Biogas Technology GmbH

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Introduction

1.1 Concept

Biogas facilities offer the possibility to transform organic waste into burnable gas. This gas can then be fired in a conventional combustion engine to produce both, mechanical and thermal power. The mechanical energy is afterwards transformed into electrical energy, while the thermal energy can be used for heating purposes. Using an “absorption freezing machine”, thermal energy can also be used for cooling purposes. This offers the possibility for cost efficient cooling and heating while generating electric energy which can be used or sold into the public grid. The concept of such a “Trigeneration” facility is visualised in figure 1.
If biomass or organic waste is available in sufficient large quantities, then the investment into biogas facilities can be a remunerative way to open a new market for farmers. Because this technology is said to be Carbon-Dioxide neutral, the international Carbon-Dioxide certificate market is another possibility to generate further benefit out of such an installation.

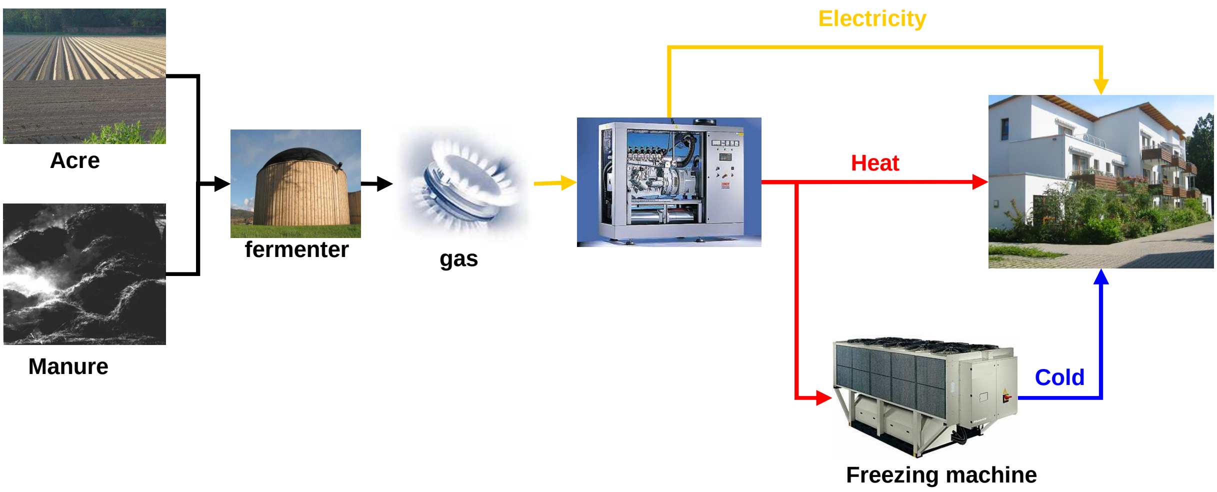

Figure 1: Schematic view on Trigeneration -facility with attached absorption freezing machine

1.2 Involved companies

1.2.1 Schulz GbR

Schulz GbR is a farming company owning 400 hectares of acres. The company is specialized in potato manufacturing and has a storage capacity of 20 000 tonnes of potatoes. These potatoes need to be stored at a constant temperature of around 8 °C for a period of up to 9 month. The storing is not to be understood as simple “putting the potatoes in a room”, but it is an important part of the whole production process, because potatoes need to be dried to a fixed value within a specific time period. At the moment, the needed cooling capacity is performed by electrically driven compression freezing machines, while heating is obtained by normal oil fuelled boilers. Cooling capacity of 200 kW are covering 2500 tonnes, while the oil burners have a power of 3x350 kW. Because of the high electric energy prices, cooling is, therefore a major cost factor in potato production.
As an average, 10 to 15 % of the stored potatoes cannot be sold, because they do not meet the quality standard of the consumers or are rotten. During harvest time, the amount of biological waste is even increased by the green parts of the potatoes, the potato haulm. Schulz GbR has

therefore large amounts of biomass that are up to now not used. In addition, high heating and cooling capacities are needed during the storage process.

1.2.2 Garcia GbR

Garcia GbR is farming company specialised on milk production. The company owns several barns with a total live stock of 1000 milkers. The cows are fed with corn from the surrounding acres which cover an area of 100 hectares. During milk-production large amounts of liquid manure occur, only a small part of this manure can be used as fertiliser on the fields. Electricity is mainly used to drive the milking machines and for illumination. In the winter, sometimes the ambient temperature is too low and the barns must then be heated. Heating is performed via classical oil fuelled burners.

1.2.3 Sonnek GmbH

Sonnek GmbH is an international company dealing with Carbon-Dioxide emission trading. Its services do not only include consulting of affected companies, but it also offers the possibility to generate emission certificates through investments into “Joint-Implementation” and “Clean- Development” projects (JI & CDM projects). For this purpose, Sonnek GmbH is searching for project ideas that are aiming to reduce emissions and is offering these projects to its clients. The generated emission certificates are then sold to the investing companies for fixed prices. Fixed prices do mean a reduction in the risks of the emission trading for these companies, because they need not buy emission certificates on the stock exchange, but can calculate with negotiated prices. Sonnek GmbH is dealing with the whole authorization procedure that is needed for these kinds of projects and is representing the investing companies.

The company is a player on the emission certificate market since it started in 2005. It has realised several JI & CDM projects in eastern countries and has therefore experience with respect to both, legislative and project-related problems. To realise JI & CDM projects, Sonnek GmbH is choosing one or several partners that are also willing to invest into new technologies to generate benefits for themselves. These partners are operating the installation, while Sonnek GmbH is looking after the Carbon-Dioxide related parts of the project.

1.3 Initial situation and market analysis

During the normal operation of both farms, large amounts of electricity, heat and cooling capacity are needed. In the initial situation, the electricity is taken from the public grid for normal prices (9 cent). Heat is generated from conventional oil-fuelled burners, while cooling is performed for the potato storage by compression freezing machines that are also consuming large amounts of electricity. In Addition, the needed electricity and the usage of old-fashioned, inefficient burners are leading to high Carbon-Dioxide emissions from fossil fuels. As by-products of the normal operation, large amounts of biomass are created which are up to now treated as fertilizer or ordinary waste.

Summarizing these input and output factors, figure 2 can be drawn.

Figure 3 is visualizing the characteristic curves of the needed heating/cooling capacity of both farms with respect to the average ambient temperature. From this graph it can clearly be seen, that Schulz GbR is needing a lot of cooling capacities during spring and summer time, while Garcia GbR needs lower amounts of heating nor cooling. In addition, the potato storages do also need forced ventilation to dry the potatoes (about 100 m^3 per tons potato). This will lead to a high electricity consumption of Schulz GbR during the drying procedure. However, after the potato storages have been emptied around November and December, Schulz GbR is no

more consuming remarkable amounts of thermal energy. In contrary, Garcia GbR has to heat up their barns to guarantee a stable milk production.
Summarizing these results, it can be derived that large amounts of thermal and electrical energy are needed over the whole year, while on the other hand a lot of valuable biomass is up to now treated as ordinary waste. Thus it becomes evident, that a Trigenerating facility can run at nearly full power over the whole year. Electricity that is not used directly on the farms is fed to the public net for normal prices. This will eventually produce additional benefits.

