COMPETITIVENESS AND RISK OF CROP PRODUCTION, MILK PRODUCTION AND BIOGAS PRODUCTION WITH RESPECT TO REGIONAL RESOURCES

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Abstract

Renewable energies in Germany are strongly supported by legislation. Farmers expect that renewable energy can help them to increase and stabilise their income. In this respect, biogas is an important pillar in the overall context of renewable energies. Feedstocks for biogas plants are energy crops (corn silage) and liquid manure, among others. A multi period farm model with different operation branches (crop production, dairy and biogas production) reflects the interactions and analyses the competitiveness applying Monte Carlo simulation.

On a single farm scale, entrepreneurs are well advised to take advantage of the current frame conditions with respect to investments in middle-size biogas plants. Up to now biogas plants are unevenly distributed at the regional level. The competitive advantage of biogas production will bring the corn cultivation area up to the regional limit of the individual agricultural region; as long as frame conditions especially remuneration will not change. At current remuneration the investments in biogas plants are expected to increase further. Appling Linear Programming models for the research area of the German federal state Schleswig-Holstein, it can be stated that the biogas production led to an increase in agricultural value added.

Considering the development of income and its distribution in investing in biogas plants, it is possible to point out over-compensation, because rising incomes are not associated with more risk but with less. The cost of the risk of investment was passed by the legislator from the investors to the electricity consumers.

Key words: renewable energy, biogas, crop, milk, competitiveness, risk

1 Introduction

In agriculture, increasingly volatile markets can be observed. The reason lies partly in the fact that especially the Common Agricultural Policy (CAP) reduced market stabilization and moreover global competition increased (globalization, trade liberalization under the WTO). Regardless, triggered by technological progress, long-term terms of trade between agricultural inputs and agricultural products have deteriorated over decades. Particularly dairy farmers, but also crop farmers were affected in recent years of extreme price volatility with long periods of low prices. By growth in new business areas, such as renewable energy (RE), new income opportunities have to be developed and the associated diversification in many cases promises to be able to limit risks.

The apparently high level of competitiveness of biogas led to around 4,950 installations in Germany by the end of 2009 (DBFZ 2010). According to a representative survey by the German Biomass Research Centre (DBFZ 2010) the biogas plants are mainly farm plants owned by firms of the legal forms 27% family farms, 21% BGB companies (German GbR), 15% limited liability companies (German GmbH & Co KG), 7% cooperatives, 2% stock corporations and 2% others (n = 439). Mass related feedstock is 41% from renewable crops (mostly corn), 43% % from manure and 16% others (waste streams), while energy yield is 73% from renewable crops (mostly corn), 11% from manure and 16% others (waste streams) (n = 420).

The flip side of this development is that the use of biomass in the renewable energy sector causes a shortage of land (rental prices rise), as well as rising prices for feed and food. The current boom in renewable energy is induced through "excessive" compensation of electricity (Renewable Energies Act, EEG 2009) that are passed on to the consumer. The state regulations (Chapter 2), economics of scale of biogas operations (Chapter 3), whole farms concepts with respect to income potential and risk of investment (Chapter 4) and the regional capacity limits at the example of the region of Schleswig-Holstein (Chapter 5) are analyzed.

2 State Regulations for Renewable Energy

Renewable energies in the EU and especially in Germany are strongly supported by legislation. The goal is "in the interest of climate and environmental protection to achieve sustainable development of energy supply, reduce the economic costs of energy supply and the integration of long-term external effects, to conserve fossil energy resources and the development of technologies for generating electricity from renewable energy" (EEG 2009). Renewable energy projects funded by the Renewable Energies Act are: Hydropower, landfill gas, sewage gas, mine gas, biomass, geothermal energy, wind, wind repowering, offshore wind energy, solar energy, solar radiation energy at or on buildings. They are funded by a fixed price for electricity, depending on the kind of feedstock used, the size of the (biogas) plant and the thermal energy recovery. For example, prices can vary between 24.77 cents/kWh for a 150 kW system, or even 15.01 cents/kWh for a 5 MW plant (Table 1).

Table 1: Remuneration of biomass according to EEG 2009 (cents/kWh)

Bonuses under the EEG 2009/Performance thresholds		150 kW	500 kW	5 MW
1.a	basic remuneration	11.67	9.18	8.25
1.b	clean air bonus	1	1	
2.	rrenewable resources bonus (energy crops)	7	7	4
2.a	landscape care bonus	2	2	
2.b	liquid manure bonus	4	1	
3.a	technology bonus (without gas supply)	2	2	2
3.b	technology bonus (gas supply)	Depending on the size of the gas treatment plant 1 to 2 Cent		
5.	combined heat and electricity power use	3	3	3
Sum (e.g.: 1.a + 2. + 2.b + 5. x 70% heat recovery⁾		**24.77**	**20.93**	**15.01**

Source: EEG 2009

Farmers expect from the new business of renewable energy opportunities to increase and to stabilize respectively their income. In this connection, biogas is a pillar in the overall context of renewable energies. Biomass from waste (manure and other plant residues) and energy crops are the essential raw materials for biogas production. Farming is the main supplier of these and agricultural enterprises are the same time main investors in this sector.

