The importance of the economic evaluation of dispersed power generation in the pre-investment phase — agricultural biogas plants

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In the case of dispersed power generation, such as renewable energy sources (RES), the investment risks are much higher than for fossil fuels. Higher are also the specific investment costs per MW_{el} of installed power capacity. Therefore, the pre-investment phase for such projects should be elaborated with due diligence. In particular it refers to emerging market technologies, where there has been little or no record of their development in the past. Despite various support schemes, a professional feasibility study is not to be afforded by smaller investors. Therefore, other simplified tools must be made available for them, especially in the pre-investment phase. In this article agricultural biogas plants (ABP) were chosen to exemplify the complexity of the techno-economic evaluation of dispersed generation in the pre-feasibility phase.

Keywords and phrases: economic evaluation, opportunity study, pre-feasibility study, agricultural biogas, renewable energy sources, dispersed power generation.

Introduction

The demand for electricity in Poland is constantly growing, on the other hand the domestic power infrastructure is in a very poor condition. Less than 10% of power units are younger than 10 years, at the same time some 39% of the generation capacity is older than 40 years. The high voltage units, which are younger than 20 years make up only 1% of the total distribution network. Some 73% of the Polish generation capacity, 50% of transmission and 59% of distribution should be retrofitted — some 103 billion EUR are required, in this 65% for new power generation capacities [1].

The key priorities in the power sector are building of new generation capacities, energy efficiency and grid retrofits. Investments in dispersed power generation, represented *i.a.* by renewable energy sources (RES) such as wind, biogas, biomass, small hydro, PV and geothermal installations would help realize the above mentioned goals.

However, the investment environment for such projects is not friendly. RES compete with conventional sector based on fossil fuels, but the later are not fully burdened with charges for the environmental damage they cause. Thus, in order to equalise the uneven competition special support schemes have been created for RES across all EU member states.

In Germany, which has a mature market of 30 years development history, the installed ABPs capacity in 2011 amounted to 2.6 GW_{el} [2]. The official documents state that in Poland, in the next decade, ABPs will develop dynamically and are supposed to become significant players on the energy market. The government assumes that to 2020 in every Polish rural community at least one ABP will be built [3]. The number agricultural biogas is supposed to grow dynamically to 2,000 in the year 2020 (from the current 17 projects). The expected installed biogas capacity in Poland is going to grow from the current 0.01 to 0.9 GW_{el} in 2020 [4]. Investors and developers have been mobilised to realise new investments (currently some 300 ABPs are under preparation).

However, the Polish market is not sufficiently prepared for the uptake of such high number of new investments. The positive policy of the state will not automatically translate into the success of investors if the technical, economic and regulatory risks are undermined.

The role of techno-economic evaluation of agricultural biogas plants in the investment planning

Preparation of an ABP investment is a multistage task and requires a specialized knowledge. This knowledge is usually provided by means of a feasibility study, which helps the investor to take economically justified decisions. A professional feasibility study, however, takes up a significant part of the investment preparation costs — it should be advised only for bigger projects (in the case of ABPs with the capacity above 500 kW_{el}).

For smaller projects an opportunity/pre-feasibility study should be advised [5]. Such studies can be preformed even by smaller investors (*e.g.* farmers or agricultural co-operatives) in order to evaluate the possibility to invest, without the need to engage a professional but costly consultants.

In the case of ABPs following points need to be critically evaluated: availability of substrates, preliminary choice of site and finally infrastructural/environmental aspects. Steps 1–5 all lead to the opportunity study, the last step 6, *i.e.* in the preliminary economic evaluation all data from steps 1–5 are gathered to produce different investment alternatives. Only investment options, which fulfil the profitability criteria will be used for further analysis. Therefore, regardless of the size of the investment, a preliminary economic evaluation must be performed, which contains: information on investment costs, annual operating costs (own energy use, purchase of substrates, employment, repairs, depreciation *etc.*), financial costs and income estimation. An important element will also be the choice of financial engineering (subsidies, preferential credits and equity contribution).

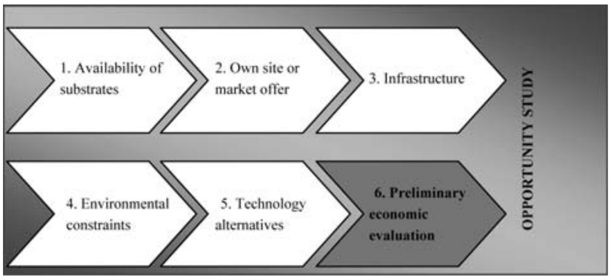

Fig. 1. The role of the economic evaluation in the investment's preparatory phase.