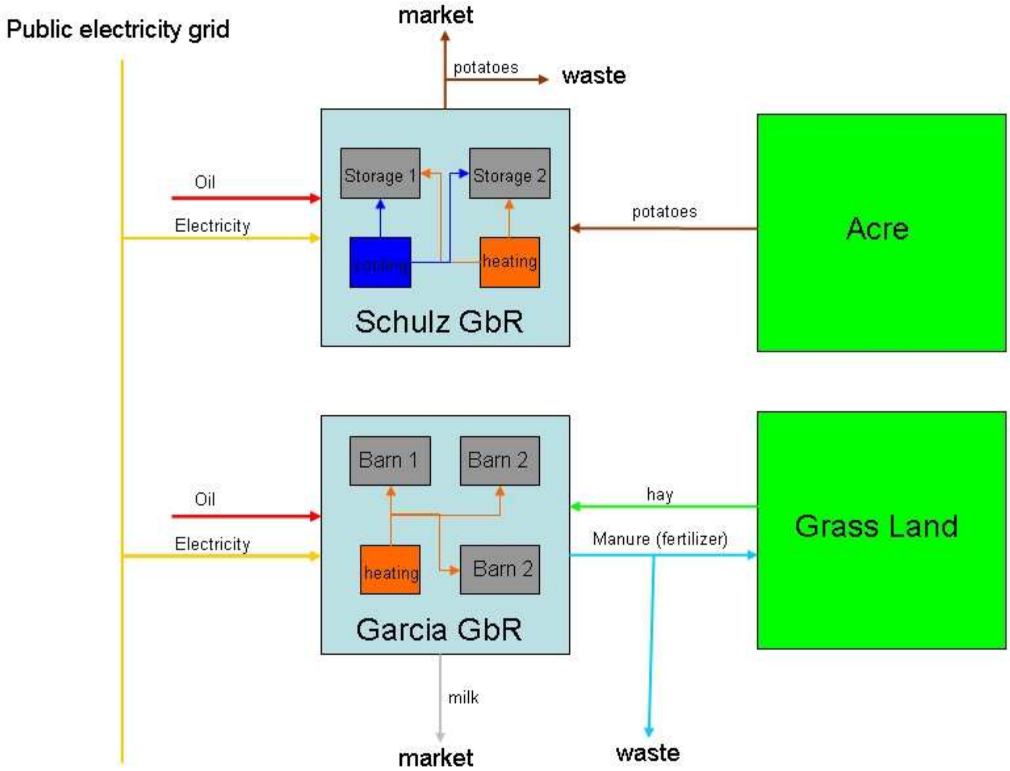

Figure 2: Actual Input and Output flows

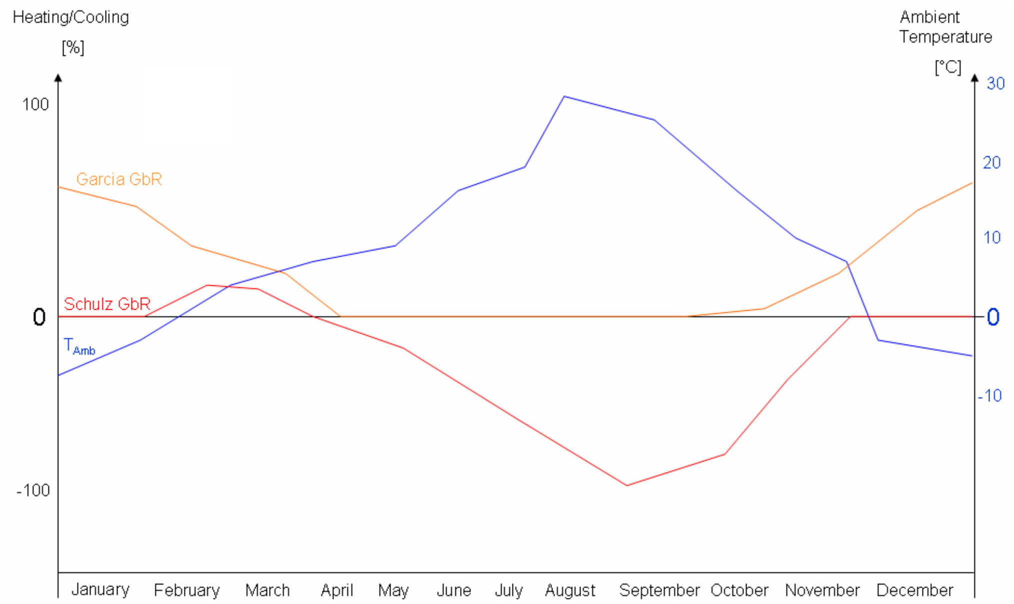

Figure 3: Characteristic curve for heating/cooling of both farms

Figure 3 is finally summarizing the new situation after installation of the biogas-facility. While heating and cooling capacities are only delivered to both farms, electricity that is not bought from the farms for special prices is sold on the public market for regular prices.

