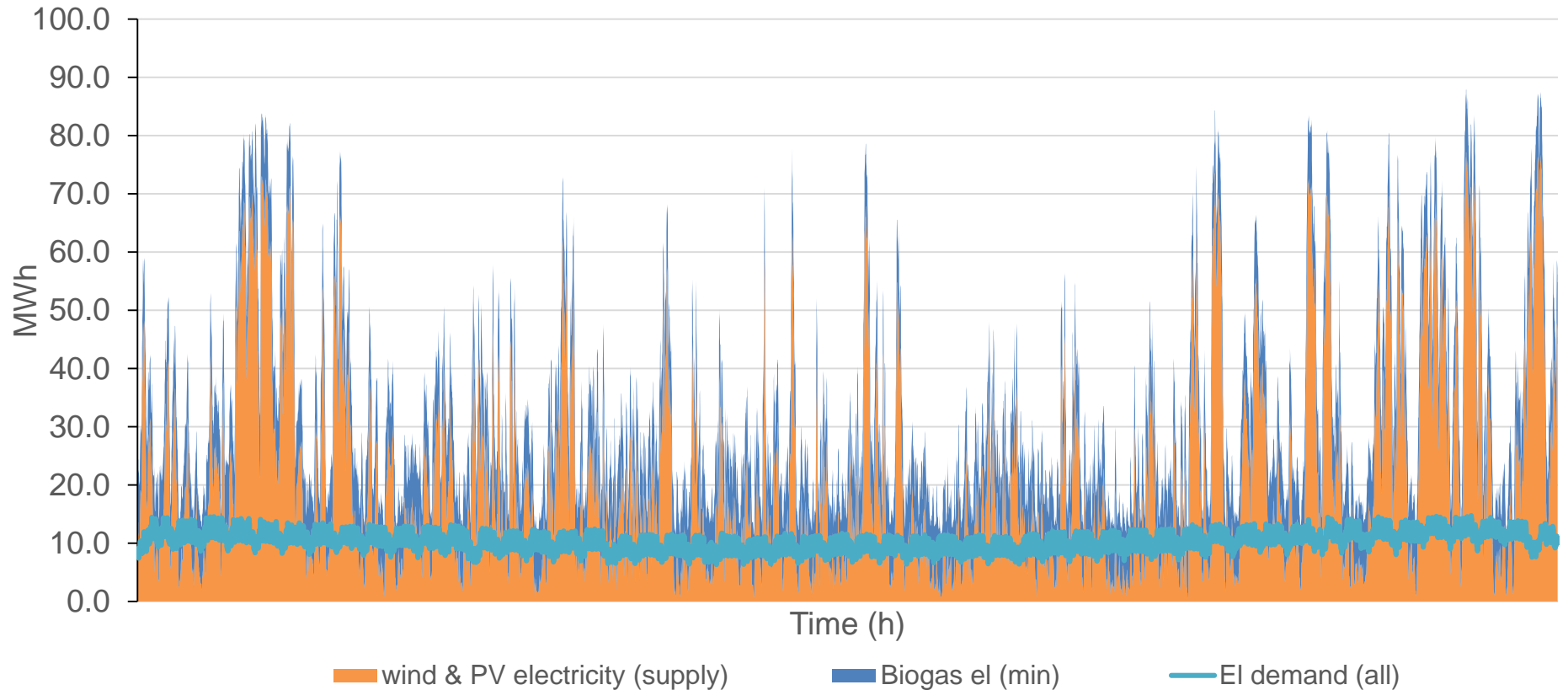


Source: Solar profile allocated per hour based on local radiation data, hourly wind profile and electricity demand scaled from national profile 2016, retrieved from ENTSO-E, gas combustion engine efficiency el: 45% (total: 90%).

