Implementing Advanced Concepts for Biological Utilization of Waste

Biogas electricity production from household biowaste

Case: Dolnoslaskie

O.2.9

Version 1.0

18.11.2014

Tuomas Huopana, Emilia den Boer, Agnieszka Łukaszewska, Harri Niska, Mikko Kolehmainen, Tuomo Eskelinen, Miika Kajanus, Mervi Lappi, Marja Kauppinen, Ari Jääskeläinen, Eero Antikainen

Baltic Sea Region
Programme 2007-2013
Part-financed by the European Union (European Regional Development Fund)

UNIVERSITY OF EASTERN FINLAND

1. INTRODUCTION 3
2. FEEDSTOCK POTENTIALS 3
3. POTENTIAL SCENARIO 5
4. OPTIMIZED SCENARIO 6
5. REFERENCES 10

1. Introduction

Due to climate warming organic waste management is guided in Europe by waste framework directive (2008/98/EC). There is need to degrease GHG emissions by avoiding waste generation as well as increasing recycling and energy utilization. In local work shop in Wroclaw in July 2014 it was found out that municipal solid waste incineration and biological utilization of source separated household biowaste are the main regional targets. In Wroclaw University of technology professor Emilia den Boer and fellows did excellent job for operating a biorefinery (also called Pilot A). Results from biorefinery testing showed interests towards biological utilization of household biowaste. It was concluded that valuable biochemical such as 2,3 butanediol could be produced from kitchen waste which is also known as house hold biowaste. It was also found out that to implement this kind of biorefining technology there is a need to find out first technical solution for treating household biowaste. And in this case, dry digestion technology is proposed as potential technology for treating separately collected household biowaste. Many reasons support this approach, because there should be no organic material landfilled after 2016, co-generation of fermentation and digestion technologies have shown to have benefits from each other's as well as biogas production technology is well known and tested in waste management sector.

In Lower Silesia and in Poland there is biogas electricity certificate system which can increase biogas plant companies' incomes from electricity (1). Thus, household biowaste potential and its utilization scenario is assessed in this study. Based on potential scenario set up there is found the most cost efficient solution for biogas electricity production system with respect to operational income of the whole production chain.

2. Feedstock potentials

Source separated household biowaste potential and its distribution was observed while also industrial biodegradable waste feedstocks in Dolnoslaskie region are introduced. Professor Emilia den Boer and fellows did excellent job for finding out industrial biodegradable waste potentials which are represented in Figure 2. Industrial biodegradable waste consisted of sludges from sugar production and other food industry. In 2011 industrial waste production was 314 kt while its total solid concentration varied from 11 to 45 % of fresh mass. If the availability of house hold biowaste is assumed to be 33.75 *kg/inh* its mass potential is around 97 kt/year (1) which is also considered as feedstock for biogas electricity production in this study.

Household biowaste production in Dolnoslaskie province was estimated for regional biogas heat and electricity production model (Figure 1). In 2012 household and similar kind of waste (EWC Stat code 10.1) production from households (Nace R2: EP HH) was *225 kg/inh* and 868 4119 ton (2). As a comparison, it was reported that generation of MSW in Dolnoslaskie was 326 kg/inh (1). The degree of source separation depends on people behavior and the availability of household biowaste can vary. Thus, in the model it is estimated that 33.75 *kg/inh* of household biowaste could be collected as source separated waste.

