Project: BiG>East

(EIE/07/214)

Biogas Show Cases in the target region of Croatia

Deliverable D 6.4

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Executive summary

Both show cases are selected for primary reason: for both regions, the interest came from the local community. It the first show case, Poslovni park Bjelovar, a regional development agency had the idea to have biogas as energy supply in their new business zone. In the case of Medjimurska County, the interest came simultaneously from numerous small poultry producers that have problem with chicken manure and from the REDEA, regional development agency. Namely, the County has plans to develop tourism for which untreated and improperly scattered chicken manure represents problem that could be solved by centralised biogas plant.

Both investments still need investors to back up the actual implementation and, in the case of second show case, the location still has to be decided.

Both show cases include chicken manure which is difficult to use in feedstock mixture in proportion more than 30%. To the best of our knowledge, there is only one company that provides solutions for anaerobic digestion with up to 70% of chicken manure. In both cases, two options have been investigated: classical case with chicken manure up to 30% and advanced case with up to 70% or total available amount of chicken manure.

The first show case indicates that larger plant, including all chicken manure available, shows better results only when heat is utilised (sold).

The second show case points out economic viability for a small centralised biogas plant prototype (500 kW) even if considering sales of electricity only.

1. Biogas Show Case: Business zone Velika Ciglena

1.1. Basic plant design

Egg and laying chickens company is about 10 km far from the site but needs to deal with the chicken manure since it is located at the outskirts of city of Bjelovar. According to the Environmental Impact Assessment study (elaborated in order to gain the permission for reconstruction of chicken houses), company produces 9 566 t/year manure of egg laying hens and 882 t/yr of laying chickens. This corresponds to biogas yield of 1 175 400 m^3/year whether it is fresh or dry, respectively. The company is obliged to make manure storage appropriate for 6 months storage. The storage facility is actually an empty chicken house of 15x84.4 meters.

Organic residues of the Zone's business activities of greenhouses will be positive but of little influence on biogas yield. Waste from biscuits and waffle factory is also in the outskirts of city of Bjelovar which is important to keep in mind.

For starters, there is following composition of biogas substrate available for the biogas site 1: Poslovna zona Velika Ciglena.

Table 1 Available feedstock with corresponding methane yields of the biogas site 1: BZ Velika Ciglena

Feedstock	Place of origin	Seasonality	Availability t/yr	Biogas yield m^3/yr	Methane content %	Methane yield m^3/yr
Cow manure	Farms with >50 heads of cattle in radius up to 2 km	No	12 330	431 556	60	258 994
Maize silage	Grown at the Zone	Yes	2 835	567 000	52	294 840
Laying hen and chicken litter	Gala d.o.o., company some 10 km away	No	10 488	1 175 400	60	705 240
Total				**2 173 956**		**1 259 074**

It can be seen that chicken litter represents 41% of available biomass. Unit recently, it was not possible to digest higher portions than 1/3 of chicken manure in the total substrate mixture. The main reason for that is the high nitrogen content that inhibits the microorganisms' activity in the digester. By limiting chicken litter in the mixture to 30% the biogas yield of the first show case site drops for about 75% as shown in the *Table 2*.

Table 2 Comparison of methane yield with and without reduction of chicken manure

Feedstock	Availability t/yr	Biogas yield m^3/yr	Methane content %	Methane yield m^3/yr	Option: maximum of 30% of chicken litter – optional mixture t/yr	Option: maximum of 30% of chicken litter – Biogas yield m3/yr	Option: maximum of 30% of chicken litter – Methane yield m3/yr
Cow manure	12 330	431 550	60	258 930	12 330	434 350	260 610
Maize silage	2 835	567 000	52	294 840	2 835	584 000	303 680
Laying hen and chicken litter	10 488	1 175 400	60	705 240	6 558	734 994	440 996
Total		**2 173 950**		**1 259 010**		**1 753 344**	**1 005 286**

In August 2008, Rueckert NaturGas have developed the first biogas plant that can accept 70 % chicken manure in its anaerobic digestion process. The plant in Baasdorf (2.1 MW electricity) is running on 70% chicken manure, 20% of maize silage and 10% of grass silage from landscaping. Until now, they have 4 references for biogas plants running on high shares of poultry litter.

Total dry matter in the substrate is 24% which makes the substrate difficult to pump and calls for water for dilution of the dry matter content.

Being on the safe side, as cow manure also contains high nitrogen content, 30% or the minimal recommended share of high carbon (i.e. maize silage, fat) is foreseen.

For this show case two calculations will be made: one for the turn key investment including all chicken manure and the other excluding chicken manure which will make the plant design typical combination of cow manure and maize silage.

The following figures are comparing process flows and basic layout of biogas plant for the Show case 1; with and without using chicken litter as feedstock.