Investment costs

The so far investments experience in Poland is rather modest. The company Poldanor S.A. (food and meat producer in the north-western Poland) is a pioneer in this field, and owner of 7 agricultural biogas plants with further expansion plans. It builds, finances and operates its own investments. Other ABPs are realized with the assistance of technology providers, which has been a solution prevailing in the projects submitted for the EU support [6]. In Germany out of 6,800 plants [2] in operation a few hundreds have been carefully monitored in terms of technical performance and economic indicators.

The typical ABPs realised in Germany are of smaller capacity (on average 0.5 MW_{el}) than in Poland (the average size of the realised projects dropped from 1.5 MW_{el} in 2009 to 0.9 MW_{el} in 2011). The preliminary analysis of the market information shows that investment costs in Poland are 20–30% higher than in Germany. It can be associated to higher investment risks on a new, emerging Polish market (including the currency

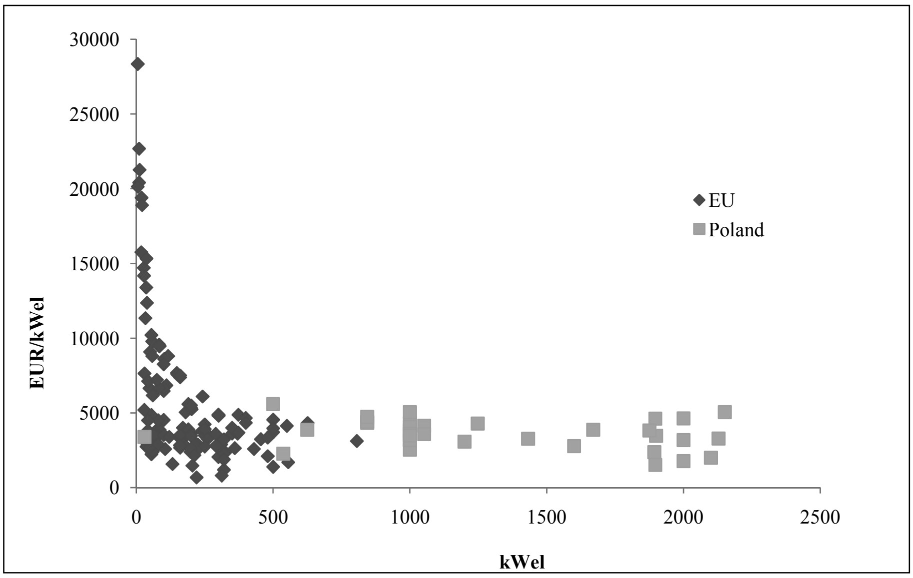

Fig. 2. The comparison of specific investment costs per kW_{el} power capacity installed in Poland and in the EU [7].