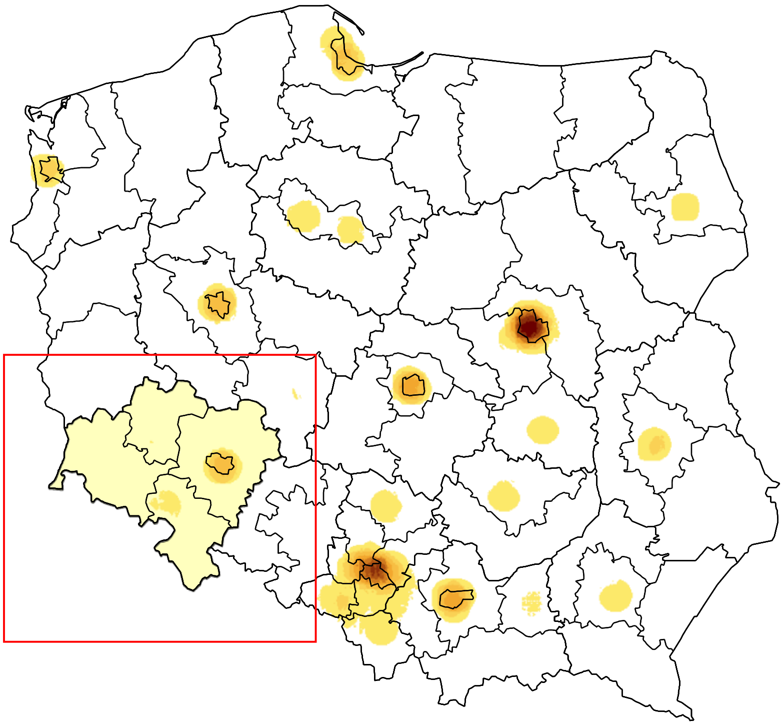

Figure 1. Distribution of population according to Eurostat grid data base while Dolnoslaskie province is highlighted as yellow color (3).

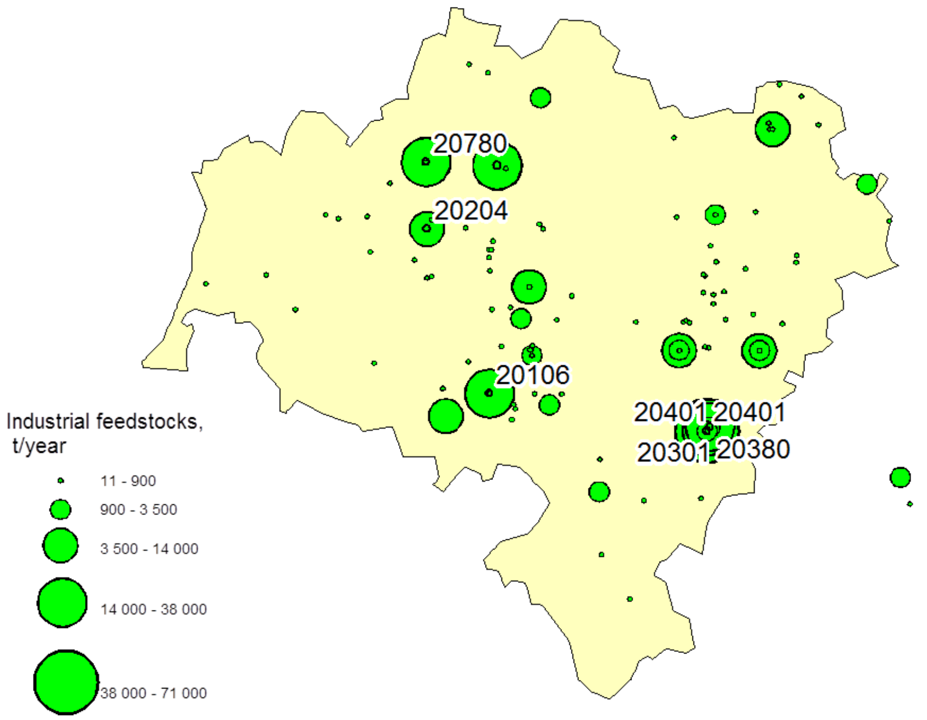

Figure 2. Industrial waste production in 2011 more than 10 000 ton per year is labeled with EWC codes (4).