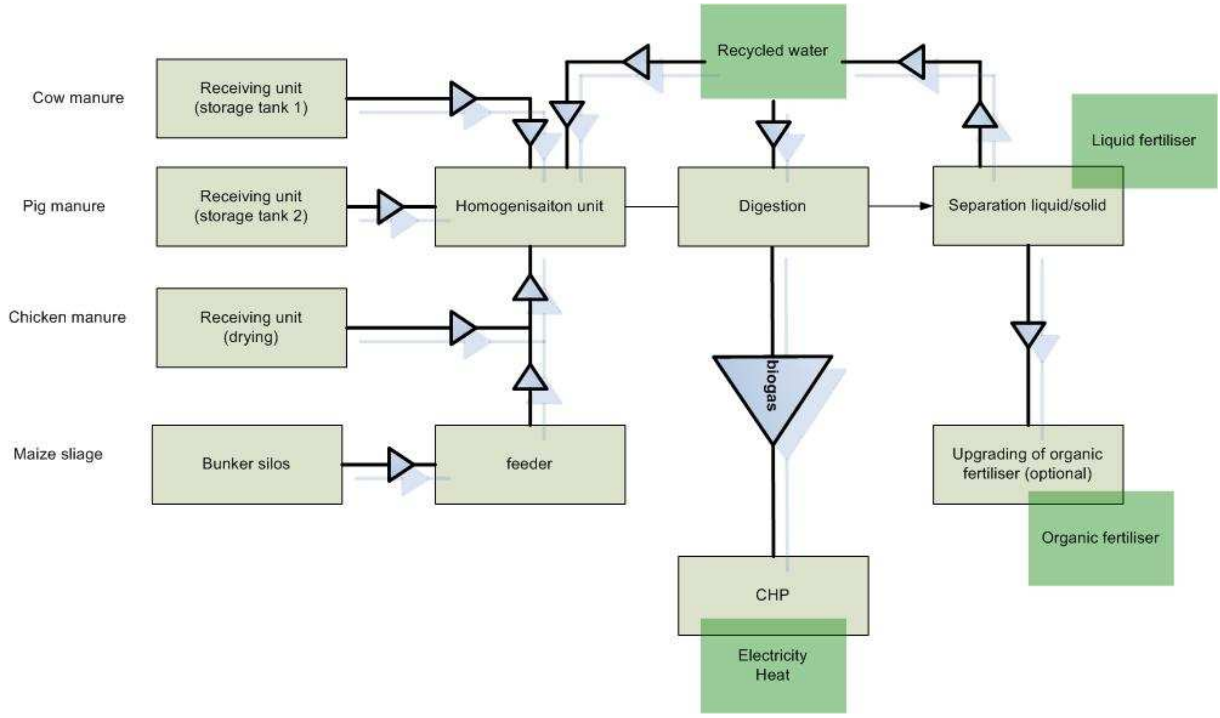

Figure 1 Show case1: large plant overall production process

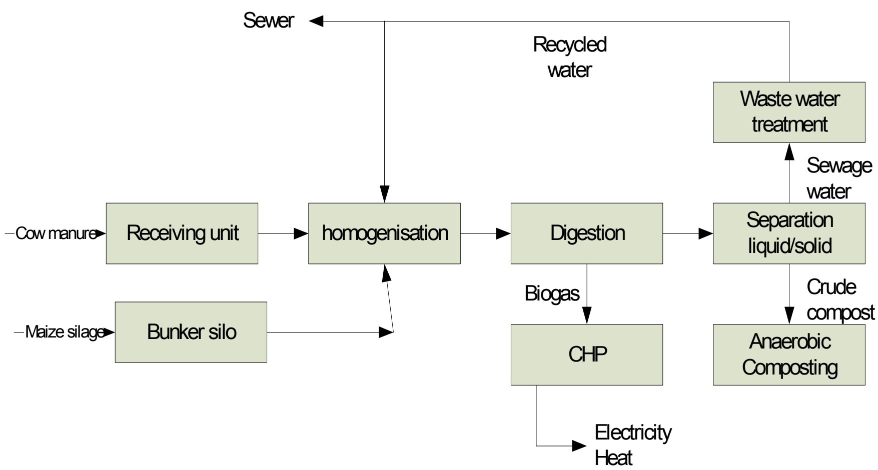

Figure 2 Show case 1: small plant overall production process

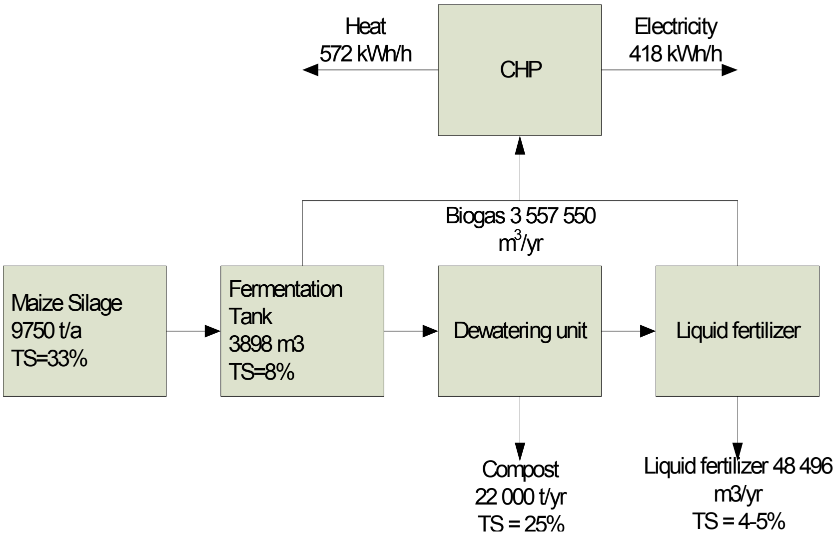

Figure 3 Show case 1: including chicken manure

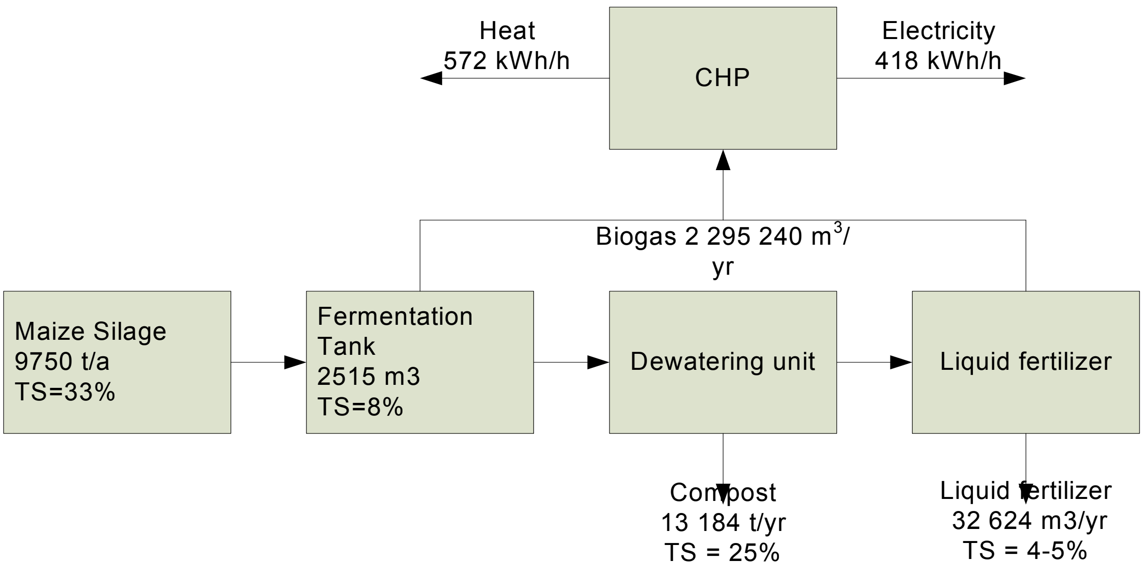

Figure 4Show case 1: excluding chicken manure

1.2. Technology Specifications

The biogas plant layout excluding the chicken litter is rather simple, “classical case” of biogas plant that uses combination of cow manure and maize silage. The usual temperature of the anaerobic process is mesophilic with temperature range of 30-42 C and 30 to 40 days of retention time.

The biogas plant layout including the chicken manure is somewhat different. Namely, the company Rueckert Naturgas[1] has developed a new process NatUrgas® (patented for Europe) that allows high percentages of manure in the feedstock mix. The feedstock is mixed and diluted with water before it is fed into a digester where microorganisms produce biomethane

[1] http://www.rueckert-naturgas.de/index.php?id=105&L=1

and CO_2 through anaerobic fermentation. The biomethane is forwarded into a combined heat and power plant (CHP) where it is used to produce electricity and heat.

Meanwhile, the fermentation residue is separated into solid and liquid fractions in a so-called “decanter”. The solid fraction is dried and pressed into pellets for use as compost. The liquid fraction is further separated by means of ultra filtration and reverse osmosis into 25 % highly concentrated liquid fertilizer and 75 % process water. The process water is reverted into the process at step one.

The fermentation process is shown at the *Figure 5*. Nevertheless, the process flow differs by size of biogas plant. For smaller biogas plants, the input substrate is pre-treated for nitrogen oxidation. After this treatment, the poultry dung can go through the fermentation process just like any other organic matter. Bigger biogas plants are equipped with a fermentation residue treatment unit. Thereby, the solid-liquid separation using a decanter is the decisive process. The targets of the procedure are the production of energy, fertilizers and process water.