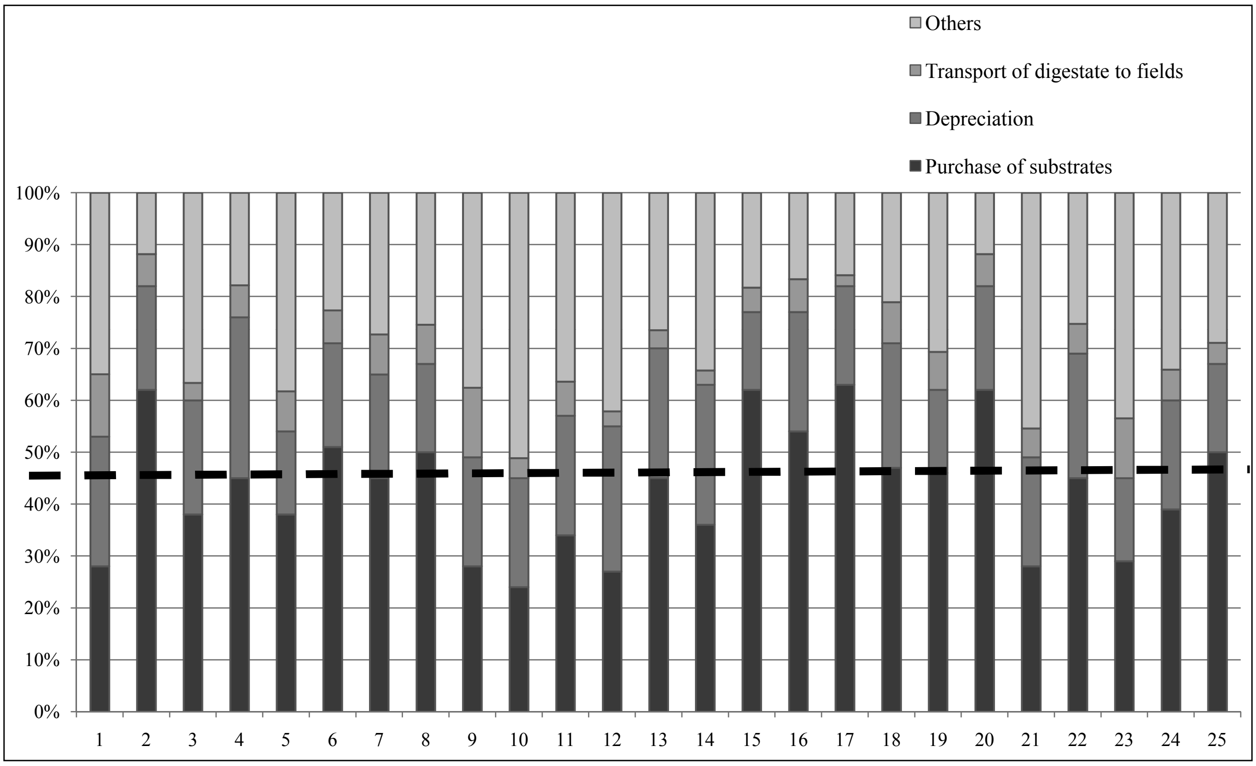

Fig. 3. Results of the monitoring of operating costs in German agricultural biogas plants [12].

conversion risk). With the maturing of the market the average specific investment costs in 2009–2010 dropped from 18–20 MPLN (4.5–5 MEUR) per MW_{el} to 14–15 MPLN (3.5–4) MEUR per MW_{el} in 2011.

The Fig. 2 presents the investment costs for ABPs in Poland and in the EU in PLN'09 (inclusion of inflation indices starting from the year of building a plant).

There is a tendency for the specific investment costs (per kW_{el} installed) to drop with the plant's size, this in particular has an impact on investments below 100 kW_{el}. It must be noted that each ABP is different and should be evaluated separately in terms of technological options (Chapter: "Brief notes on the agricultural biogas technology").

Operating costs

Operating costs are annual costs, which are connected with the functioning of the plant, such as: purchase of substrates, operation and maintenance, oil for CHP, repairs, logistics, distribution of digestate as fertilizer, employment and insurance). Depreciation is an important item of operating costs, all equipment should be depreciated with rates regulated by law in a given country (in Poland 4.5–20% depending on a component). However, in the pre-feasibility study it would be a horrendous work to list all depreciated items, so it is usually assumed that the appreciation amounts to 10% of the total investment costs. Financial costs such as the credit costs are accounted for as annual costs but not as operating costs.

There is no universal formula for calculating operating costs — they should be calculated individually for each plant. The highest position in the operating costs are those related to purchase of substrates (even up to 65% of the all operating costs, 45% on average in Germany) [12], Fig. 3.

In Poland the market price for maize silage (most often used energy crop in ABP) varies between 100 PLN/t (own production costs) and 130–150 PLN/t (contracting from farmers). The cost for the slurry can be assumed from zero (own substrate) to 25 PLN/t. A separate issue is the logistics and storage costs for such substrates. Usually the transportation from a distance exceeding 20 km for maize silage (solid form) and 5 km for swine slurry (liquid form) would not be profitable.

Income

ABPs generate own income from the sale of generated products such as electricity, heat and digestate as fertilizer. Such products should be expressed either as a market average prices (Table 1) or preferably on the basis of the preliminary contracts. Such prices (usually confidential) are negotiated case by case with either an energy distributor for electricity, local farmers for the uptake of digestate as fertiliser, or a local district heating operator for the sale of produced heat.

Table 1. Specific income items for agricultural biogas plants in Poland.

Income items	Income per unit
Sales of electricity	195 PLN/MWh
Sales of green certificates	275 PLN/MWh
Sales of yellow certificates (cogeneration)	125 PLN/MWh[1]
Sales of purple certificates (cogeneration)	56 PLN/MWh[2]
Sales of heat	20–25 PLN/GJ[2]
Sales of digestate as fertiliser	0–20 PLN/t

(as of December 2011)

The main sellable product of an ABP is green electricity. The support system in Poland is based on the quota system, tradable green certificates and high efficiency cogeneration (yellow[3] or purple certificates)[4]. The total support (electricity price + green certificates + cogeneration certificates can amount up to *c*. 530 PLN/MWh (*c*. 13 c€/kWh). However, the calculation is more complicated due to price fluctuations.

It is interesting to compare prices for green electricity in Poland with the current support schemes in other EU countries. In Germany, which takes up over 80% of all EU agricultural biogas market, the support for bigger plants is not much smaller than in Poland. Why then do not they develop as dynamically as in Germany? It is not only the level of support, which matters but also the predictability of its payment. In Germany the feed-in tariffs are guaranteed for 20 years, in Poland green certificates are guaranteed only to 2019. The investors are thus unsure of the income during the investment's life span. The current investments were realized either with high investment risk (Poldanor S.A.) or with additional support in the form of subsidies (up to 40--70%, depending on the region).