3. Potential scenario

Cogeneration benefits with other industry would play the most important role in defining location for biogas plant. For example, it is shown that for electricity production from household biowaste, plants energy balance is playing the most dominant role (5). In case of Dolnoslaskie province the difference between feedstock transportation distances between different potential options can be maximally some hundreds of kilometers (Figure 3). In case of house hold biowaste its maximum sustainable transportation distance is around thousand kilometer (5). Heat balance is also playing large role in the overall energy balance. Heat is needed in sanitation and digestion itself. And it is shown for example that in Nordic climate conditions heat demand in a biogas plant can be one fourth of the produced biomethane (6). Thus, there should be first put attention for dealing with most suitable waste heat sources for biogas plants.

Current coal and gas fired cogeneration (CHP) plants could be potential waste heat sources for biogas plants (Figure 3). When typical feedstock amounts of several tens of thousand tons is processed, possible heat power need in the biogas plant can be several hundreds of kW. In cogeneration plants there is produced huge amounts of condensate that could possibly be utilized in a heat network that is connected to biorefinery. If available condensate heat is in order of some per cent of produced heat it could easily fulfill the heat need in biorefinery which is in order of several hundreds of kW. In addition, by degreasing condensates temperature the theoretical power production efficiency can be increased. When feedstock processing temperature is in fermentation process around 35 °C, low temperature condensate fluids that have temperatures slightly more than that could offer excellent waste heat for biorefinery. Thus, large scale CHP plants with heat production power more than 10 MW were considered as potential locations for biogas CHP plants. Those potential biogas CHP plant locations were named according to the community where it was located:

- Lubin
- Radwanice
- Glogow
- Legnica
- Jelenia Gora
- Wroclaw
- Siechnice miasto
- Polkowice
- Brzeg Dolny

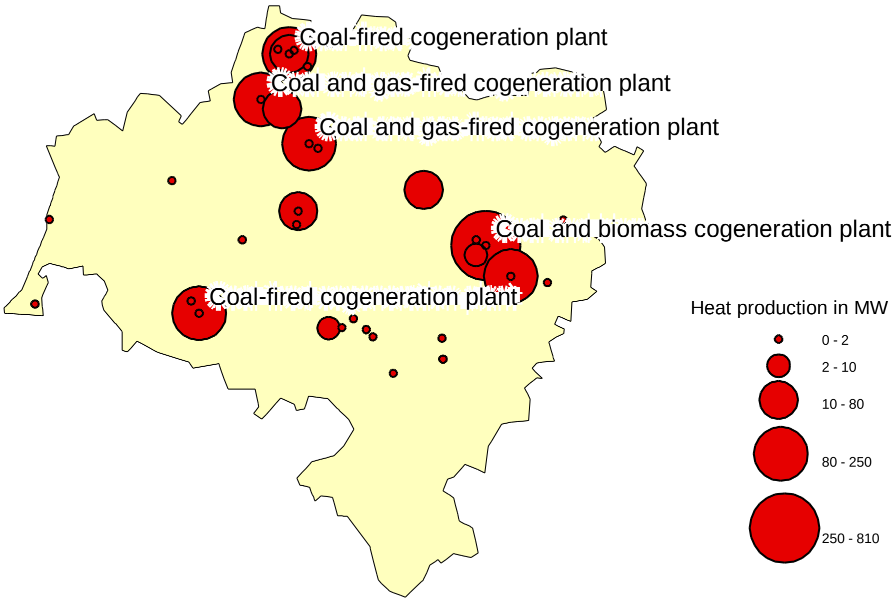

Figure 3. Heat production in CHP plants with electricity production more than 50 MW (4).

4. Optimized scenario

Operational income of the whole production chain was maximized (Figure 4). The most optimal household biowaste collection areas, destinations for digestate and scale of potential biogas electricity production plants were found. Thus, model (7) input data is consists of household biowaste origin data, field block data, regional parameters (Table 1) and potential heat network locations (Figure 3). As stated previously, it is seeing that by connecting biogas CHP to a large scale CHP heat network (10 MW_h) the overall electricity production efficiency could be increased. This would be possible by utilizing condensate heat from large scale CHP plant in digester heating. Then biogas CHP could produce higher value heat to the heat network without losing heat for sanitation or digester auxiliary heating. In addition, digestate fertilizer transportation to the nearest fields was also considered which price is connected to nitrogen content.