3 Economics of Scale of Biogas Production

Biogas is produced by fermentation (anaerobic digestion) of biomass (organic raw materials) in biogas plants. The gases are primarily methane and CO_2. Fermentation residues which also remain are used as liquid fertilizer in crop production. Methane can be supplied into the natural gas pipeline after special treatment or in most cases, it is burned in a gas-combustion engine generating electricity and thermal energy.

3.1 Investment Requirements

The economics of scale in biogas plants refer to investment capital and labour costs per installed $kW_{el.}$. The relevant limits for the plant size are determined by the remuneration rates (Table 1) and depend on the available quantities of biomass which will be used as feedstock for the particular operation. The latter, however, only as long as a purchase and trade of feedstock is not considered. Available data of the size of biogas plants range from 50 $kW_{el.}$ to 800 $kW_{el.}$ (KTBL 2010).

The specific investment costs for smaller plants are around 6,000 €/$kW_{el.}$ and fall to about 2,400 €/$kW_{el.}$ (Fig. 1). However, the cost of the building site is not included. Annual labour time which is needed for small plants amounts to 7.8 hours/kW, this decreases in larger plants to about 2.7 hours/kW (FNR 2009, p. 209).

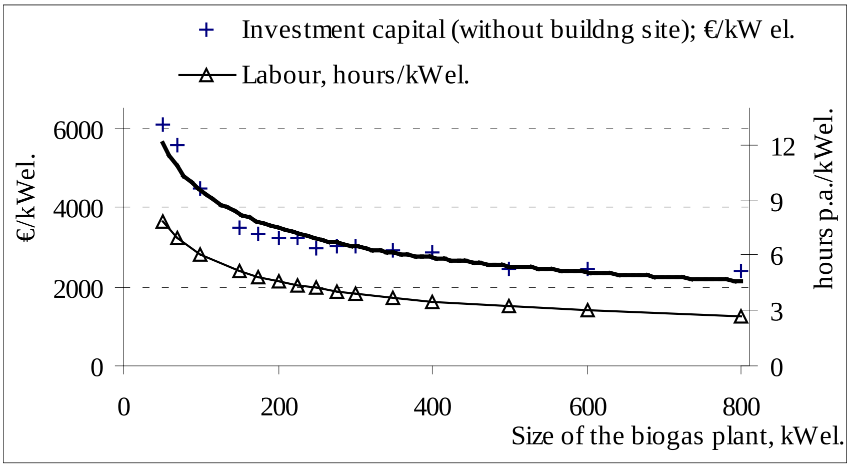

Figure 1: Economies of scale of investment capital and the labour needs depending on the size of the biogas plant (electricity capacity). Source: KTBL (2010) and FNR (2009)

The annual fixed costs of investment are depreciation, interest, the cost of repairs and insurance and labour costs. Depending on the size of the biogas plant, small biogas plants cause annual fixed costs of about 800 €/$kW_{el.}$, which decrease to about 300 €/$kW_{el.}$ for larger biogas plants (Fig. 2). With an average of 8,000 full load working hours the revenue reaches 1,494 €/$kW_{el.}$ for small scale units and deceases to 1,214 €/$kW_{el.}$ for an 800-kW biogas plant. The difference between revenue and fixed costs shows the break even for maximal feedstock costs (corn silage production or purchase), which range between 720 €/$kW_{el.}$ or 31 €/t fresh mass corn silage and 1,039 €/$kW_{el.}$ or 44 €/t fresh mass corn silage. This distance is lowest for small biogas plants; it increases to medium-sized biogas plants and decreases again towards larger units.

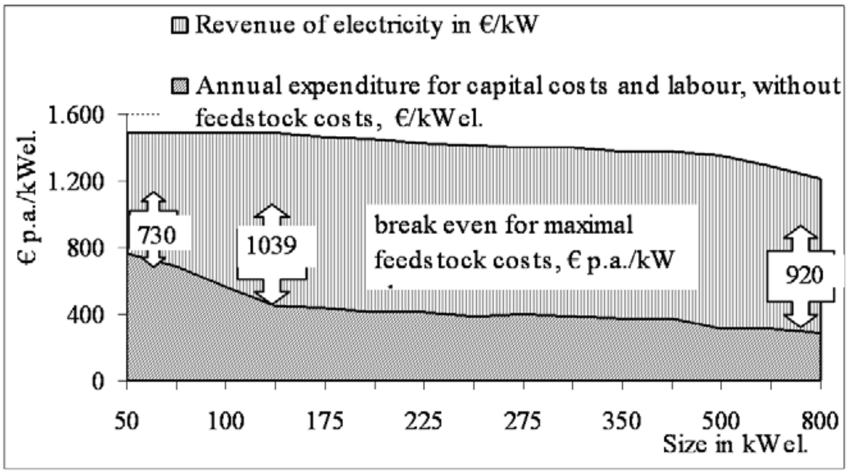

Figure 2: Revenue from electricity sales, economics of scale for fixed costs (annual capital costs and labour costs without feedstock costs); corn fermentation and 8,000 full load working hours, without thermo energy concept, depending on the plant size