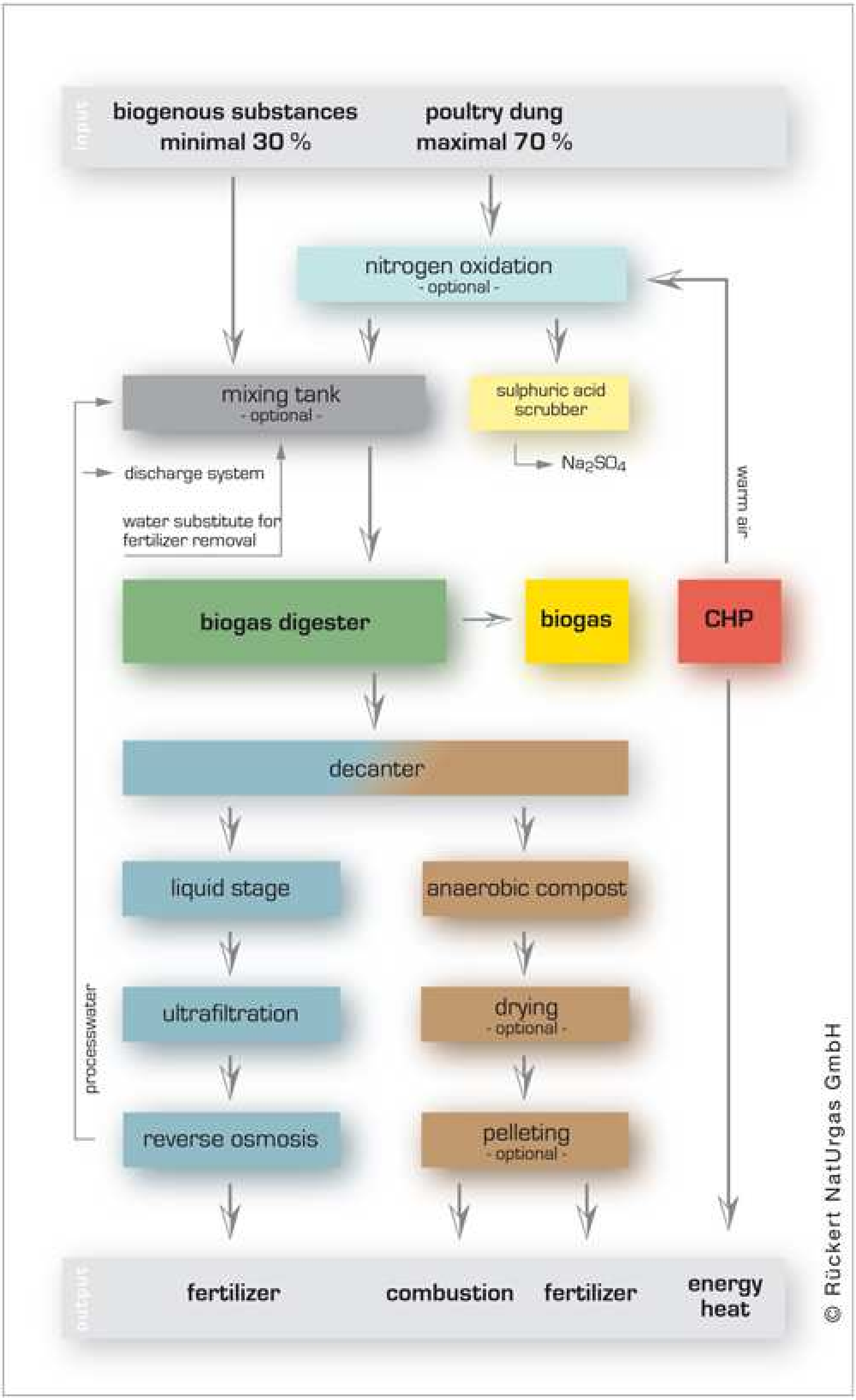

Figure 5 Fermentation process where up to 70% of chicken manure is viable

1.3. Economical specifications

In order to have realistic calculations, only those outputs that have a market price were included in the economy of the biogas plant. Namely, it is difficult to estimate heating costs if the plant site (neighbourhood) is to be developed. The same is valid in estimation of the price for the organic fertilizer.

That is why the economical specifications are made only on the backbone of the investment in Croatia: the feed-in tariff for sales of electricity to the grid. The feed- in tariff for biogas plants less than 1 MW equals 1.3312 HRK/kWh and 1.1537 HRK/kWh in 2010. The exchange rate for Euro is fixed at 7.3 HKR for 1 €. This means that, as the business zone develops, it can add heating demand and organic fertilisers' sales to its economy.

The calculations were made in the calculation tool developed in the WP4. The Excel too is available at the *www.big-east.eu* or as a supplement of the hard copies of the Biogas Handbooks.

It has been assumed that the chicken farm will be willing to pay 100€ per ton of chicken litter for its disposal. Maize silage costs are taken from the advertisement of a biogas plant investor looking for supply from farmers. The price is 15€/t.

The actual price of biogas plant of Rueckert was unavailable. That is why here it is assumed that its' investment is in the level of the high cost standardised plant or 4 000 €/kW.

BIG>East Biogas Calculation		
Farm based biogas plant, turn key project		
Project name:	BZ Velika Ciglena-big	
Date:	31.03.2010	
1. Investment costs		
Total of Investment	-10 000 000,00	€
Liquid assets	-300 000,00	€
2. Feedstock data (Year 1):		
Quantity of maize silage TS=32%	9 750	t/year
Quantity of cattle/pig manure TS=10%	12 330	t/year
Quantity of chicken manure	10 500	t/year
Feedstock in biogas plant total	**32 580**	t/year
Average costs/income of feedstock per year	903 750,00	€/year
3. Plant data		
Average biogas yield	3 557 550	m³/year
Average energy yield	19 785 300	kW/year
estimated electrical power output	678	kWh/h
estimated electrical power consumption	47	kWh/h
produced amount of compost TS=25%	22 062	t/year
produced amount of liquid digestate TS= 5%	50 551	t/year
4. Revenues on energy		
Revenues from selling electricity	872 402,45	€/year
Revenues from selling heat	0,00	€/year
5. Plant working costs		
General Business Costs	-369 484,00	€/year

6. Earnings before Interests	1 406 668,45	
7. Internal Return Rate of Project (IRR)	**8,00%**	
8. Capital costs:	-1 228 553,40	€/year
9. Total earnings	**178 115,05**	**€/year**

Calculation for the smaller plant are assuming low costs of standard plant of 2800 €/kW and the same price for maize silage of 15€/t.

BIG>East Biogas Calculation **Farm based biogas plant, turn key project**		
Project name:	BZ Velika Ciglena-small	
Date:	31.3.2010	
1. Investment costs		
Total of Investment	-800 000,00	€
Liquid assets	-20 000,00	€
2. Feedstock data (Year 1):		
Quantity of maize silage TS=32%	9 750	t/year
Quantity of cattle/pig manure TS=10%	12 330	t/year
Feedstock in biogas plant total	**22 080**	t/year
Average costs/income of feedstock per year	-146 250,00	€/year
3. Plant data		
Average biogas yield	2 295 240	m³/year
Average energy yield	12 211 440	kW/year
estimated electrical power output	418	kWh/h
estimated electrical power consumption	29	kWh/h
produced amount of compost TS=25%	-14 446	t/year
produced amount of liquid digestate TS= 5%	33 887	t/year
4. Revenues on energy		
Revenues from selling electricity	621 285,95	€/year
Revenues from selling heat	0,00	€/year
5. Plant working costs		
General Business Costs	-32 144,00	€/year
6. Earnings before Interests	442 891,95	
7. Internal Return Rate of Project (IRR)	**8,00%**	
8. Capital costs:	-97 807,16	€/year
9. Total earnings	**345 084,79**	**€/year**

It turns out that larger biomass quantity does not justify the higher investment costs per kW as the total annual earnings are about 1.5 higher than at the biogas plant option including chicken manure.

Nevertheless, at this stage of calculations, none of the options should be excluded. The main reasons are heat energy that has not been evaluated in this assessment. Larger plant produces larger heat quantities and could significantly chance the outlook of the investment.

1.4. Organizational structure

In both cases, quantities of maize silage are needed more than is possible to grow at the land of business zone. Moreover, it is the assumption that the land under the ownership of the zone will have more value per m^2 if it would be rented for business activities.