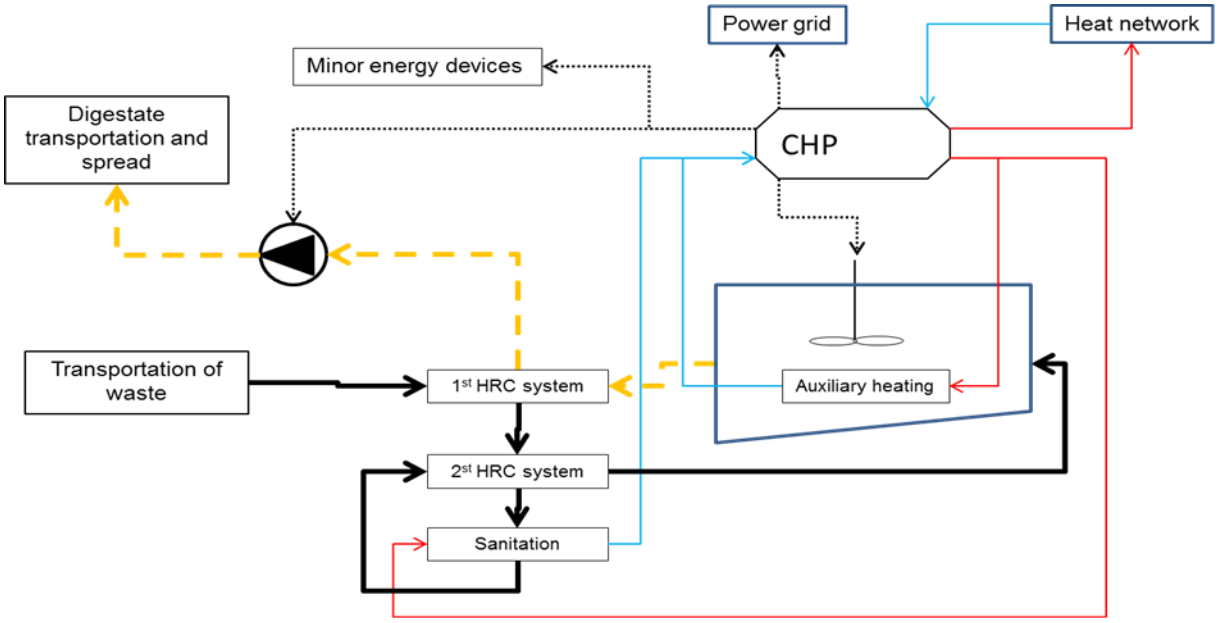

Figure 4. System boundary in Lithuanian case includes biogas CHP production system.

Lower Silesia specific parameters were starting values for the regional model (Table 1). One of the most important input variable is the availability of household biowaste whish is in this case 33.75 kg/inh. It was estimated that about 50 €/MWh would be paid to the top of electricity sale price according to Polish certificate system when plant would receive 150 €/MWh (1). Plant would buy electricity from power grid at price of 101.5 €/MWh which is price for electricity consumers that have consumption between 500 MWh and 2 000 MWh/year (2). This price includes all taxes and levies included. Plant would receive incomes also from digestate fertilize sales, heat sales as well as gate fees from household biowaste.

Table 1. Parameters that were different than in a biogas electricity production model (7) are introduced here.