Source: KTBL (2010) and FNR (2009), own calculations

Crucial to the success of the investment in a biogas plant is often the thermal energy concept. The biogas plant itself has a demand for thermal process energy of about 30 % (at a range of 20 – 78 %)of the total heat production, e.g. to heat the feedstock to the required temperature of 42 °C in the thermophile stage or to the required temperature range of about 30 - 35 °C in the mesophilic phase. For the remaining surplus of thermal energy external heat customers are required, who should be located in close proximity, because heat transportation is not cost-effective over long distances.

Burning biogas for heating purpose (thermal energy locally used) is not economical due to higher returns from electricity production or delivery of up-grade biogas into the public natural gas pipeline.

The following assumptions are based on an extraction and use of the thermal energy at 70 % of electricity. The heat recovery in turn usually requires additional investments; the costs should not be higher than the savings of fossil fuels (typically natural gas or fuel oil). For many biogas plant operators, it is already be worthwhile if they deliver heat at price null, because in exchange they can get the combined heat recovery and electricity power use bonus (Tab. 1). Thus heat users could take over the required investments and therefore biogas plant operators (in this case the farmers) do not have to pay for these investments.

The reference system in this analysis is without a heat using concept, as there are many operations working now. Concepts that use thermal energy which is produced in the biogas plant as much as possible are economically and ecologically justified and therefore recommended and required in a foreseeable time. According to Schulz and Heitmann (2007) and DBFZ (2010) different principle economically feasible options are identified: heating of private and public buildings (including schools, hospitals, pools etc.), drying plants, greenhouse heating, aquaculture, cooling, heat supply for laundries, fruit and vegetable juice and milk processing.

3.2 Feedstock and its Cost

Livestock farms can use their liquid manure as a cheap resource for biogas production. In addition and in the case of crop farmers, corn silage is the main feedstock for biogas plants. To get the liquid manure bonus, the portion of liquid manure has to reach at least 30% by fresh mass of total biomass. For safety, operation strive a ratio of 35% liquid manure and 65% corn silage, so both bonuses, the liquid manure bonus and the renewable resources bonus (for energy crops) are secure.

The option to use liquid manure is extremely profitable because of the above mentioned bonuses and due to the low costs for liquid manure. To run larger biogas plants only on base of liquid manure, large livestock farms or cooperatives, which have correspondingly high number of animals, are needed. The (relatively high) costs of transport with increasing distance from livestock operations and biogas plant make this option uneconomical. With a supply of 20 m³ manure per cow per year, a herd of 450 cows is needed to run a 50 $kW_{el.}$ plant. Larger systems e.g. for a 150 $kW_{el.}$ plant approximately 1,350 animals are necessary. Even in East-Germany, the region with large scale farms, such stocks are rare.[3] In the cases of lack of animals, the substitution of liquid manure by corn is highly recommended as corn delivers a high biomass yield, which transformed to biogas, i.e. methane, may yield a high energy output.
Very small plants (under 100 $kW_{el.}$) with expensive raw materials (corn only) and without heat concept cannot reach profitability. For all other facilities profit will be as up to 108,000 € per annum for the 500 $kW_{el.}$ biogas plant under the above mentioned frame conditions (no heat selling, feedstock corn silage). If a plant of this size operates with manure and silage corn, the profit would

[3] Separation of slurry could increase the yield of biogas significantly, but is considered as a too costly alternative; in most cases the use of liquid manure has the main purpose to ensure the remuneration of the liquid manure bonus.

rise to 212,000 € p.a. (Fig. 3). It is assumed that 8,000 full load hours p.a. could be achieved, wages are at 15 €/h and purchase of corn silage costs 35 €/t fresh mass.

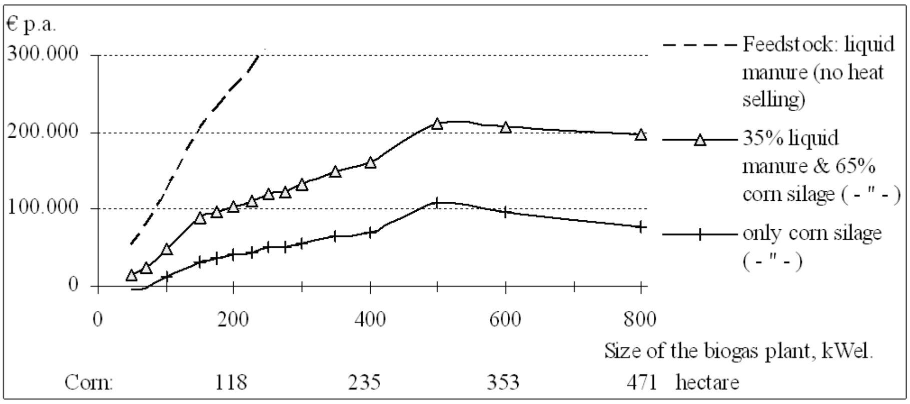

Figure 3: Total profits (€ per year) depending on the size of the biogas plant and the kind of feedstock (8,000 full load hours and corn price 35 €/t fresh mass)