Since there is no market for maize silage yet in Croatia, the biogas plant operator could contract farmers at annual or 5-years basis for maize silage. Few times in the farmers' newspaper it was possible to see an advertisement looking for farmers to provide maize silage for price of 15€/t. Given the insecure and deteriorating status of Croatian farmers and the fact that Bjelovarsko-bilogorska County is abundant in rural areas, this would be the logical solution for maize silage.

Cow manure will be delivered by farmers in the radius of 2 km since they all need storages for complying the Nitrate directive and the biogas plant will provide the service of taking care of the excess manure free of change.

Laying eggs company is 10 km distant from the envisaged biogas site. That is why the biogas plant will charge 100 €/t of the manure delivered to the biogas plant. Namely, currently cattle breeders that do not have sufficient land to spread the manure are paying 0.5-1 HKR/kg for taking care of manure.

1.5. Risk management

Financing a biogas plant from a bank loan understands that Environmental impact assessment is made. In that case, risk management is minimised.

Regarding the feedstock supply, given the conditions and trends in Croatian agriculture, contracting farmers for maize silage supply will not be a risk.

Once activities of companies in the business zone are established and they business activity known, it would be possible to calculate heat demand and, corresponding heating costs. Having business activity will create heating demand at least in the winter. Depending on the profile (food processing industry, heat intensive processes) of the companies, it would be also possible to develop utilisation of heat over the year.

No other risks are foreseen.

2. Biogas Show Case: Centralised biogas plant in Medji-murska County

2.1. Basic plant design

The County is among the most developed counties in Croatia. Medjimurska county is among the most intense farming area and very much known for numerous scattered poultry producers. Regardless on the hard working people living in the County, the natural conditions are not suitable for farming. Namely, as it could be seen from the Figure 6, the area is abundant with surface and underground waters which bring special focus on manure management.

Having in mind its development strategy with focus on tourism, the County is trying to be proactive in manure management. In autumn 2009, the Department for Economy have invited agricultural husbandries that have documentation for building waterproof manure storage at their farms to apply for subventions. The department also reminds farmers on the negative consequences of inadequate or absent manure management. This show case is providing the idea that a centralised biogas plant or several of them could be an excellent tool for manure management.

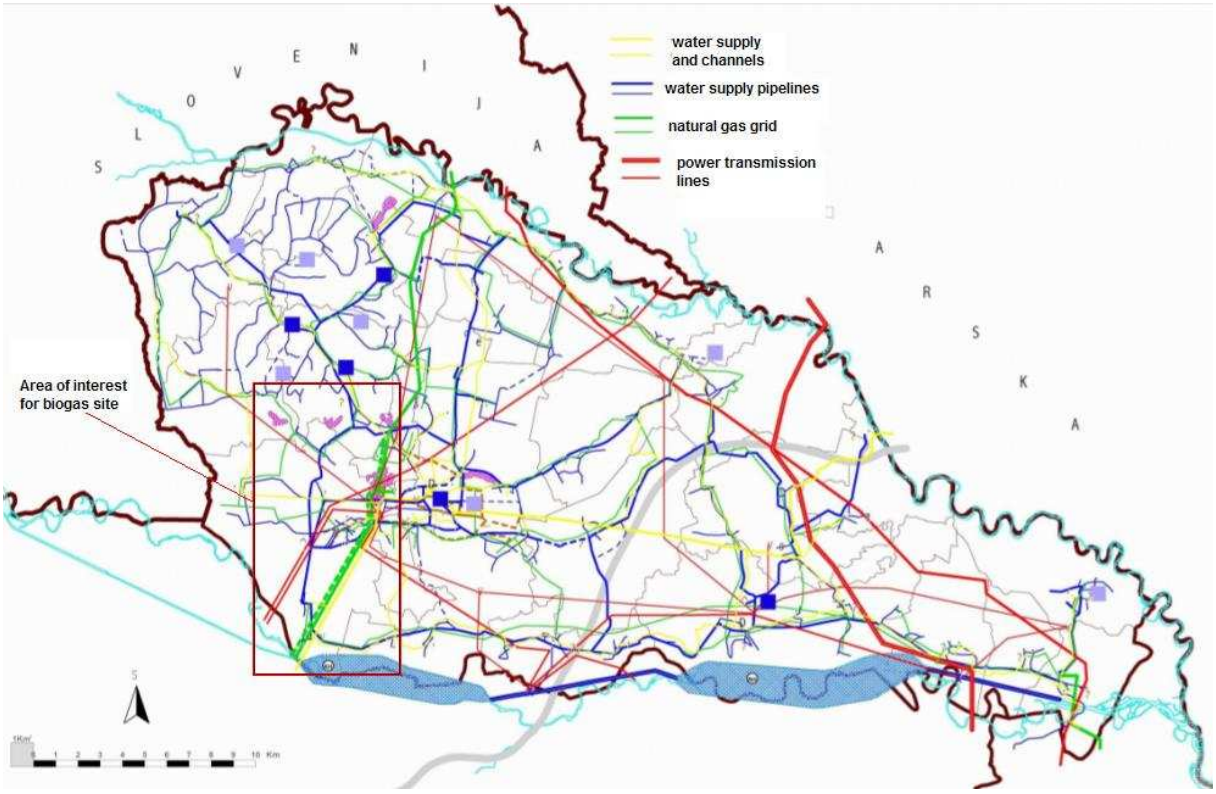

Figure 6 Narrowing down biogas plant location in Međimurska County

Source: Spatial Plans of Međimurska County, Ministry of Environmental Protection, Spatial Planning and Construction, http://www.mzopu.hr/doc/Prostorni_planovi/21PPZ_WEB.htm, visited December 2008

The estimated biomass available for the centralised biogas plant in the second show case is shown in Table 3.