# Role of biogas – step 4.

## Dynamic analysis

Enough biogas to buffer deficit?  
*-whole "powiat"*

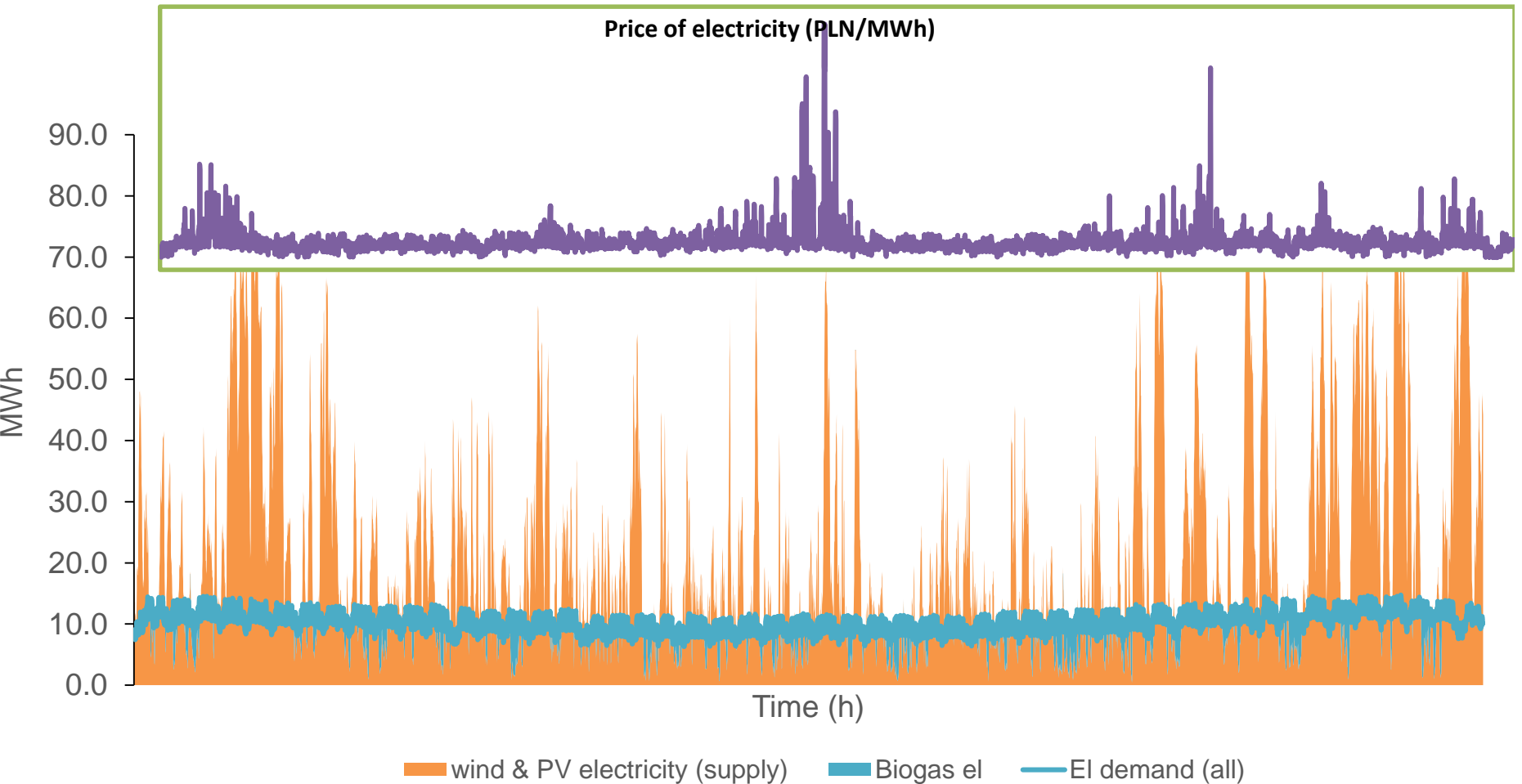


Source: Solar profile allocated per hour based on local radiation data, hourly wind profile and electricity demand scaled from national profile 2016, retrieved from ENTSO-E, gas combustion engine efficiency el: 45% (total: 90%). Biogas (min): all manure, no grass and half the straw.

# Role of biogas – step 4.

## Dynamic analysis

Upgraded biogas (water scrubber) + biomethane electricity on deficit periods? - whole "powiat"



Source: Solar profile allocated per hour based on local radiation data, hourly wind profile and electricity demand scaled from national profile 2016, retrieved from ENTSO-E, gas combustion engine efficiency el: 45% (total: 90%). Biogas (min): all manure, no grass and half the straw. Loss during scrubbing: assumed as 2% of input CH<sub>4</sub> (high). Price of el from Polish Power Exchange/Nasdaq (2016). DAM.

# Conclusion & insights

# Conclusion & insights

- Useful method developed/operationalized for opportunity analysis at local level. Both geo-localized and dynamic.
- In T-L case study: Biogas can play a role in balancing fluctuating power. Residual biomass resources are enough for that. However, biogas-to-CHP increases surplus in excess hours.
- In T-L: Focusing on self-supply only, investing in more fluctuating power (e.g. PV) is shown NOT to be the first priority.
- In T-L: gas infrastructure and road network are in good match for intercity buses & municipal waste trucks on CNG. May be a key role for biogas.
- In T-L: Little industrial demand, and IPH stems mostly from coal boilers. Therefore, this offers little opportunity for biogas, now.
  - Boilers could be changed to hybrid (gas/electricity at high surplus). This also applies for smaller “individual” customers
- In T-L: Storage solutions must be investigated to store excess fluctuating power (CAES, hydro-pumped storage)



# Perspectives (what's next)

- **Strategic localization of biogas/upgrading plants**
  - Transporting gas vs transporting biomass
  - Synergies with building biogas plant close to DH plants?
- **Quantify the transport demand for gas (intercity bus and municipal trucks for CNG, long-distance for LNG)**
- **Optimization (cost, pressure/operation mode, strategic gas storage facilities, relevance of a local gas grid to avoid upgrading)**
- **Storage options (hydro-pumped; CAES-sand) to buffer fluctuating to be investigated**
- **Gas demand: Complete the localization of gas customers and demands**



*This project has received funding from the European Union's HORIZON 2020 research and innovative programme, under Grant Agreement No. 669062  
Call: H2020 WIDESPREAD-2014-2015, topic: WIDESPREAD-2014-2 ERA Chairs*

**More info on the Bioecon project:**  
<http://bioecon.iung.pulawy.pl/en/>



**More info on this study:**

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