Table 2. Support schemes for electricity production in chosen EU member states [7, 8].

Country	% of total EU production in 2010	Support scheme	Tariff, c€/kWh
Germany	82%	Feed-in tariff	5–25
Austria	3.3%	Feed-in tariff	13–19
Czech Republic	1.6%	Feed-in tariff	12–16
Poland	below 1%	Certificates	7 (only green certificates) 13 (all support)

[1] Depends on the utilizable heat.

[2] Lower than the market price, which is c. 40 PLN/GJ.

[3] To be withdrawn in 2012.

[4] There are also investment subsidies available under the EU structural funds.

Currently the biggest problem in Poland is to predict the future income in the project's lifespan. Unlike in Germany, where feed-in tariffs are guaranteed for 20 years in Poland the prices are unpredictable and subject to legal changes. The price of green certificates cannot be easily predicted. The new RES Act (a draft as of December 2011) also does not guarantee the long term stability of income. Once accepted it will change the income levels for green electricity, till now regulated by the Energy Law.

Examples of economic evaluation of big projects

The techno-economic analysis was performed with the help of a Biogaz Inwest software[5], a tool created by the Institute for Renewable Energy especially for the evaluation of the investments at the pre-feasibility study phase.

The first analysed investment is earmarked here as the ABP1 based on agricultural materials the second as the ABP2 based on industrial waste materials. The Fig. 4 below gives basic information about input substrates and the plant's final products, more detailed information is presented in Table 3.

In the ABP1 the substrate input amounts to 36,000 t/a, consisting in 20% of swine slurry (the acquisition price is 0 PLN/t), and 80% of maize silage (crop production costs amount to 100 PLN/t), which will be used to produce 2 Mm^3 of biogas. This will allow to install a 500 kW_{el} CHP unit, producing 4.0 GWh of electricity annually.

In the ABP2 substrates mainly from meat processing industries will be used to produce 2.6 Mm^3 of biogas. All substrates will be obtained free of charge: blood 2,000 t/a, fat separator waste 2,000 t/a; intestines and other body parts 2,000 t/a; meat screenings 2,000 t/a and kitchen waste — 2,000 t/a. Due to utilization of abattoir waste the biogas plant will apply sanitation measures for some wastes at the temperature of 133°C, for the others at 70°C [9]. This will allow to install a 700 kW_{el} CHP unit producing 5.3 GWh of electricity annually. The technological options are summarised below.

Investment costs

For the technological options investment costs were calculated. The total investment costs for the ABP1 amounted to 7.6 MPLN (15 $MPLN/MW_{el}$). In the case of the ABP2 the total investment costs amounted to 13.1 MPLN (19.5 $MPLN/MW_{el}$). The specific investment costs are higher in the later case

[5] www.biogazinwest.pl.

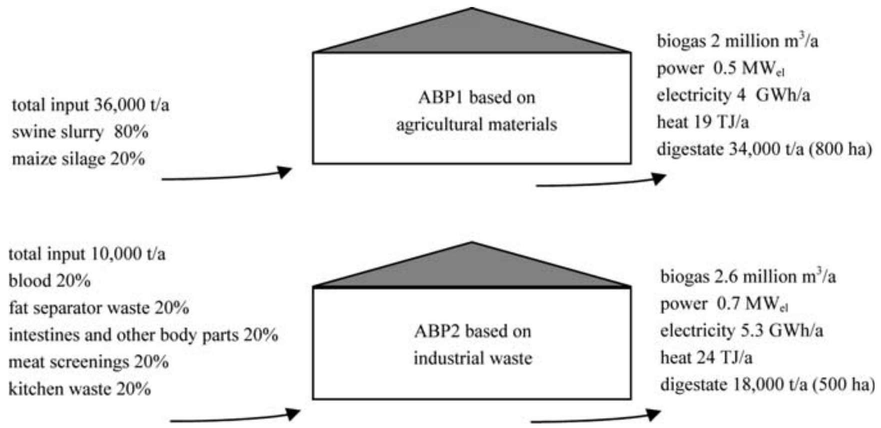

Fig. 4. Input-output data for the analysis of two big agricultural biogas plants.

due to the need to install a sanitation unit for abattoir waste.

Economic evaluation

It was assumed that ABPs will be realized without additional subsidies. 80% of investment cost will be covered by a commercial credit (8.5% interest rate and 12 year crediting period), 20% of own equity. The acquisition of EU funds for the period 2008–2013 will no longer be possible due to running out of available fincial resources, on the other hand perspectives for the next period 2014–2020 remain yet unknown.