Table 3 Biomass available for anaerobic digestion in the 2nd biogas show case

Feedstock	Place of origin	Approximate distance (km)	Availability t/yr	Biogas yield m^3/yr	Methane content %	Methane yield m^3/yr
Cow manure	2 farms with 1 995 heads of cattle on East Group of dairy farms on South	4	35 910	1 005 480	60	603 288
Pig farm	HSC Služba Čakovec	4	4 410	110 250	60	66 150
Chicken litter	Breeders from Kuršanec neighbourhood		2 122	127 320	60	76 392
	Breeders from Dragoslavec Selo (North-West)	7	1442	86 520	60	51 912
Total			**43 884**	**1 329 570**		**1 093 905**

The availability of biomass has been reported by biomass owners. Naturally, on manure type biomass has been reported while carbon bearing substrate still needs to be identified. For the purpose of this exercise, maize silage will be used as carbon providing substrate. It has been assumed minimum amount of maize silage, as seen from the table

Table 4 Starting substrate mixture for the Show Case 2 (manure:silage ratio=70:30)

Biomass	Quantity	Biogas yield	Methane yield
	t/yr	m3/yr	m3/yr
Cow manure	35 910	1 005 480	603 288
Pig slurry	4 410	110 250	66 150
Chicken litter	3 564	213 840	128 304
Maize silage	18 805	3 761 000	1 955 720
Total	**62 689**	**5 090 570**	**2 753 462**