Source: KTBL (2010) and FNR (2009), own calculations

The optimal size of a biogas plant is influenced by two factors, firstly by the economies of scale in investment costs and in labour need due to larger sizes, and secondly by the also decreasing remuneration rates for biogas, which in contrast benefit smaller plants. Because of these opposing trends the optimal plant size is at medium sizes. The optimal plant size is quite clear at 150 $kW_{el.}$ or multiple units of this size (Fig. 4).

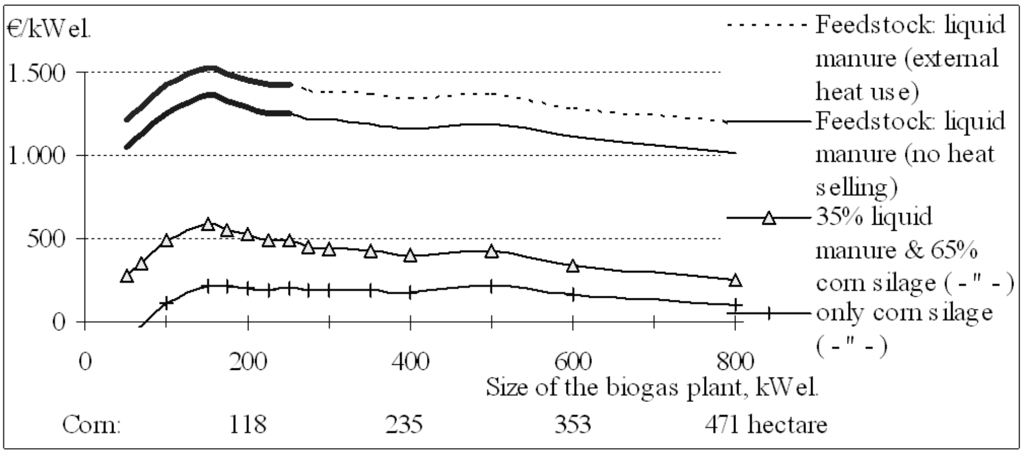

Figure 4: Average profit (€/$kW_{el.}$) depending on the size of the biogas plant and the kind of feedstock (8,000 full load hours and corn price 35 €/t fresh mass; but long distance transport costs not considered).

Source: see Figure 3

The analysis shows that biogas plants can be operated efficiently at average performance level (costs and revenues). Successful operations also have a viable concept of external heat use which increases profits by 20% in the case of liquid manure as feedstock up to 45% in the case of production on the base of corn silage.

On the other hand, there are numerous plants retract with low efficiency and losses. In most of the cases this is due to technical factors (poor quality of feedstock or missing specific mineral supplement and consequently low biogas output or repairs and downtime of the system, etc.) or high costs due to expensive feedstock purchase, lost bonuses, etc. An analysis of such natural and economic risk factors on overall farm level is given in the next chapter.

4 Risk Analysis

Previously shown is that biogas plants operating separately from the entire farm could be profitable. But here are interactions between other branches e.g. crop production and milk production with the new business of biogas production. The links here can be of various natures, ranging from competition for land between all three operating sectors to supplement, if manure is processed by the livestock production branch as a cheap feedstock in the biogas plant. In addition, the risks are widely different. Firstly, for cereals and oilseeds, there is a yield and a price risk, secondly foremost a price risk in milk production under largely controlled conditions of production and protection (e.g. revenue insurance in the case of diseases), whereas guarantees for biogas are being paid for 20 years. However, the natural efficiency of the system and the opportunity costs for the corn acres are subject to fluctuations as well. These risk factors are considered in the following stochastic and dynamic farm model by using triangular distributions and Monte Carlo simulation (Table 2).

Table 2: Triangle distributed variables for the farm models

Variable	Unit	Minimum	Modal value	Maximum
Rape seed yield	dt/ha	25	42	50
Rape seed price	€/dt	20	25	35
Wheat yield	dt/ha	65	75	85
Wheat price	€/dt	10	13,5	20
Milk price	€/kg	0.20	0.28	0.35
Full load working hours of biogas plant	hours p.a.	7,496	8,000	8,504

Source: Own assumptions according to KTBL (2010) and FNR (2009)

The aim of the analysis is to determine the success and the related risk. As success criteria the average profits after tax and the change in equity during the period of 20 years are used. A measure of risk is the corresponding standard deviation of these quantities.