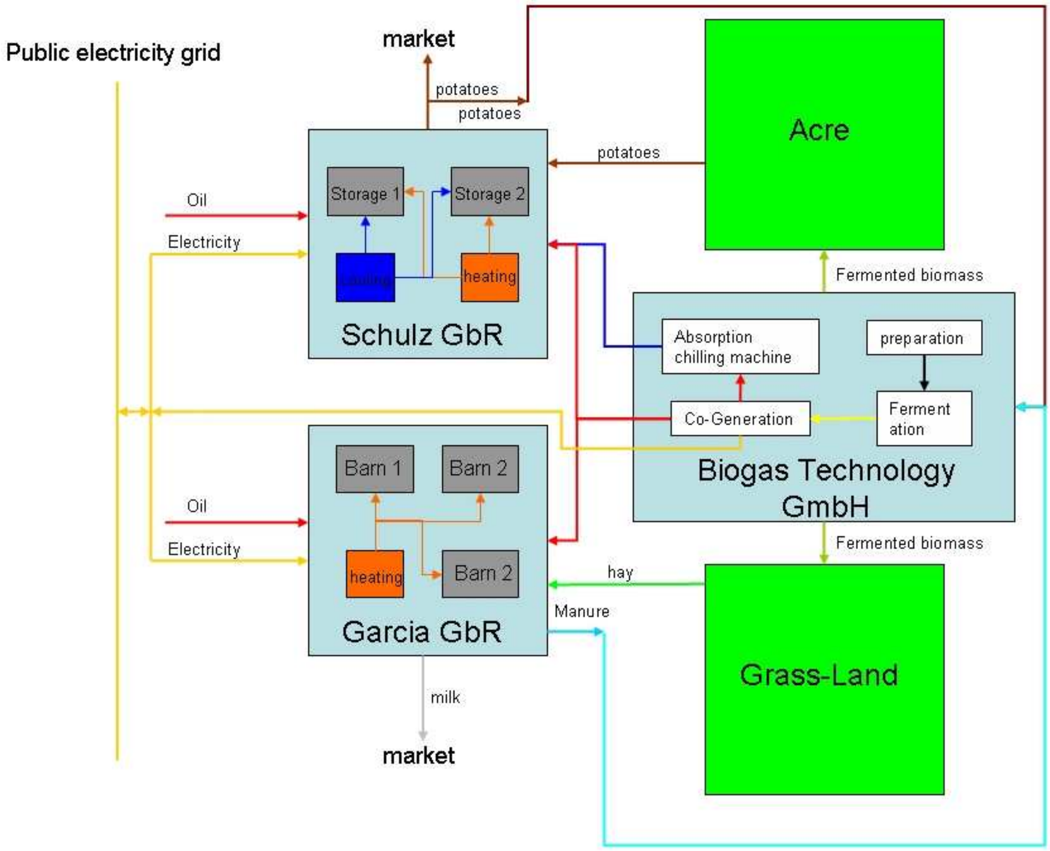

Figure 4: Input and output flows with biomass recycling

Replacing the old-fashioned burner and cooler technology by a Trigeneration facility will further decrease Carbon-Dioxide emissions. This reduction can be sold in the form of Emission Reduction Units on the European Emissioncertificate market. Finally the fermented substrate is still a valuable fertilizer; both farms will use it on their lands.

1.4 Location

Garcia GbR and Schulz GbR are both located in Rumania, about 20 kilometres away from Bucharest, see figure 5.

Figure 5: Position of Schulz and Garcia GbR [© Google Earth 2006]

Because Rumania has ratified the Kyoto Protocol, it can participate in the international emission trading; an exchange of Emission Reduction Units from JI Projects between Rumania and Germany is consequently possible.
As it can be derived from figure 6, both companies are located next to each other. This fact is important, because it simplifies the positioning of the biogas facility: Both farmers do not need to overcome large distances concerning the biomass supply and the heat transfer.

Figure 6: Location of Schulz and Garcia GbR to each other [© Google Earth 2006]

Summarizing, the location of both enterprises and the host country has a promising and a stable environment for the project.

1.5 Competitors

Schulz and Garcia GbR are both investors of the planned facility, thus both will benefit from the new company. It is therefore improbable that they will start selling excessive biomass to other companies nor would they start buying electricity or heat from other companies. In addition, heating and cooling capacities and electricity will be sold to both farms cheap, as compensation, they will supply the installation with low-cost biomass.
Therefore it is improbable that other competitors might appear on the market.

2 Basics of emission trading

All countries that ratified the famous Kyoto Protocol in 1997 obliged themselves to reduce their emissions of 6 green-house-gases by a specific amount within the period from 2008 to 2012 with respect to the base year 1990. The European Community set itself a very challenging goal: -8% of their total emissions in 1990. To achieve this aim, the European Emission Trading System (ETS) has been established in 2005. Within this System, companies that are taking part in emissions trading can buy or sell so called “emission certificates” on the market. One emission certificate equals the total amount of one tons of Carbon-Dioxide. The ETS is a closed system, which means that only member countries of the European Community can take part it this system and at the moment it is only covering Carbon-Dioxide as green-house-gas.
However, with the ratification of the Kyoto Protocol, the European Community is also taking part in the “International Emission Trading”. International Emission Trading means that all

countries that ratified the protocol can exchange so called Emission Reduction Certificates (ERU) or Certified Emission Reduction Certificates (CER) on an international market. These kinds of international certificates can be generated through the "flexible mechanism", Clean Develop Mechanism (CDM) and Joint Implementation Projects (JI), which are also described in the Kyoto Protocol. JI projects can take place between two industrialised countries, CDM projects are in contrary taking place between an industrialised and a developing country.
Even though International Emission Trading and the European Emission Trading System are different systems, they are connected via the "EU-Linking-Directive". This means that certificates from the International System can be transferred to the ETS. This is important, because at the moment only the ETS is a functional system where Carbon-Dioxide emissions do have a real value. Figure 7 is summarizing the different markets.

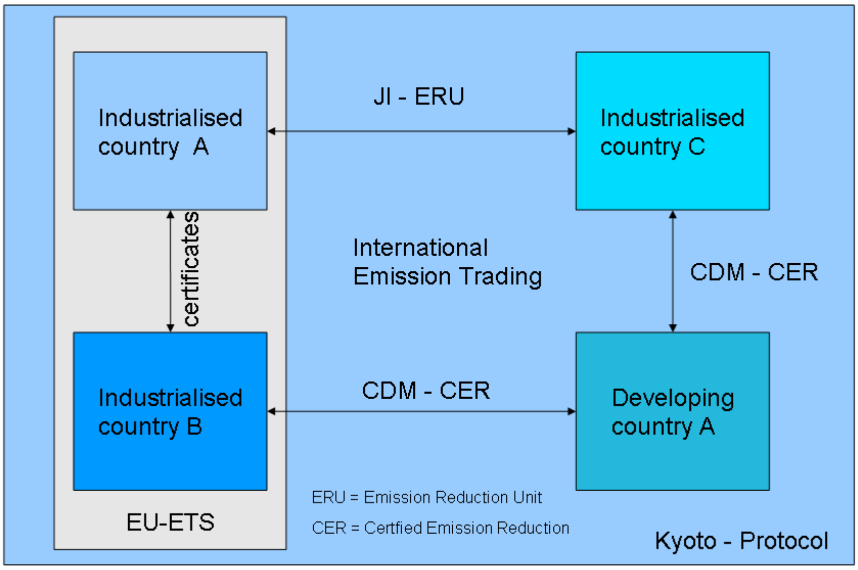

Figure 7: The International Emission Trading and the ETS

The general idea behind both Flexible Mechanism is simple: It is not important where emission reduction is taking place, it only matters that it is taking place. These mechanisms are however offering advantages for both countries and companies:

- The investing enterprise can generated additional certificates, thus it is able to increase its Carbon-Dioxide budget.
- The country where the project is taking place and the national industry will benefit through investments from abroad and modern technologies that will be installed on its ground.

Summarizing, Emission Trading offers a chance for investments into new technologies. A classical "win-win-Situation" is created where all partners will benefit.
Related to the foundation of the Biogas-Technology GmbH, it offers a chance to attract investors.