In the case of the ABP1 the total operating costs (without depreciation) amount to 1.6 MPLN/a, whereas the biggest share is for the purchase of substrates. The slurry is obtained without additional payment, however, the production costs of maize silage are high (100 PLN/t), its additional storage in a plastic sleeve increases the cost by 20% annually. In the case of ABP2 the total operating costs (without the depreciation) amount to 0.9 MPLN/a. Another important position is the logistics of digestate as fertilizer to nearby fields, although in both cases fields are located close to the investment 0.5 km. The results of the economic evaluation are presented in Table 4.

The profitability indicators are very sensitive to change of substrate prices. For instance, for the ABP1 the increase of the production costs for maize silage from 100 to 120 PLN/t (*e.g.* due to costs of agrotechnical operations connected with the fuel price surge) would result in the IRR decrease from 15% to 9%. If it is contracted at 130 PLN/t the investment will not be profitable, even though the mass contribution of this substrate is only 20%. The same rule applies for swine

Table 3. Summary of the technical options for the 2 analysed agricultural biogas plants.

Type of biogas plant		ABP1 based on agricultural material	ABP2 based on industrial waste
Power capacity of CHP	[MW_{el}]	0.5	0.7
Heat capacity of CHP	[MW_t]	0.6	0.8
Biogas production	[‘000 000 m^3/a]	2	2.6
Plant availability 8000h/a	[%]	91	91
Efficiency of electricity production	[%]	37	38
Efficiency of heat production	[%]	48	47
Electricity production	[GWh/a]	4	5.3
Heat production	[TJ/a]	19	24
Electricity use for own needs of the plant	[%]	9	9
Heat use for own needs of the plant	[%]	29	26
Hydraulic retention time	[days]	29	72
Volume of fermentation chambers	[‘000 m^3]	2.9	2.0
Secondary fermentation biogas production	[%]	3.7	3.7
Sale of electricity produced	[%]	100	100
Sale of heat accessible	[%]	0	0
Amount of digestate	[‘000 t/a]	34	18
Acreage for lagoons	[ha]	1.9	1.0
Required area for spreading out the fertilizer	[‘000 ha]	0.8	0.5

Table 4. Results of the economic evaluation.

Economic indicators		ABP1 based on agricultural material	ABP2 based on industrial waste
Total investment costs	[MPLN]	7.6	13.1
Annual income	[MPLN/a]	2.1	2.8
Operating costs (without depreciation)	[MPLN/a]	1.6	1.0
NPV	[MPLN]	1.7	10.5
IRR	[%]	15	36
Discounted payback time	[years]	13	7
Simple payback time	[years]	7	3
Overall evaluation	Profitable/not profitable	profitable	profitable

slurry, the investment is profitable only provided that substrates are obtained for free.

The ABP2 obtains substrates for free, however, the long-term supply should be secured. Different events can impact the profitability of the installation. For instance the financial insolvency of the industrial partner supplying waste can force the ABP operator to look for another contractor. If the purchase price of substrates increases to 50 PLN/t, IRR will drop from 36% to 18%, and at 70 PLN/t to 13%. While it is still a profitable investment, the above mentioned situation illustrates the case of *ceteris paribus*, the overlapping of many unfortunate events can lead to the bankruptcy of the plant. The only way to minimize the risk in this case is to sign long-term contracts for the delivery of substrates at a reasonable price.

Other unfortunate events impacting profitability can be associated with the technical dysfunction of the plant. The income to large extent depends on the electricity produced, so any disturbance in its production can lead to lower profits. A high overall efficiency of the ABP expressed in working hours 8,000 h should be secured in the contract with the technology provider. For instance the malfunction of a biogas desulfurization can cause CHP failutres — higher oil usage, more frequent stoppages of the engine. The electric efficiency of the CHP unit is indicated by a manufacturer for the best conditions; lowering of gas inflows can result in lower efficiency and thus the electricity production. For instance lowering of the efficiency by 3% for the ABP1 will result in lowering for the IRR from 15% to 9% and in case of the ABP2 from 36% to 27%.