Parameter	Value	Unit	Ref
Annual average temperature of surroundings	9	°C	(8)
Average heat consumption power	263	W/inh.	(9)
Availability of household biowaste	33.75	kg/inh.	Estimation
Electricity prize for the plant	101.5	€/MWh	(2)
Feed-in tariff from electricity	150	€/MWh	(1)
Heat sell prize for the plant	33.8	€/MWh	(10)
Fertilizer prize for the plant (Agro 16-7-13)	391	€/t Nitrogen	(11)
Gate fee for household biowaste	42	€/t	(12)

Optimized result showed that biogas CHP plants would have 7 potential locations out of expected 9 locations (Figure 5). Plants house hold biowaste collection areas and field blocks for digestate fertilizer spread are also illustrated as "*". In total these 7 plants would process 94 kt/year of household biowaste and produce 32 GWh/year of electricity (Table 2). Scales and feedstock potentials for each plant consider also demand about positive energy and economical balance. Feedstock is considered to be transported to the plant where its production to electricity is the most cost efficient.

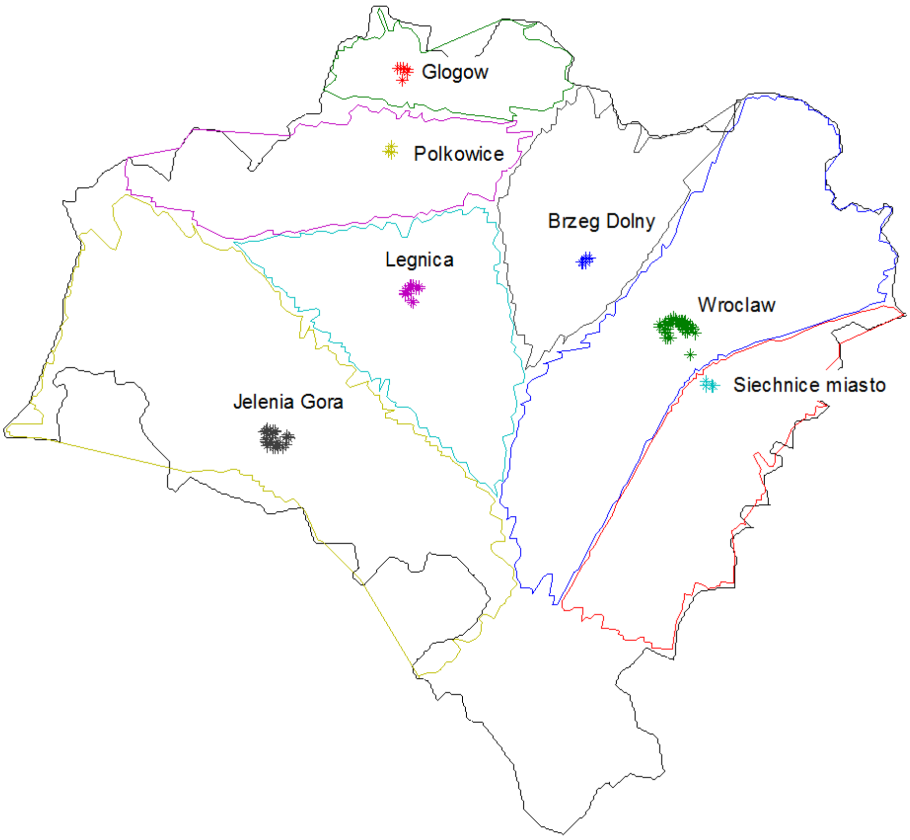

Figure 5. Waste collection areas are shown as polygons around plants.

Table 2. Plant specific parameters are based on the regional model where operational income in the production chain was maximized.