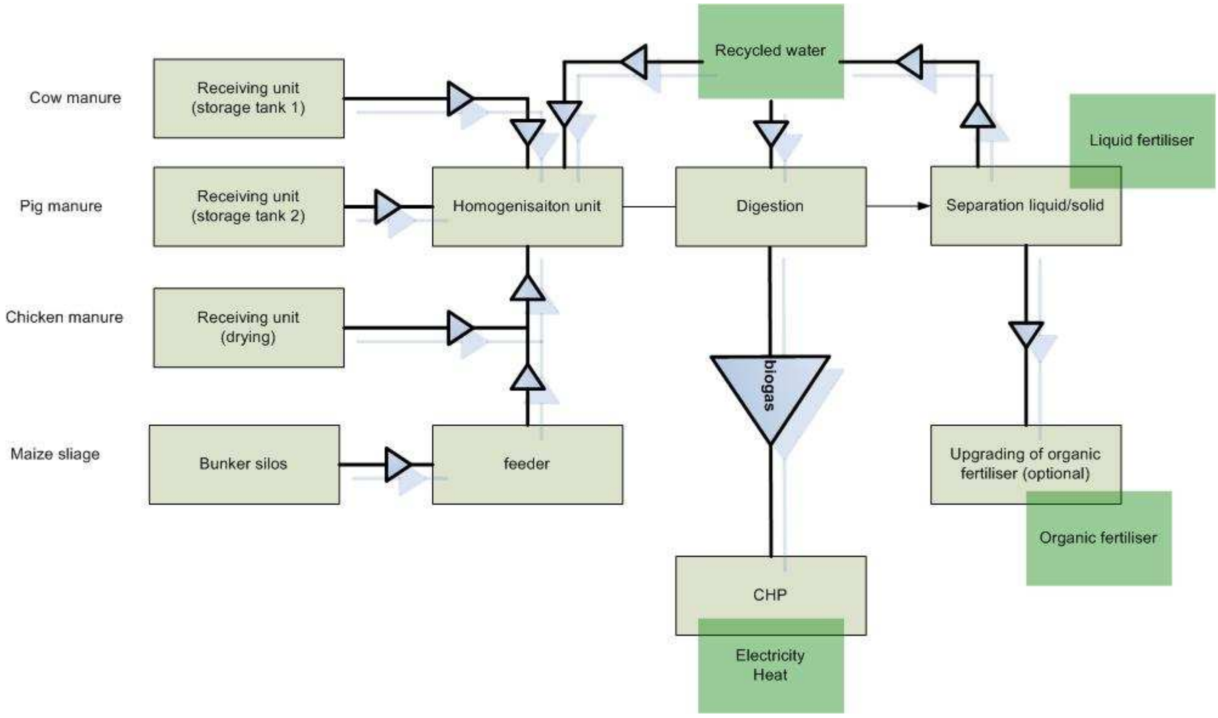

Figure 7 Show case2: overall production process

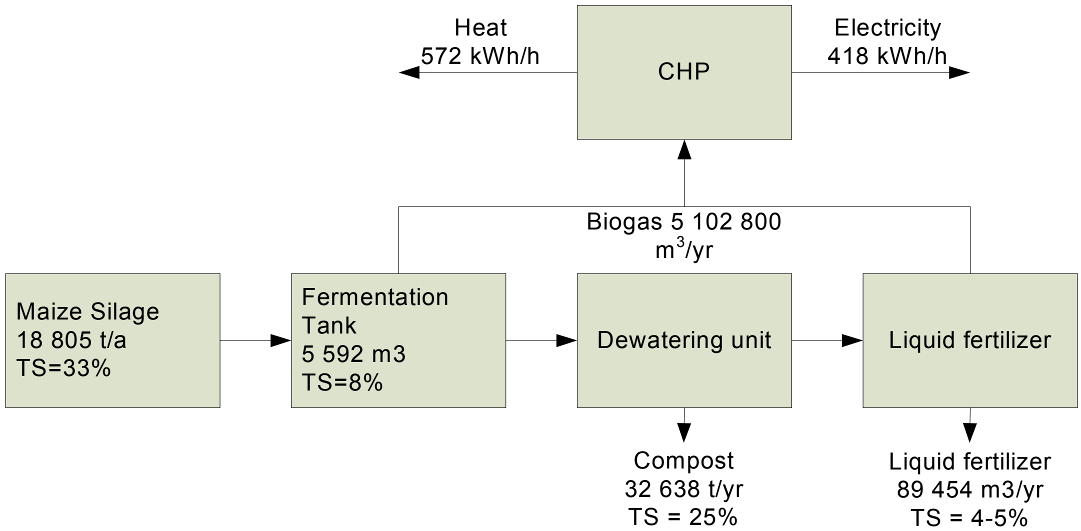

Figure 8 Show case 2: large centralised biogas plant

Another biogas solution is investigated as possible solution for the chicken litter. In general, the farm sizes are 20 000 – 30 000 beaks per turn which makes approximately 1 000 t of chicken litter per year. Following the Baasdorf example, a centralised biogas plant could be designed at 500 kW and with 5 000 t of chicken manure and 2 000 t maize or grass silage. It will serve as manure management point for four to six farmers in the vicinity. The process flow is similar to the one described for the first show case while the input/ output flow is somehow different.

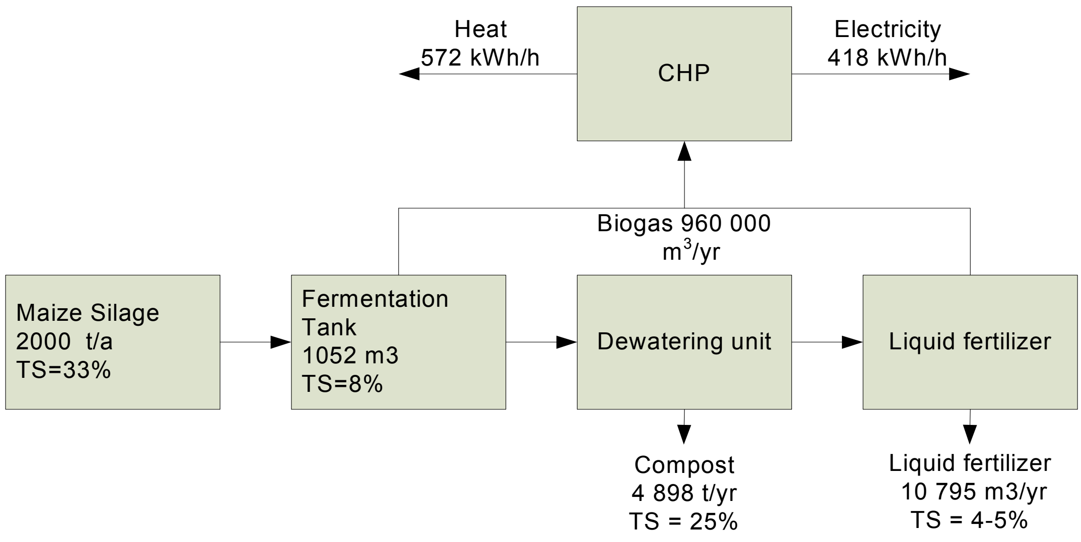

Figure 9 Show case 2: small centralised biogas plant- prototype

2.2. Technology Specifications

The first option includes 70% of substrate that is very rich in nitrates which will demand for higher cost plant but it is still a standard plant.

The centralised biogas plant prototype represents reduced size of Baasdorf biogas plant.

The feedstock is mixed and diluted with water before it is fed into a digester where microorganisms produce biomethane and CO_2 through anaerobic fermentation. The biomethane is forwarded into a combined heat and power plant (CHP) where it is used to produce electricity and heat.

Meanwhile, the fermentation residue is separated into solid and liquid fractions in a so-called "decanter". The solid fraction is dried and pressed into pellets for use as compost. The liquid fraction is further separated by means of ultra filtration and reverse osmosis into 25 % highly concentrated liquid fertilizer and 75 % process water. The process water is reverted into the process at step one.

The fermentation process is shown at the *Figure 5*. Nevertheless, the process flow differs by size of biogas plant. For smaller biogas plants, the input substrate is pre-treated for nitrogen oxidation. After this treatment, the poultry dung can go through the fermentation process just like any other organic matter. Bigger biogas plants are equipped with a fermentation residue treatment unit. Thereby, the solid-liquid separation using a decanter is the decisive process. The targets of the procedure are the production of energy, fertilizers and process water.