3 Technical Background

3.1 Biogas generation

Biogas is burnable gas which is created due to the metabolization of highly energetic organic compounds, like sugar or starch, through microorganisms. These organic compounds are summarized as "substrates". The process can simplified be described as rotting without air. In classical biogas generation facilities, the process will automatically start when liquid manure

is locked away from air. Then so called anaerobic microorganisms will start to propagate themselves. These organisms are using the substrate as Carbon-source to feed their metabolism. As by-product of their metabolism, methane rich gas will be released. The gas can reach methane concentrations of more then 70 %. However, concentrations of around 40% are sufficient to drive classical combustion engines. Because the process is performed by living organism, the gas quality will differ with respect to the substrate, temperatures, pH-value and various other factors. Liquid manure is a preferable substrate because it contains large amounts of microorganisms. Conversely, liquid manure alone will not be sufficient to produce enough biogas, thus other biological waste is added (Co-substrate). If air would enter the process-room, then the Methane producing bacteria would die and Carbon-Dioxide producing organisms could propagate.
The air sealed room where the whole process is taking place is a so called “Bio-Reactor”, or fermenter. To guarantee biogas of high quality, which means high Methane content and a low Sulphur content, the controllable process parameters must be kept as fixed as possible. For this reason, a part of the heat that is generated by burning the biogas is used to keep the fermenter at a temperature level of around 35 °C. In addition, the whole substrate in the fermenter needs to be continuously stirred.
In reality, the process is divided in several stages and several bio-reactors as it is described in figure 6. Feeding only liquid manure to the fermenter is in general not sufficient to generate enough biogas to continuously run a combustion engine. Therefore the “Co-Substrate” like corn or potatoes is used together with liquid manure as substrates.
Even though the process is not yet fully understood and is therefore up to now not really controllable, the fermentation technology is state of the art. It is seen as a key technology to produce sustainable energy in the future energy mix. In addition, it is opening farmers a new market.

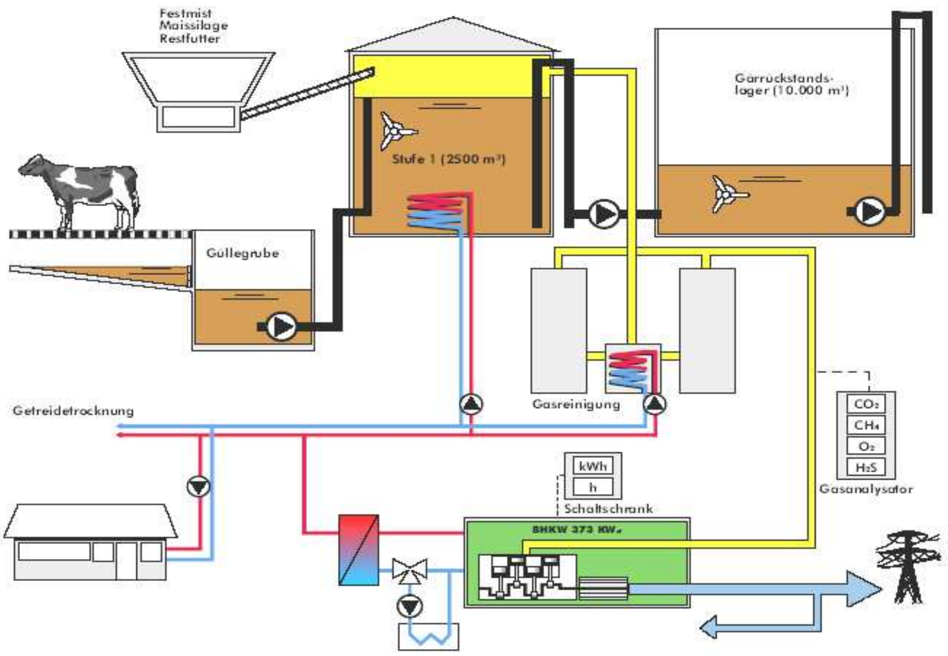

Figure 8: Complete biogas cycle

3.2 Co-Generation

In Co-Generation facilities, fuel is not only used to drive an electric generator via a combustion engine, but also the heat that is released during the conversion process is collected and used for various purposes. In normal biogas installations, it is for example transferred to the fermenter and the barns to heat them up, see figure 8. In large facilities it is sometimes even fed to a public district heating network. Using the heat which is normally just released via a stack is leading to a very high efficiency of the overall process.

Normal combustion engines are in general reaching efficiencies of around 30%, because only the mechanical part of the total energy is used. In contrary, Co-Generation facilities can reach overall efficiencies of 80 to 90 %. It is therefore obligatory to install Co-Generation aggregates if a biogas-installation needs to compete against normal fossil-fuel fired combustion engines or boilers.

Figure 9: Co-Generator

It should be kept in mind that the quality of biogas differs with respect to various factors. Therefore it can sometimes reach high Sulphur contents that will damage the combustion engine. To avoid a quick destruction of them, a gas cleaning installation is often installed. This installation is filtering the gas and is therefore reducing the Sulphur content. Nevertheless, the lifetime of biogas fuelled engines is normally limited to around 8 to 10 years. Figure 9 is showing a Co-Generating aggregate.

3.3 Absorption freezing machines

Figure 10: Absorption freezing machine

Absorption freezing machines do offer the possibility to transfer heat into cooling capacity. Combined with a Co-Generating aggregate, they thus open the option to deliver both, heating and cooling, while electricity is still be produced. This capability is leading to a highly efficient installation that can be operated at nearly full output over the whole year.

This kind of machine is based on a two-substance-system, which means that one liquid is absorbing the other one just to be again separated from each other.

The absorbed substance is serving as refrigerant, while the other one is used as a solvent. In classical absorption freezing machines for small-scale applications, lithium-bromide is taken as solvent which is absorbing water as refrigerant. Both substances together are indicated as “working-couple”. and are separated in the ejector drift through heating up the solution, see figure 11. To perform this heating, heat from the exhaust gas of an engine can for example be taken. Because the refrigerant has a lower evaporation temperature than water, it will start boiling first. The produced steam will then be separated into both substances through a liquid separator. The evaporated refrigerant is then liquified in a condenser and relaxed to the desired temperature through a throttling valve with respect to the evaporation pressure. At the end of the refrigerant branch, heat from the ambient is taken to

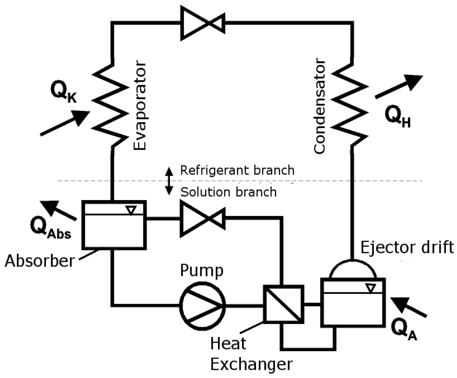

Figure 11: Cycle of an absorption freezing machine

again evaporate the refrigerant. This is creating the desired cooling effect. To close the cycle, the refrigerant is again mixed with the absorbing-liquid; heat is given back to the environment while both gaseous substances are again liquefied. Finally, a pump is pumping the mixture back into the ejector drift, the cycle is closed.