4.1 Example Farm with 250 hectare

In six scenarios, the investments for a crop farm (Reference 1) and a combined dairy farming operation (Reference 2) respectively are presented. The example farm is equipped with 250 hectare (617.5 acre) of land lease and with 250,000 € own funds, all investments are financed by loans. In crop production, the agricultural machinery has to be replaced all ten years, while buildings (barn and biogas plant) hold for 20 years (Fig. 5). The planning covers a period of 20 years. The model considers all financial transactions and continues with an economic evaluation calculating profit and equity after taxes. Due to CAP-reforms it is assumed that direct payments of actual 300 €/hectare on average could decline to 250 €/hectare from 2015 on. Because of the legally established and therefore fixed biogas remuneration an inflation rate of 1.5% declines its revenue in real terms.

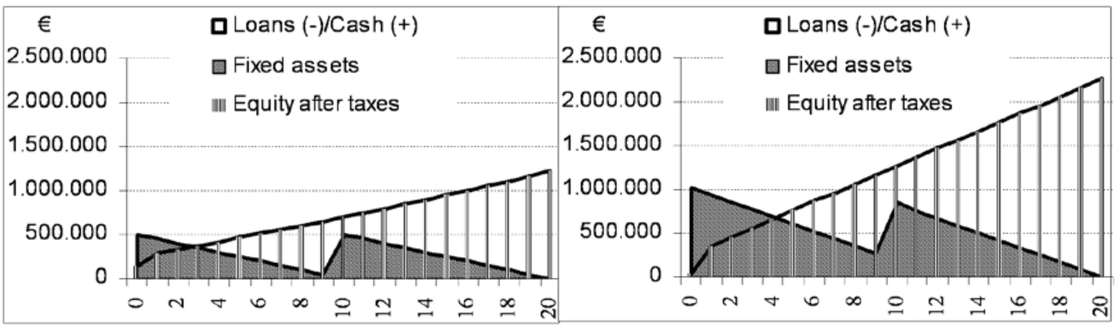

Figure 5: The development of the property and financial assets in the crop farm (Reference 1, left) and a crop-cow-biogas farm (150 $kW_{el.}$) (Scenario 6, right), 250 hectare with 250,000 € own funds in t_0, 20-year planning period

Source: Own assumptions and calculations

4.2 Six scenarios of business development

Starting from a crop farm (reference 1 and scenario 1) the options for growth could be investment in a new dairy (scenario 2) or in a medium-sized biogas plant with 250 $kW_{el.}$ (Scenario 3) or in both, dairy and small biogas plant with 150 $kW_{el.}$ (Scenario 4). If there is a dairy operation already on the farm (Reference 2 and Scenario 5), this can be supplemented by a new small biogas plant with 150 $kW_{el.}$ (Scenario 6) (Table 4). Two simultaneous branches of dairy and biogas are limited by rotation restrictions for corn, thus the capacity of the biogas plant should not exceed 150 $kW_{el.}$ in this case.

Results of 10,000 simulations show that the crop farm (Reference 1) could only get worse, if it invested in a new dairy. The average profit after taxes would strongly decrease from about 45,000 € to 3.500 € (Tab. 4). This would be an investment that shows how difficult the economic situation in milk production currently is and therefore should not be considered further.

Table 4: Description of scenarios for a 250-hectare farm with operating branches in crop production, dairy and biogas production

Scenario		1	2	3	4	5	6
Assumptions		**(Reference 1):** Crop pro-duction	Crop production & new dairy	Crop production & biogas (250 kW)	Crop production & new dairy & biogas (150kW)	**(Reference 2):** Crop production & dairy	Crop production & dairy & biogas (150kW)
Arable land hectare		250	250	250	250	250	250
Cows, head			90		90	90	90
Investment, €/cow place			5,000		5,000		
Biogas $kW_{el.}$				250	150		150
Investment needs, €/kW				2,971	3,506		3506
Corn for biogas plant				147 ha	82 ha		82 ha
Remuneration, ct/kWh				17.67	22.67		22.67
Simulation results (10.000)							
Profit after taxes, € p.a.		45,032	3,540	80,173	68,820	48,485	101,761
Risk measure: Std. Dev.		5,992	10,781	2,792	4,896	6,334	4,908
Equity change $_{t0\text{-}20}$,€		967,050	97,710	1,523,507	1,349,724	1,039,940	2,015,190
Risk measure: Std. Dev.		96.809	257,599	45,171	78,869	102,929	80,065
Ranking	Profit	5	6	2	3	4	1
	Risk	4	6	1	3	5	2

Source: Own assumptions according to KTBL (2010) and FNR (2009) and own calculations

In contrast, the investment in a biogas plant with 250 $kW_{el.}$ would increase average profit after taxes from the initial 45,000 € to about 80,000 € and at the same time decrease risk (scenario 3). In this case, the distribution function for the variable profit after taxes is shifted compared with Scenario 1 by about 35,000 € to the right and runs much steeper (Fig. 6). The additional investment in a dairy (new barn, scenario 4), with the effect of cheap use of liquid manure in the biogas plant, cannot compete with scenario 3, because the ranking for profit or equity change $_{t0\text{-}20}$ and risk (Std.Dev.) lags behind Scenario 3 (Table 4).