Sensitivity analysis should concern not only risks involved but also opportunities to increase the profitability, *e.g.* by means of securing sells from the heat and digestate (fertilizer). The location of an ABP in the proximity of housing estates or industrial units, where 20% of the excess heat can be utilized at the price of 22 PLN/GJ will lead to increasing of IRR from 15% to 18% for the ABP1 and from 36% to 38% for the ABP2. The possibility to sell the fertilizer at the price of 20 PLN/t will also increase the profitability significantly, however, it is a vague option as permitting procedures are complicated. On the other hand the lack of permission to spread digestate to fields (also probable in the case of abattoir waste [9]) will make the investment unprofitable. Negotiation of gate fees

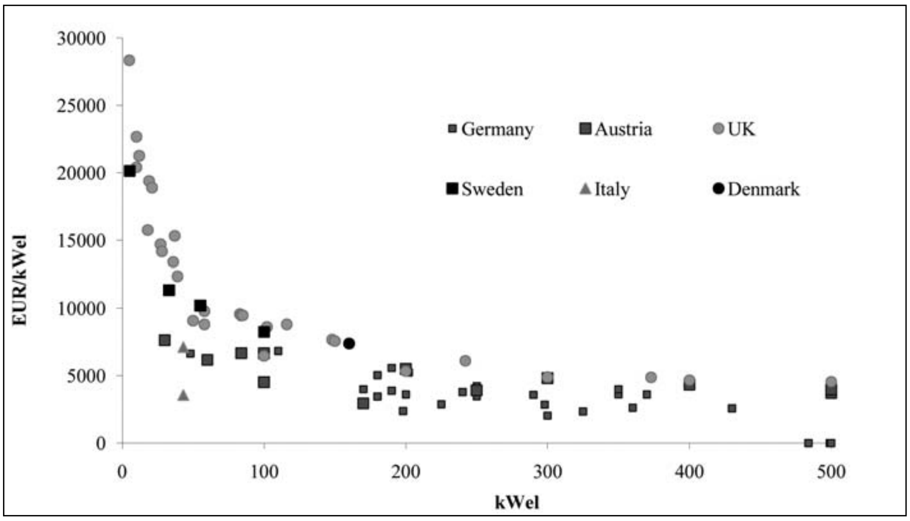

Fig. 5. The comparison of the specific investment costs per kW_{el} power capacity installed in Poland and in the EU [7].

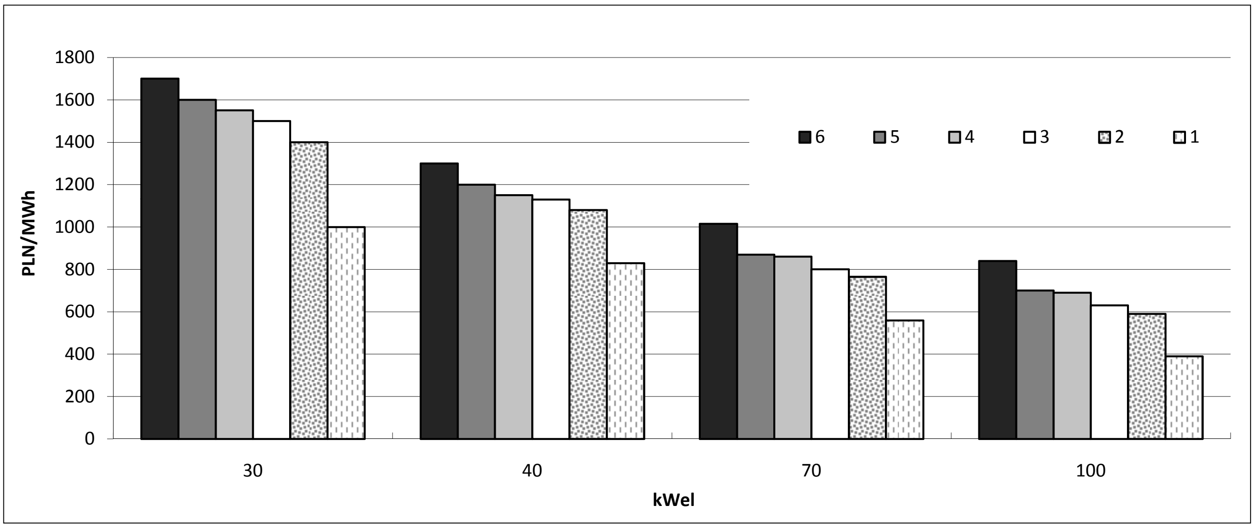

Fig. 6. Required level of production support for green electricity generated by micorbiogas plants [7].

for utilisation of dangerous industrial wastes is also possible, they will be accounted for as plant's income thus improving its profitability indicators.

Examples of economic evaluation of small projects

Poland has almost no experience with microbiogas plants (below 100 kW_{el}), except for 2 hand-made projects. However, in November 2011 some 176 installations were submitted for financing to the Agricultural PROW 311 programme, but the proposals are in a very preliminary planning stage. Due to above an analysis of the investment costs in other countries was assumed as input data for the economic analysis. As indicated in Fig. 2 and 5, the investment costs drop logarithmically with the increasing of the plant's size.

The expected investment costs for a 100 kW_{el} is 0.7 MEUR (2.8 MPLN). First emerging domestic suppliers advertise the possibility to build such plants at 40% lower costs, however, such declarations should be treated with due caution.