4 Company formation

As legal form of the company, a limited structure (GmbH) is chosen. This is reducing the risk of each partner, because in a limited company they are only liable with their share of the original share capital.
As Chief Executive Officer (CEO) Mr. Garcia is going to be chosen, because decision making on place is necessary. Figure 12 is visualizing the investments of each partner.

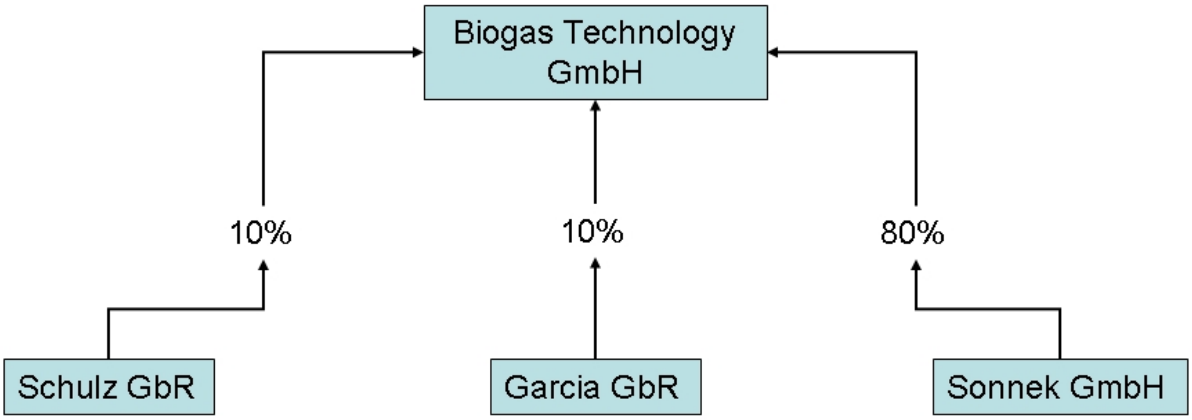

Figure 12: Company formation

Sonnek GmbH is investing all the money which will be generated from the Carbon-Dioxide emission trading (240 100,00 €) in advance. This is necessary to reduce the investment costs and will lead to a majority of Sonnek GmbH in the new company. However, because Sonnek GmbH is placed in Germany, on side decision making will be performed by Garcia and Schulz GbR. Both companies are investing each 30 000,00 €. This capital (60 000,00 €) will not be invested, but will remain in the company as cash money to cover the operating costs.

5 Dimensioning of the facility

5.1 Biomass from Schulz GbR

Schulz GbR has an annual potato production of around 20 000 tons. During the storage procedure, 10 to 15% of these potatoes cannot be sold because they are rotten or do not meet the quality standard. The potatoes that do not meet the quality standard, around 10 %, are sold on the market as animal food for cows, while approximately 5% are rotten and can't be sold. Because Schulz GbR will safe costs for the waste disposal, these potatoes are delivered to the biogas facility for very low prices. The annual amount of available biomass from potatoes can than be approximated as:

$$\text{biomass} = 20000\ \text{ton} \times \frac{5}{100} = 1000\ \frac{\text{ton}}{\text{year}}$$

During harvest time, the total amount of biomass is even further increased by the green parts of the potato, the potato haulm. The mass of these parts are approximately making additional 30% of the total weight of the potatoes:

$$20000\,\text{ton} \times \frac{30}{100} = 6000\,\frac{\text{ton}}{\text{year}}$$

The daily amount of biomass that can be delivered from Schulz GbR can thus be calculated according to:

$$\frac{1000\,\text{ton} + 6000\,\text{ton}}{365\,\text{days}} = \frac{7000\,\text{ton}}{365\,\text{days}} = 19{,}2\,\frac{\text{ton}}{\text{day}} \approx 20\,\frac{\text{ton}}{\text{day}} \approx 0{,}8\,\frac{\text{ton}}{\text{hour}}$$

5.2 Biomass from Garcia GbR

Garcia GbR has an average live stock of 1000 milkers. One milker is delivering approximately 55 kg of liquid manure per day. The total daily amount of liquid manure can thus easily be calculated:

$$1000\,\text{milkers} \times 55\,\frac{\text{kg}}{\text{day}} = 55000\,\frac{\text{kg}}{\text{day}} = 55\,\frac{\text{ton}}{\text{day}}$$

After the fermentation process, the value of the manure as fertilizer is not decreased. Only carbon is removed during the generation of methane. The fertilizing affects of the Nitrate are thus fully conserved. This means that Garcia GbR will also deliver the liquid manure for low prices.

5.3 Calculation of the fermenter size

1. To calculate the needed volume of the fermenter, the amount of potatoes and the amount of potato haulm needs to be expressed in cubic meters:

$$1000\,\frac{\text{ton}}{\text{year}} \times 0{,}92\,\frac{\text{m}^3}{\text{ton}} = 920\,\frac{\text{m}^3}{\text{year}} = 2{,}52\,\frac{\text{m}^3}{\text{day}} = 0{,}105\,\frac{\text{m}^3}{\text{hour}}$$

$$6000\,\frac{\text{ton}}{\text{year}} \times 0{,}75\,\frac{\text{m}^3}{\text{ton}} = 4500\,\frac{\text{m}^3}{\text{year}} = 12{,}3\,\frac{\text{m}^3}{\text{day}} = 0{,}51\,\frac{\text{m}^3}{\text{hour}}$$

Then the amount of liquid manure also needs to be expressed in cubic meters:

$$1000\,\text{milkers} \times 0{,}046\,\frac{\text{m}^3}{\text{milkers} \cdot \text{days}} \times 365\,\text{days} = 16790\,\frac{\text{m}^3}{\text{year}} = 46\,\frac{\text{m}^3}{\text{days}} = 1{,}9\,\frac{\text{m}^3}{\text{hour}}$$

2. Taking into account the average time that is needed to ferment all substrates, the theoretical fermenter volume can be obtained:

$$2{,}52\,\frac{\text{m}^3}{\text{days}} \times 40\,\text{days} = 100\,\text{m}^3$$

$$12{,}3\,\frac{\text{m}^3}{\text{days}} \times 50\,\text{days} = 615\,\text{m}^3$$

$$46\,\frac{\text{m}^3}{\text{days}} \times 30\,\text{days} = 1380\,\text{m}^3$$

$$\text{Theoretical Volume} = 2095\,\text{m}^3 = 2100\,\text{m}^3$$

In reality, 20% in excess of the theoretical volume is added as storage room for biogas. This storage is important to guarantee a continuous supply of the Co-Generation facility with gas and too compensate peaks in the biomass supply.