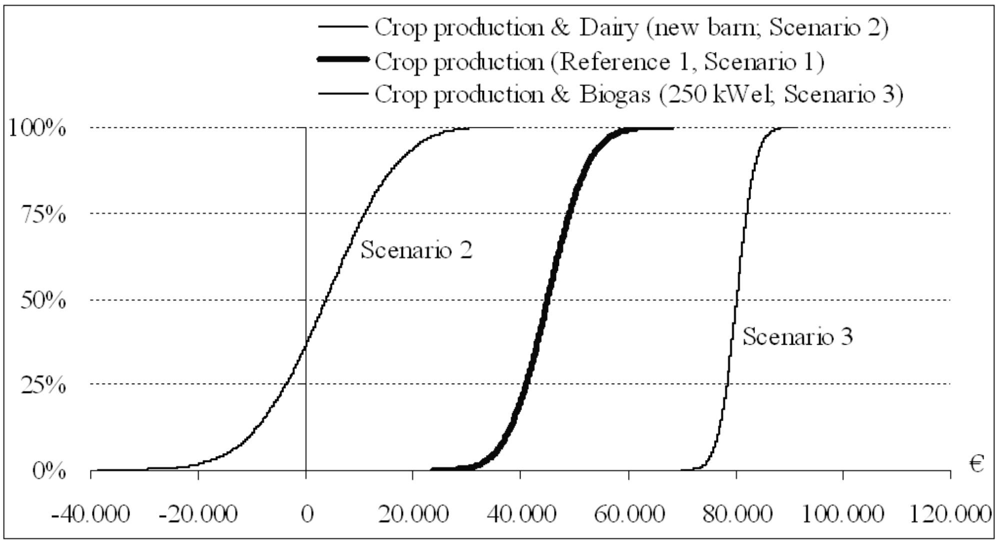

Figure 6: Distribution function for profit after taxes for Scenario 1 to 3 (10,000 simulations)

If there are already a dairy herd and a barn (Reference 2, Scenario 5), average profit is by about 3,500 € slightly higher than in the crop farm (scenario 1; Table 4). Simultaneously, the fluctuations in income and equity are larger (Fig. 7). The expansion by investing in a small biogas plant with 150 $kW_{el.}$ (Scenario 6) offers the most opportunities for the example farm. Profit after tax could increase on average to about 100,000 € a year which is a relatively high net income with reduced risk. The risk measure "Std. Dev." for average profit after taxes as well as for the variable equity change $_{t0\text{-}20}$ is in fact lower in scenario 6 than in the two reference scenarios with only crop production (scenario 1) or mixed farming with only crop production and dairy operation (scenario 5).

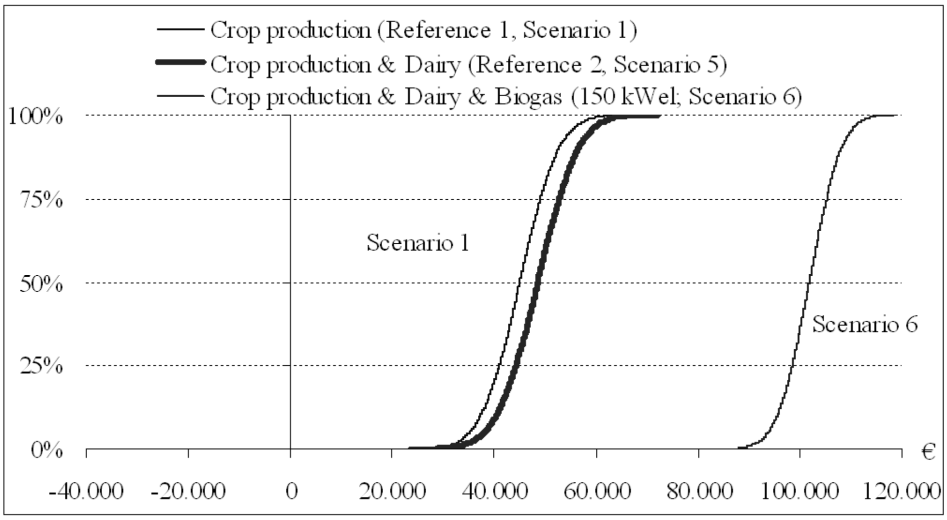

Figure 7: Distribution function for profit after taxes for Scenario 1, 5 and 6 (10,000 simulations)

4.3 Evaluation of the promotion of biogas and the development of plants

It could be demonstrated that the investment in a biogas plant increases in all cases income and reduces the risk of income variability. On a single farm scale, entrepreneurs are well advised to take advantage of this investment. The Renewable Energies Act (EEG 2009), with his objectives to promote development of renewable energies and to reduce dependence on fossil fuels shows effect, because many farmers have already invested in this technology and have been anticipating in the development. The apparently high level of competitiveness of biogas in Germany has led to the increase of stock of biogas plants from about 1,000 plants in 2000 to about 4,950 units by the end of 2009 (DBFZ 2010, p. 24) and further operations are in the planning and approval process.