In the analysis 6 microbiogas typologies of such plants were analysed, differentiated by mass proportions of the substrate and costs [7]:

- ABP1 — 100% swine slurry,
- ABP2 — 20% maize silage (100 PLN/t), 80% swine slurry,
- ABP3 — 20% maize silage (120 PLN/t), 80% swine slurry,
- ABP4 — 50% maize silage (100 PLN/t), 80% swine slurry,
- ABP3 — 20% maize silage (160 PLN/t), 80% swine slurry,
- ABP6 — 50% maize silage (160 PLN/t), 80% swine slurry.

The analysis was supposed to show which types of agricultural farms in Poland are best suited for such investments (size of farm, intensity of animal and plant production) as well as the impact of fluctuations of substrate costs on plant's profitability. The results were supposed to be used as input for the new draft of the RES Act. Figure 6 indicates the required support level for different types of investments 1–6, at the IRR level of 16%.

The most profitable seem to be small plants based solely on animal waste (100% swine slurry), however, the realization of such is not viable due to technical and territorial constraints. A 100 kW_{el} plant would require the number of animal breaded of 800 LSU[6] (2,700 animals) and the area for spreading of fertilizer of 300 ha (it is a very big farm, the average farm size is *c.* 8 ha).

The required domestic support level drops logarithmically with the increasing of the plant's size. Currently the breakeven point, *i.e.* where the ABP reaches its profitability under current support schemes is *c.* 350 kW_{el}. The ABP of smaller size with admixture of energy crops will either need a higher long term guarantee of support at the level of 600–800 PLN/MWh (15--20 c€/kWh) for 100 kW_{el}, 1,100–1,300 PLN/MWh for 40 kW_{el} (27,5–32,5 c€/kWh). The benchmarking with the current version of the German support scheme contained in the German Renewable Energy Act [10] shows that the results of the economic calculations are correct. The new support scheme in Germany assumes 25 c€/kWh production support for capacities lower than 75 kW_{el} under the condition that they are based prevailingly on animal waste.

[6] LSU: livestock unit.