The real volume can finally be calculated:

$$2100\,\mathrm{m}^3 \times \left(1 + \frac{20}{100}\right) \approx 2500\,\mathrm{m}^3$$

5.4 Total biogas production and Co-Generator size

To determine the required engine size, the average daily biogas production must be calculated:

1. Biogas from the green potato parts

$$6000\,\frac{\mathrm{ton}}{\mathrm{year}} \times 90\,\frac{\mathrm{m}^3}{\mathrm{ton}} = 540000\,\frac{\mathrm{m}^3}{\mathrm{year}}$$

2. Biogas from rotten potatoes

$$1000\,\frac{\mathrm{ton}}{\mathrm{year}} \times 180\,\frac{\mathrm{m}^3}{\mathrm{ton}} = 180000\,\frac{\mathrm{m}^3}{\mathrm{year}}$$

3. Biogas from liquid manure

$$1000\,\mathrm{milkers} \times 1{,}11\,\frac{\mathrm{m}^3}{\mathrm{milkers} \cdot \mathrm{days}} \times 365\,\mathrm{days} = 405150\,\frac{\mathrm{m}^3}{\mathrm{year}}$$

4. Total gas production per year:

$$540000\,\frac{\mathrm{m}^3}{\mathrm{year}} + 180000\,\frac{\mathrm{m}^3}{\mathrm{year}} + 405150\,\frac{\mathrm{m}^3}{\mathrm{year}} = 1125150\,\frac{\mathrm{m}^3}{\mathrm{year}}$$

To calculate the required electric power, the following assumptions are made:

Table 1: Calculation of the annual electricity generation and rated power of the Co-Generator

Electric efficiency	37 %	
Thermal Efficiency	45 %	
No operation at	30 days = 8040 h/year	Availability = 91,78
Energy content of biogas	6 kWh/m^3	
Average operation time	8.040 h/ year	
Rated engine power	$\dfrac{1125150\,\frac{\mathrm{m}^3}{year}}{8040\,\frac{h}{year}} \times \frac{37}{100} \times 6\,\frac{kWh}{m^3}$	310 kW_{el}
+ 20% peak load	310 kW x 1,2	**375 kW_{el}**
total generated power per year (including heat)	$1125150\,\frac{m^3}{year} \times \frac{91{,}78}{100} \times 6\,\frac{kWh}{m^3}$	**619 597 6 kWh**

6 Investment analysis

6.1 Estimated heat production

With respect to the thermal efficiency of the Co-Generator unit, the produced heat can be calculated. However, around 500 kWh of energy per year and per cubic meter fermenter volume, not including the 20% excess volume as gas storage, are needed to keep the temperature level of the fermenter constant. This amount of energy must be subtracted from the total usable thermal energy.

$$\text{Heat Production} = 6195976\,\frac{\text{kWh}}{\text{year}} \times \frac{45}{100} = 2788189\,\frac{\text{kWh}}{\text{year}}$$

$$\text{Heat needed for fermenter} = 2100\,\text{m}^3 \times 500\,\frac{\text{kWh}}{\text{m}^3 \cdot \text{year}} = 1050000\,\frac{\text{kWh}}{\text{year}}$$

$$\text{Total usable heat} = 2788189\,\frac{\text{kWh}}{\text{year}} - 1050000\,\frac{\text{kWh}}{\text{year}} = 1738189\,\frac{\text{kWh}}{\text{year}}$$

6.2 Estimated electricity generation

Taking into account the electric efficiency of the Co-Generator unit, the produced annual electric energy can be calculated:

$$\text{Electric energy} = 6195976\,\text{kWh} \times \frac{37}{100} = 2292511\,\text{kWh}$$

However, around 10% of the generated electricity is needed for the supply of the facility. Consequently the usable electricity is calculated according to:

$$\text{Usable electric energy} = 2292511\,\text{kWh} \times \left(1 - \frac{10}{100}\right) = 2063260\,\text{kWh}$$

6.3 Estimated cooling capacity

The efficiency of absorption freezing machines is expressed as “coefficient of performance” (COP). The COP value describes the ability of the machine to transform heat into cooling capacity; it can reach values of up to 70 %. The possible amount of produced heat can, with respect to the COP, easily be calculated from the total amount of produced heat:

$$\text{Maximal produced cooling} = 1738189\,\frac{\text{kWh}}{\text{year}} \times \frac{70}{100} = 1216732\,\frac{\text{kWh}}{\text{year}}$$

At the moment, 8 compressor freezing machines with each a total power of 200 kW are installed at the potato storage. A 200 kW absorption freezing machine could substitute one of these machines.

6.4 Calculation of generated Emission Reduction Units

An additional benefit will be achieved via the generation of Emission Reduction Units (ERUs). The certificates equal to the total amount of saved Carbon-Dioxide with respect to the old scenario, minus the new one. To calculate these scenarios, first all Carbon-Dioxide sources of the old installations must be approximated, then the overall emissions can be calculated. To simplify the calculation, the characteristic curve, see figure 3, is approached by an average annual operation time at full power. The Compression freezing machines are of

course not directly emitting Carbon-Dioxide, but they are consuming large amounts of electricity. This electricity is in Rumania mainly generated by coal-fired power plants. To calculate the emissions that are set free by these plants, an average emission factor of 0,00036 tCO_2 per kWh is used with respect to an efficiency of the compression machine of 0,75 . Table 2 is summarizing the emissions of Schulz GbR. For oil-fired burners, the emission factor equals 0,00028 tCO_2 per kWh.
The calculated emissions of both companies according to the business a usual scenario are listed in table 2 and 3.

Table 2: Emissions of Schulz GbR

Schulz GbR			
Carbon-Dioxide Source	**Power**	**Average annual Operation at full power**	**Carbon-Dioxide Emissions**
Compressing freezing machines	8 x 200 kW	$8\,\text{Month} \times 1/3 = 1792\,\text{h}$	$1600kW \times 1792h \times 1{,}25 \times 0{,}00036 \frac{tCO_2}{kWh} = 1291{,}25\,\text{tCO}_2$
Oil Burners	3 x 350 kW	$2\,\text{Month} \times 1/3 = 448\,\text{h}$	$1050kW \times 448h \times 0{,}00028 \frac{tCO_2}{kWh} = 132{,}1\,\text{tCO}_2$
Total annual emissions			**1423,35 tCO_2**

Table 3: Emissions from Garcia GbR

Garcia GbR			
Carbon-Dioxide Source	**Power**	**Average annual Operation at full power**	**Carbon-Dioxide Emissions**
Oil Burners	4 x 300 kW	$6\,\text{Month} \times 1/3 = 1344\,\text{h}$	$1200kW \times 1344h \times 0{,}00028 \frac{tCO_2}{kWh} = 451{,}5\,\text{tCO}_2$
Total annual emissions			**451,6 tCO_2**

After the biogas-facility would have been installed, the new emission scenario needs to be calculated. Because the absorption freezing machine is operated with the exhaust gas of the Co-Generator, its operation is not consuming any fuel. The generated cooling capacity is therefore cheap, thus the machine will run at full power as long as possible, while the old compression freezing machines will only run to overcome peak loads. To simplify the scenario, during potato production (for 8 Month) all heat will be put into the cooling machine. During the rest of the year, it is used to cover the heating.