Where regional capacity limits might be and how the biogas plants are distributed at the regional level, has been studied at the example of the region Schleswig-Holstein. At current remuneration levels the investments in biogas plants are expected to be only limited by crop rotation restrictions for corn cultivation (Bogatov, 2010).

Considering the development of income and its distribution in investing in biogas plants (Table 4), it is possible to point out over-compensation, because rising incomes are not associated with more risk but with less. The cost of the risk of investment was passed by the legislator from the investors to the electricity consumers.

5 Regional Site Capacity for Biogas Plants - example Schleswig-Holstein

In this final section, relative locational advantages of the biogas production at the example of the German federal state Schleswig-Holstein shall be pointed out. As in other regions also, biogas plants are economically interesting for investors. In addition to the above carried out single firm consideration, it is shown, where biogas plants are currently concentrated on regional scale, which trends are expected and most importantly, when it will be expected that limited regional capacity will prevent additional investments of biogas plants. The initial situation is described by the natural agricultural conditions; crop rotation restrictions, animal husbandry facilities, and biogas plant development are considered at the county level (Tab. 5).

A Linear Programming model (LP) considering crop, husbandry, and biogas capacities, is used on the assumptions of current frame restrictions like availability of grassland and arable land, crop rotations restrictions and current husbandry facilities, disaggregated on county level (eleven multi-divisional LP-matrices). Particularly corn cultivation is limited due to crop rotation restrictions ranging from 25% on unfavourable locations to 40% on favourable sites. The result of the optimization shows size and possible locations of future development for biogas production. The objective is to maximize income, which is calculated as sum of gross margin in crop production and animal husbandry in addition to the profits of new biogas plants. These biogas plants operate either on the basis of corn silage, as e.g. medium size biogas plants with 500 $kW_{el.}$, or with liquid manure, as e.g. smaller biogas plants with 150 $kW_{el.}$ (feedstock: 35% liquid manure and 65% corn silage). The assumptions allow also corn transportation across district boundaries.

5.1 Initial Situation at the County Level in Schleswig-Holstein

Schleswig-Holstein has eleven counties located between the North Sea in the West, the Baltic Sea and Mecklenburg-Vorpommern in the East, Hamburg and Lower Saxony in the South and Denmark in the North. The natural spatial structure is from West to East the Marsh (severe productive soils, used mostly as pasture), the Vorgeest (fertile soils), High Geest (sandy soils) and the Upland (average and better credit ratings with a focus on agriculture).

In Schleswig-Holstein regional differences are apparent (Table 5). In crop production, winter wheat (29.3% of arable land), corn (19.2%), and rape seed (14.8%) dominate. The share of corn production is highly dependent on the density of cattle and the production of biogas. Within just a decade, the number of biogas plants in Schleswig-Holstein has increased to 275 plants with an installed capacity of about 120 MW_{el}.. So far, the number of biogas plants has been especially high in the Northern part of the federal state.

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Table 5: Land use, livestock and number of biogas plants at the district level in Schleswig-Holstein – initial situation in 2007

County/City	Share of agricultural land in %					Animal density[1]	No. of biogas plants	Installed capacity [$MW_{el.}$]
	Wheat	Barley	Rape seeds	Corn	Grass land			
Dithmarschen	21%	1%	4%	10%	44%	1,37	18	9
Hzgt. Lauenburg	25%	12%	-	7%	16%	0,46	8	4
Nordfriesland	15%	1%	7%	15%	52%	1,57	53	27
Ostholstein	41%	10%	24%	3%	13%	0,28	15	8
Pinneberg	9%	2%	4%	13%	59%	1,36	2	1
Plön	28%	11%	20%	9%	20%	0,67	13	7
Rendsburg-Eckernförde	13%	6%	11%	14%	38%	1,36	26	13
Schleswig-Flensburg	13%	6%	10%	22%	33%	1,55	67	34
Segeberg	14%	7%	12%	13%	30%	0,95	18	9
Steinburg	10%	3%	6%	12%	53%	1,83	8	4
Stormarn	24%	12%	-	8%	21%	0,56	4	2
Schleswig-Holstein	**19%**	**6%**	**10%**	**12%**	**35%**	**1,17**	**232**	**116**

[1] 500 kg-Units/hectare agricultural land; (- unknown); Source: Statistikamt Nord, 2007, Bogatov (2010)

5.2 Optimization results

An optimum crop production program for selected crops (winter wheat, rape seed, winter barley, corn silage for feeding and biogas purpose, sugar beet and set aside land) is determined on county level with Linear Programming. Crop rotation restrictions for corn are exceeded in four of eleven counties only and corn area decreases therefore. Areas for winter wheat and rape seed decrease, whereas corn increases overall, which is used to feed newly established biogas plants. The share of set aside land decreases, since these areas were originally introduced as a tool to limit production surpluses, what has now been abolished. In the optimal scenario, the sugar beets cultivation stays in the region to the maximum extent. In competition with Renewable Energies, animal husbandry would decline slightly (Tab. 6). Biogas production funded by the EEG (2009) is increasingly replacing the traditional cultivation of market products.