2.3. Economic specifications

It has been assumed turn key investment. The labour costs are average gross salary of 692 €/month. The price of maize silage has been assumed at 15 €/t. The feed-in item is 0.158 €/kWh since the plant exceeds 1 MW size. For the calculation of the economic specifications, Biogas calculation tool, developed under the WP4, was used. Two employees are foreseen for running the plant.

Unfortunately, the first biogas plant under the 2nd show case does not perform positive economic results without heat and/or organic fertilisers sales, even if estimated low cost standard plant.

Table 5 Medjimurska County-large biogas plant (low costs)

BIG>East Biogas Calculation		
Farm based biogas plant, turn key project		
Project name:	Medjimurska County-large	
Date:	31.3.2010	
1. Investment costs		
Total of Investment	-10 000 000,00	€
Liquid assets	-30 000,00	€
2. Feedstock data (Year 1):		
Quantity of maize silage TS=32%	18 800	t/year
Quantity of cattle/pig manure TS=10%	40 320	t/year
Quantity of chicken litter	3 564	t/year
Feedstock in biogas plant total	**62 684**	t/year
Average costs/income of feedstock per year	-282 000,00	€/year
3. Plant data		
Average biogas yield	5 102 800	m³/year
Average energy yield	27 608 800	kW/year
estimated electrical power output	946	kWh/h
estimated electrical power consumption	66	kWh/h
produced amount of compost TS=25%	-34 836	t/year
produced amount of liquid digestate TS= 5%	91 652	t/year
4. Revenues on energy		
Revenues from selling electricity	1 217 367,68	€/year
Revenues from selling heat	0,00	€/year
5. Plant working costs		
General Business Costs	-353 500,00	€/year
6. Earnings before Interests	581 867,68	
7. Internal Return Rate of Project (IRR)	**8,00%**	
8. Capital costs:	-1 196 348,60	€/year
9. Total earnings	**-614 480,93**	**€/year**

The prototype centralised biogas plant showed different outcome. The feed-in tariff is 0,18 €/kWh while the maize silage costs are 15€/t. It has been assumed that chicken litter has been transported to the biogas plant for free. Only income from electricity has been considered.