Table 4: Emissions of Schulz GbR with installed biogas facility

Schulz GbR			
Needed cooling capacity			$8 \times 200\ kW \times 1792\ h = 2867200\ kWh_{cooling}$
Absorption freezing machine	200 kW	8 Month = 5376 h	$200\ kW \times 5376\ h = 1075200\ kWh_{cooling}$
Cooling that needs to be performed by Compressing freezing machine			2867200kWh – 1075200 kWh = 1792000 $kWh_{cooling}$
Needed electricity for cooling with Compression machines			1792000 kWh x 1,2 = 2240000 kWh_{el}
- Electricity produced by facility (2063260 kWh)			= 176740 kWh_{el}
Residual Carbon-Dioxide emissions from cooling			$176740\ kWh_{el} \times 0{,}00036 \frac{tCO_2}{kWh}$ $= 63{,}6\ tCO_2$
Needed heating capacity			$3 \times 350\ kW \times 448\ h = 470400\ kWh_{heating}$
Heating performed by Co-Generation unit			1738189*kWh*
Heating that needs to be performed by oil burners			470400 kWh – 1738189 kWh = -1267789 kWh
Oil Burners	3 x 350 kW	Not needed any more	
Total annual emissions			**63,6 tCO_2**

Table 5: Emissions of Garcia GbR with installed biogas facility

Garcia GbR	
Needed heating capacity	$4 \times 300\ kW \times 1344\ h = 1612800\ kWh_{heating}$
Heating performed by Co-Generation unit	1267789 kWh
Heating that needs to be performed by oil burners	1612800 kWh – 1267789 kWh = 345011 kWh
Residual Carbon-Dioxide emissions from heating	$345011\ kWh_{el} \times 0{,}00028 \frac{tCO_2}{kWh}$ $= 96{,}6\ tCO_2$
Total annual emissions	**96,6 tCO_2**

According to this analysis, all the generated electricity, heating and cooling capacity are consumed by both farms. The amount of carbon dioxide reduction can be obtained when the emissions from both scenarios are substracted:

Table 6: Calculation of the Carbon-Dioxide reduction

Scenario I	Scenario II
Emissions from Schulz GbR 1423,35 tCO_2	Emissions from Schulz GbR 63,6 tCO_2
Emissions from Garcia GbR 451,6 tCO_2	Emissions from Garcia GbR 96,6 tCO_2
Total emissions: 1875 tCO_2	Total emissions: 160,2 tCO_2
Emissions saved: 1715 tCO_2	

<u>Net turnover from Emission reduction Units</u>
The ERUs are paid by the clients of Sonnek GmbH in advance. A JI project will take place over a total period of 7 years. Taking into account the saved emissions from table 6, the total amount of generated ERUs can be obtained:

$$1715 \frac{tCO_2}{year} \times 7 \text{ years} = 12005 \ tCO_2 = 12005 \text{ ERUs}$$

One Emission Reduction Unit will be sold for 20 €. Thus the income, with respect to the emission trading can be calculated:

$$12005 \text{ ERUs} \times 20 \frac{€}{ERU} = 240100{,}00 \text{ €}$$

6.5 Investment and depreciation costs

The Biogas facility consists out of several functional groups. The costs for each group can be obtained by applying some proved rule of thumb. These rules are provided by the manufacturer of biogas facilities and include most Off-site costs like engineering.
The actual fermenter is of course the first cost-factor. Table 7 to 10 are summarizing all costs:

Table 7: Building costs

	Cost Position		
Building			
1	Granular subbase		
2	Bio-reactor		
3	Heat insulation		
4	Gas line		
5	Gas storage		
6	Substrate line		
7	Granary		
Techniques			
8	Heating		
9	Pump		
10	Gas preparation		
11	Electrical installation		
12	Tube extruder		
13	Sensors		
14	Controller		
=	$23182\,€ + 98\frac{€}{m^3} \times \text{Fermenter Volume}$		
Total fermenter costs	$23182\,€ + 98\frac{€}{m^3} \times 2100\,m^3$		**228 982,00 €**
Depreciation costs	16 years		**14 311,38 €**

The depreciation of a biogas facility does normally happen over a period of 16 years. However, after around 10 years the engine must be replaced. Consequently, the depreciation period of the engine is 10 years. Table 8 is summarizing the machinery costs.

Table 8: Machinery costs

	Cost Position	
Co-Generator equipment		
1	Engine equipment	
2	Heat line	
3	Electrical installation	
4	Sonic insulated site	
5	Emergency cooling system	
=	$23182\,€ + 283\frac{€}{kW} \times \text{rated engine power}$	
Equipment costs	$11870\,€ + 283\frac{€}{kW} \times 375\,kW$	**117995,00 €**
Tri-Generator		

1	Gas-Engine (300 € x kW) with Generator	112 500,00 €
1	200 kW Absorption freezing machine	50 000,00 €
Tri-Generator costs		**162500**
Machinery costs		**280 495,00 €**
Depreciation costs		
Equipment	16 years	**10 500,00 €**
Engine	10 years	**11 250,00 €**
Depreciation costs		**21 750,00 €**

Table 9: Co-fermentation costs and Off-sites

	Cost Position	
1	Storage room	
2	Substrate preparation	
3	Substrate crushing	
4	Pasteurizing	
5	Additional pumps	
=	$10983\,€ + 4055\frac{€}{m^3 \cdot day} \times \text{volume co-substrate}$	
Total Co-Fermentation and Off-sites	$10983\,€ + 4055\frac{€}{m^3 \cdot day} \times 14{,}8\, m^3 \cdot day$	**70 997,00 €**
Depreciation costs	16 years	**4 437,31 €**

Table 10: Total investment and depreciation costs

Cost Position			
Fermenter costs	228 982,00 €		14 311,38 €
Machinery costs	280 495,00 €		21 750,00 €
Co-Fermentation costs	70 997,00 €		4 437,31 €
Unexpected	10 000,00 €		-
Total investment costs	**590 474,00 €**	**Total depreciation costs**	**40 498,69 €**