The EEG remuneration sets a clear incentive for further increase of biogas plants in the agricultural regions of Schleswig-Holstein, an overall increase in the number of biogas plants by 609 units and in the installed capacity by 84 $MW_{el.}$, which means an increase by 72% in $MW_{el.}$. Major changes take part in the counties Dithmarschen (+93 biogas plants), Ostholstein (+97 units), Plön (+211 units), Segeberg (+96 units) and Stormarn (+119 units) (comparing Table 5 and 6). This result can only be reached considering transport of corn silage over short distances across county boarders, while transportation of liquid manure is not cost-worthy.[4] The counties of Dithmarschen, Nordfriesland, Steinburg and Stormarn deliver corn silage to neighbouring counties.

[4] There is still an idle amount of liquid manure which could be used in future to up-build another capacity of about 213 biogas plants of the capacity of 150 $kW_{el.}$ each (about +32 $MW_{el.}$ for the whole country).

Table 6: Change in land use, stocking density comparing initial situation and optimal solution and the number of biogas plants and corn transport across county boundaries

County/City	Changes				No. of biogas plants		Installed capacity [$MW_{el.}$]	Net corn transport [hectare]
	Share of agricultural land in %			Animal density[1]				
	Wheat	Rape seeds	Corn		150 $kW_{el.}$	500 $kW_{el.}$		
Dithmarschen	-3%	0%	8%	0,00	99	12	21	-6505
Hzgt. Lauenburg	-1%	-	18%	0,00	0	12	6	7860
Nordfriesland	5%	-1%	-5%	-0,28	0	39	20	-19953
Ostholstein	-8%	-16%	30%	0,00	110	2	18	2020
Pinneberg	7%	-1%	-5%	-0,19	0	4	2	1934
Plön	-28%	-13%	20%	0,00	215	9	37	2333
Rendsburg-Eckernförde	-13%	-6%	-2%	-0,08	0	28	14	12399
Schleswig-Flensburg	14%	-2%	-8%	-0,43	0	72	36	6975
Segeberg	11%	-5%	0%	-0,02	93	21	25	505
Steinburg	-10%	-3%	-4%	-0,21	0	2	1	-1010
Stormarn	2%	-	19%	0,00	113	10	22	-6558
Schleswig-Holstein	**-2%**	**-3%**	**4%**	-0,14	**630**	**211**	**200**	**0**

[1] 500 kg-Units/hectare agricultural land; (- unknown); Source: Own calculations, Bogatov (2010)

5.3 Income Potential and Conclusion

The model calculations show that farmers will include winter wheat, winter barley, sugar beet, as well as corn in their future cultivation program. In the optimization scenario, which includes biogas plants as an alternative investment possibility, a high regional growth of corn is observed. The total gross margin in agricultural production (453 Mio €), biogas profits (54 Mio €) included, was in the initial situation 507 Mio €. An increase in income by 31 Mio € could be observed in optimizing the traditional agricultural branches, i.e. crop production and animal husbandry. Biogas production led to an increase in profits of 86 Mio € (Fig. 8). This increase in income is mainly due to cultivation of corn as feedstock for biogas plants on set aside areas and the further expansion of the biogas sector in Schleswig-Holstein. In summary, it can be stated that the biogas production in Schleswig-Holstein led to an increase in regional agricultural value added. The competitive advantage of biogas production will bring the corn cultivation area up to the regional limit of the individual agricultural region, as long as frame conditions especially remuneration will not change.

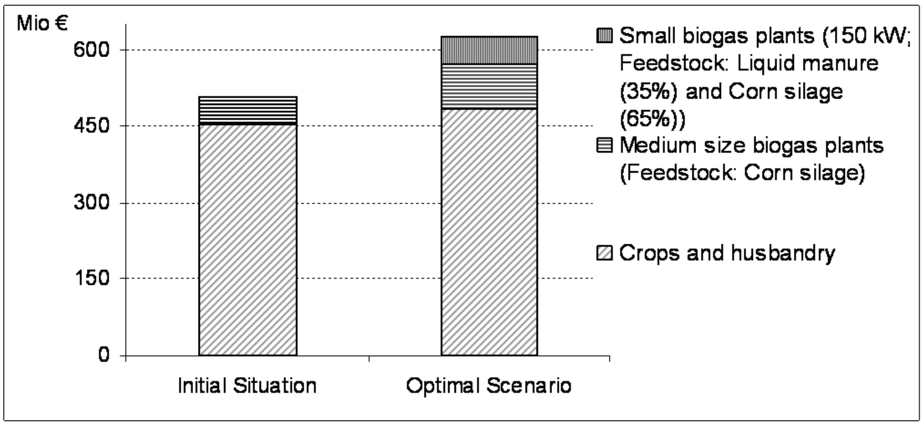

Figure 8: Income contribution of traditional agriculture branches (gross margin of crops and husbandry) and profits from biogas, in Schleswig-Holstein (Initial Situation and Optimal Scenario). Source: Own calculation; Bogatov (2010)

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