Economic performance of prototype centralised biogas plant is positive if the investment costs are kept below 4000 €/kW. In that case, only sales of electricity make it positive.

Table 6 Medjimurska county-prototype-low cost (2800 €/kWh)

BIG>East Biogas Calculation		
Farm based biogas plant, turn key project		
Project name:	Medjimurska county-prototype-low cost	
Date:	31.3.2010	
1. Investment costs		
Total of Investment	-1 459 000,00	€
Liquid assets	-80 000,00	€
2. Feedstock data (Year 1):		
Quantity of maize silage TS=32%	2 000	t/year
Quantity of chicken litter	5 000	t/year
Feedstock in biogas plant total	**7 000**	t/year
Average costs/income of feedstock per year	-30 000,00	€/year
3. Plant data		
Average biogas yield	960 000	m³/year
Average energy yield	5 440 000	kW/year
estimated electrical power output	186	kWh/h
estimated electrical power consumption	13	kWh/h
produced amount of compost TS=25%	-5 595	t/year
produced amount of liquid digestate TS= 5%	11 491	t/year
4. Revenues on energy		
Revenues from selling electricity	276 772,89	€/year
Revenues from selling heat	0,00	€/year
5. Plant working costs		
General Business Costs	-15 984,00	€/year
6. Earnings before Interests	230 788,89	
7. Internal Return Rate of Project (IRR)	**8,00%**	
8. Capital costs:	-183 567,35	€/year
9. Total earnings	**47 221,54**	**€/year**

Table 7 Medjimurska county-prototype-medium costs (3500 €/kWh)

BIG>East Biogas Calculation		
Farm based biogas plant, turn key project		
Project name:	Medjimurska county-prototype-medium costs	
Date:	31.3.2010	
1. Investment costs		
Total of Investment	-1 830 000,00	€
Liquid assets	-80 000,00	€
2. Feedstock data (Year 1):		
Quantity of maize silage TS=32%	2 000	t/year
Quantity of chicken litter	5 000	t/year

Feedstock in biogas plant total	**7 000**	t/year
Average costs/income of feedstock per year	-30 000,00	€/year
3. Plant data		
Average biogas yield	960 000	m³/year
Average energy yield	5 440 000	kW/year
estimated electrical power output	186	kWh/h
estimated electrical power consumption	13	kWh/h
produced amount of compost TS=25%	-5 595	t/year
produced amount of liquid digestate TS= 5%	11 491	t/year
4. Revenues on energy		
Revenues from selling electricity	276 772,89	€/year
Revenues from selling heat	0,00	€/year
5. Plant working costs		
General Business Costs	-15 984,00	€/year
6. Earnings before Interests	230 788,89	
7. Internal Return Rate of Project (IRR)	**8,00%**	
8. Capital costs:	-227 819,13	€/year
9. Total earnings	**2 969,77**	**€/year**

Table 8 Medjimurska county-prototype-high cost (4000 €/kWh)

BIG>East Biogas Calculation		
Farm based biogas plant, turn key project		
Project name:	Medjimurska county-prototype-high cost	
Date:	31.3.2010	
1. Investment costs		
Total of Investment	-2 000 000,00	€
Liquid assets	-80 000,00	€
2. Feedstock data (Year 1):		
Quantity of maize silage TS=32%	2 000	t/year
Quantity of chicken litter	5 000	t/year
Feedstock in biogas plant total	**7 000**	t/year
Average costs/income of feedstock per year	-30 000,00	€/year
3. Plant data		
Average biogas yield	960 000	m³/year
Average energy yield	5 440 000	kW/year
estimated electrical power output	186	kWh/h
estimated electrical power consumption	13	kWh/h
produced amount of compost TS=25%	-5 595	t/year
produced amount of liquid digestate TS= 5%	11 491	t/year
4. Revenues on energy		
Revenues from selling electricity	276 772,89	€/year
Revenues from selling heat	0,00	€/year

5. Plant working costs		
General Business Costs	-15 984,00	€/year
6. Earnings before Interests	230 788,89	
7. Internal Return Rate of Project (IRR)	**8,00%**	
8. Capital costs:	-248 096,22	€/year
9. Total earnings	**-17 307,33**	**€/year**

2.4. Organizational structure

Considering proactive approach from the County, locations for the small prototype centralised biogas plants should be optimised. Optimisation could be made by cross-referencing data on farm locations from the Extention service and detail geological maps describing underground water streams.

Implementation of biogas plants could be organised either in a form of private- public partnership or local/County could perform as energy player. In the case of private-public partnership, the County could form a partnership with farmers providing biomass where each farmer would be a proportional shareholder to the biomass supplied. Other option is to engage a third party investor where biogas plant will be only a manure management facility in the eyes of farmers. The same perception would be in the case if the county decides to become an energy player.

Two employees are foreseen for each biogas plant.

2.5. Risk management

The largest risk in this case is finding a suitable location for a biogas plant due to the hydrology of the County.

Attracting financing could be challenging but feasible if properly marketed and presented.

Other risks are not foreseen.