		Glogow	Legnica	Jelenia Gora	Wroclaw	Siechnice miasto	Polkowice	Brzeg Dolny
Feedstock	Household biowaste, kt/year	4.14	12.03	24.28	36.09	7.46	5.48	4.45
	Nitrogen potential, t/year	27	79	160	238	49	36	29
	Phosphorus potential, t/year	5	16	32	48	10	7	6
Scale	Reactor volume, m^3	234	680	1 372	2 039	421	310	251
Sales	Electricity, GWh/year	1.31	3.90	8.30	12.71	2.35	1.73	1.40
	Heat, GWh/year	1.49	4.18	7.95	11.46	2.53	2.00	1.55
	Nitrogen fertilizer, k€/year	11	31	63	93	19	14	11
	Electricity sales, k€/year	196	585	1 245	1 906	352	259	210
	Heat sales, k€/year	50	141	269	387	85	68	52
	Gate fees, k€/year	174	505	1 020	1 516	313	230	187
	Incomes in total, k€/year	431	1 263	2 597	3 903	770	571	461
Costs	Digestate spread & transportation, k€/year	2.19	8.53	18.68	42.09	2.51	1.51	2.05
	Feedstock transportation, k€/year	55	320	1 151	877	294	120	102
	Plant costs, k€/year	72	176	328	468	117	90	76
	Overall costs, k€/year (inc. Operat. & inv.)	129	505	1 498	1 387	414	211	180
Conclusions	Operational income, k€/year	302	758	1 099	2 515	357	360	281
	Saved GHG emissions in ETS, CO_2 t	755	2 251	4 791	7 335	1 355	998	809
	Savings in ETS, k€ (15.28 €/(t CO_2))	12	34	73	112	21	15	12

5. References

1. **Emilia den Boer, Jan den Boer, Ryszard Szpadt.** *Waste-to-energy in the baltic sea regions.* Wroclaw : Remowe project, 2011. Report no: O3.2.2.

2. **Eurostat. [Online] European Commission. [Citat: den 3 Syyskuu 2012.] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.**

3. **Reference Data. [Online] Eurostat, den 15 May 2012. [Citat: den 30 January 2013.] http://epp.eurostat.ec.europa.eu/portal/page/portal/gisco_Geographical_information_maps/geodata/reference.**

4. **Boer, Emilia den. *Waste and energy data for the regional model for energy from waste in lower silesia.* u.o. : Abowe project milestone 2.3, 2014.**

5. ***A regional model for sustainable biogas electricity production: A case study from a Finnish province.* Huopana T., Song H., Kolehmainen M., Niska H. u.o. : Applied Energy, 2013, Vol. 102:676-686. http://dx.doi.org/10.1016/j.apenergy.2012.08.018.**

6. **T., Huopana. Energy efficient model for biogas production in farm scale. [Online] University of Jyväskylä, 2011. [Citat: den 26 Sebtember 2012.] http://urn.fi/URN:NBN:fi:jyu-201103211905.**

7. **fellows, Tuomas Huopana and. *Heat and electricity production from biodegradable waste.* u.o. : Abowe project: Integrated report considering outputs: O.2.2 and O.2.6., 2014.**

8. **A, Dubicki. Klimat Wrocławia, Środowisko, str. 9 - 25, strona internetowa: . [Online] [Citat: den 28 March 2014.] http://www.eko.org.pl/wroclaw/pdf/klimat.pdf.**

9. **GUS, Zużycie paliw i nośników energii w 2012 r., Warszawa 2013, strona internetowa. [Online] [Citat: den 28 March 2014.] http://www.stat.gov.pl/cps/rde/xbcr/gus/SE_zuzycie_paliw_nosnikow_energii2012.pdf.**

10. **Urząd Regulacji Energetyki, Średnie ceny sprzedaży ciepła wytworzonego w jednostkach wytwórczych niebędących jednostkami kogeneracji za 2012 rok, Warszawa 28.03.2013, witryna Urzędu Regulacji Energetyki. [Online] http://www.ure.gov.pl/pl/urzad/informacje-ogolne/ak.**

11. **SkładRolny.pl, Nawozy Fosforowe, witryna SkładRolny.pl. [Online] [Citat: den 28 March 2014.] http://skladrolny.pl/pl/c/Nawozy-Fosforowe/65.**

12. **ZGO Gać, Cennik usług, 09.01.2014, witryna ZGO Gać. [Online] [Citat: den 28 March 2014.] http://zgo.org.pl/oferta-wspolpracy/cennik-uslug.html.**

Baltic Sea Region
Programme 2007-2013
Part-financed by the European Union
(European Regional Development Fund)
UNIVERSITY OF EASTERN FINLAND