Natural Sciences

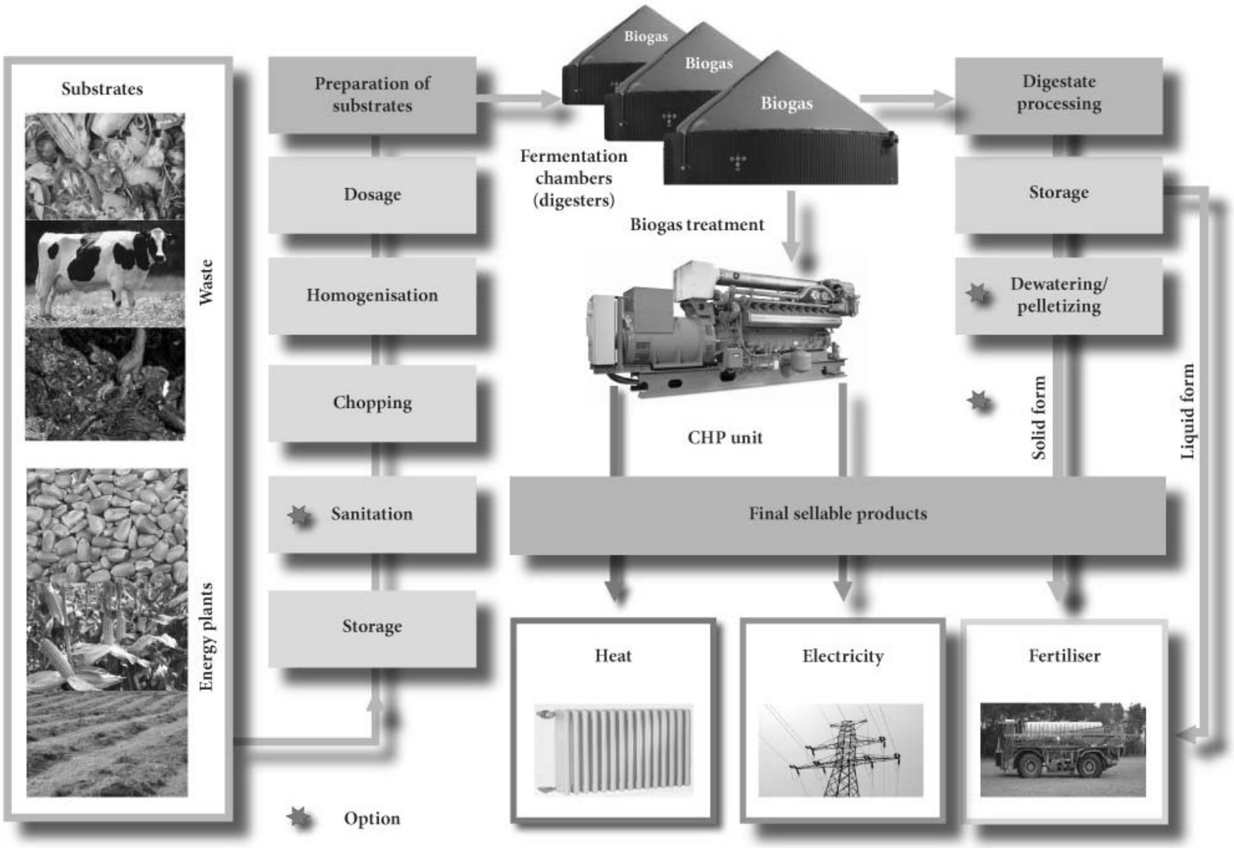

Fig. 7. Flow chart of an agricultural biogas plant.

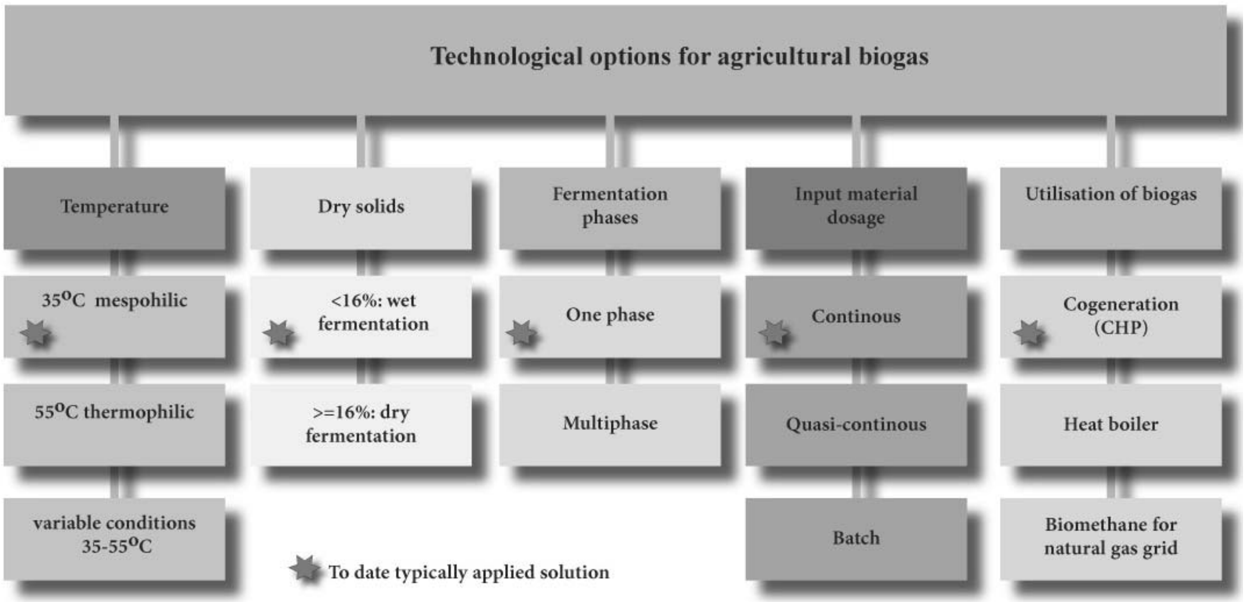

Fig. 8. Technological options for agricultural biogas plants.

Brief notes on the agricultural biogas technology

Methane fermentation is biological decomposition of organic material under anaerobic conditions. Biogas, which is the final product of this process, is a mixture of different gases — on average 60% of CH_4, 40% of CO_2, and other gases such as very corrosive H_2S.

The elements of the technological chain are chosen individually for a given ABP (Fig. 7), depending on the site, access to substrates and possibility to utilise end products. The technological configuration of an ABP takes place during the planning process, a determining factor is the availability of substrates (agricultural or industrial waste, energy crops). The most important information is the biogas production capacity from 1 ton of a given substrate (obtainable from substrate atlases) [11].

Cogeneration (CHP[7]) is currently the most popular way to utilise biogas in order to produce electricity and heat from biogas. Electricity is transmitted to the nearby electricity grid infrastructure, some 9% of is used for the plant's own needs (pumps, mixers, steering, lightning) [12]. However, in the case of heat some 35--40%, is used on-site for the heating of the fermentation chamber.

Many technological options are at hand (Fig. 8). For the biological process it is important to stick to a chosen technology and substrates, the change in fermentation conditions, in an uncontrolled way, can result in a system fatal failure [12].

Acknowledgements

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[7] CHP: combined heat and power.

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