6.6 Raw material costs

All substrate are waste products of the farms. However, because Schulz GbR is profiting more from the biogas facility, the Liquid manure from Garcia GbR will be bought for a good price:

Table 11: Raw material costs

	Cost Position	Price [€/m^3]	Annual demand [m^3/year]	Costs
1	Liquid manure	2	16 790	33580,00 €
2	Rotten potatoes	1	920	920,00 €
3	Potato haulm	0,5	4500	2250,00 €
Total raw material costs				**36 750,00 €**

6.7 Labour costs

Labour costs are very cheap in Rumania. In addition, the only work that needs to be performed by humans is feeding the fermenter and the substrate preparation. Table 12 is summarizing the labour costs:

Table 12: Labour costs

	Cost Position	Wage [€/h]	Annual demand [h/year]	Costs [year]
1	Partner			18000,00 €*
2	Labour	4	350	1400,00 €
Total labour costs				**19400,00 €**

*These are the total salary cost per year, incl. insurance and social fees

6.8 Additional expanses

Table 13: Additional

	Cost Position	Price	Costs
1	Assurance	0,5 [% of Investment costs]	2952,37 €
Maintenance			
2	Building	1 [% of Building costs]	2289,82 €
3	Equipment	1 [% of Equipment costs]	1179,95 €
4	Freezing machine	1 [% of machine costs]	500,00 €
5	Engine	10 [% of Engine costs]	11250,00 €
6	Rental fee	500 € per month	6000,00 €
Additional costs			**24 172,14 €**

6.9 Financing costs

The complete benefit from the Emission Reduction Units will be invested into the facility; consequently the credit volume can be decreased. The depreciation time will be 16 years, but in the first year no payback will take place. However, after 10 years a reinvestment of 112 500 € must be made to replace the engine. The company supply 41% of the total needed investment. The last 59% will be financed through a bank loan.

$$\frac{590\,474{,}00\text{ €} - 240\,100{,}00\text{ €}}{15\text{ years}} = 23.358{,}27\,\frac{\text{€}}{\text{year}}$$

Table: 14

Total credit volume	350 374,00 €	
Interest rate	7	
Payback period	16 years	1st year no payback
Payment	Half-yearly	
Securities	Regular securities	

Table 15 is summarizing the costs that are generated through the credit.

Table 15: Financing costs

Year	Remaining debt	Interest fee costs	Payback	Overall Payback
1	350,374.00 €	24,526.18 €	0.00 €	23,826.18 €
2	350,374.00 €	24,526.18 €	23,358.27 €	47,884.45 €
3	317,682.40 €	22,891.10 €	23,358.27 €	46,249.37 €
4	294,990.80 €	21,256.02 €	23,358.27 €	44,614.29 €
5	272,299.20 €	19,620.94 €	23,358.27 €	42,979.21 €
6	249,607.60 €	17,985.87 €	23,358.27 €	41,344.13 €
7	226,916.00 €	16,350.79 €	23,358.27 €	39,709.05 €
8	204,224.40 €	14,715.71 €	23,358.27 €	38,073.97 €
9	181,532.80 €	13,080.63 €	23,358.27 €	36,438.90 €
10	158,841.20 €	11,445.55 €	23,358.27 €	34,803.82 €
11	136,149.60 €	9,810.47 €	23,358.27 €	33,168.74 €
12	113,458.00 €	8,175.39 €	23,358.27 €	31,533.66 €
13	90,766.40 €	6,540.31 €	23,358.27 €	29,898.58 €
14	68,074.80 €	4,905.24 €	23,358.27 €	28,263.50 €
15	45,383.20 €	3,270.16 €	23,358.27 €	26,628.42 €
16	22,691.60 €	1,635.08 €	23,358.27 €	24,993.35 €

$$\boxed{\text{Financing costs} = 220\,735.62\text{ €}}$$

7 Profit preview

The facility will generate profit out of several products that are sold to Schulz and Garcia GbR for special prices. Sonnek GmbH will additionally sell the generated Emission Reduction Unit to its clients. The clients are paying for their certificates in advance, so that the outside capital can be decreased.

It is a well known effect that it will take several months until the gas generation will reach a stable level. Therefore the gas production during the first half year will be set to half the regular production; the payback of the credit will because of this fact also only start in the second year. The depreciation period will be 16 years for the building, however because the lifetime of the engine is limited to maximum 10 years, it will be depreciated over this period.

Net turnover from electricity

During normal operation, all generated electricity will be fed to both farms for 7 cents per kWh. Compared to the normal electricity prices (9 cents per kWh), both enterprises will take an advantage from the installation. The total benefit from electricity generation can be calculated from:

$$2063260\,\frac{\text{kWh}}{\text{year}} \times 0{,}07\,\frac{€}{\text{kWh}} = 144\,428\,\frac{€}{\text{year}}$$

Net turnover from heat

Heat must be provided during winter time for 4 months to both farms. Normally one kWh heat can be charged with 0,040 €. This lead to another benefit of:

$$579396\,\frac{\text{kWh}}{\text{year}} \times 0{,}040\,\frac{€}{\text{kWh}} = 23175{,}84\,\frac{€}{\text{year}}$$

Net turnover from cooling capacity

Providing cooling capacity via the absorption freezing machine means using the output heat of the Co-Generator. Therefore no heating will take place when the freezing machine is running. Cooling will only be delivered to Schulz GbR over a period of 8 month and is normally charged with 0,060 € per kWh. The benefit from cooling can consequently easily be calculated:

$$1075200\,\frac{\text{kWh}}{\text{year}} \times 0{,}060\,\frac{€}{\text{kWh}} = 64512{,}00\,\frac{€}{\text{year}}$$

7.1 Equivalent cost calculation

Table 16: Depreciation costs

Divsion with equivalents for deprecitation costs for the first year					
Total costs:			40,498.69 €		
Sort	1 Equivalent	2 Qty. Produces [kWh]	3 Units of account 1*2	4 Units costs [€/kWh] Unit of all * 1	5 Total costs per sort
Heat	0.5	1,738,189.00	869,094.50	0.005	8,241.44 €
Electricity	1.0	2,063,260.00	2,063,260.00	0.009	19,565.45 €
Cooling energy	1.1	1,216,732.00	1,338,405.20	0.010	12,691.81 €
			4,270,759.70		40,498.69 €
Unit of all=	Total costs / Total Qty. Produced	40,498.69 € / 4,270,759.70	= 0.01		

Table 17: Raw material

Divsion with equivalents for raw material costs for the first year					
Total costs:			36,750.00 €		
Sort	1 Equivalent	2 Qty. Produces [kWh]	3 Units of account 1*2	4 Units costs [€/kWh] Unit of all * 1	5 Total costs per sort
Heat	0.5	1,738,189.00	869,094.50	0.004	7,478.58 €
Electricity	1.0	2,063,260.00	2,063,260.00	0.009	17,754.41 €
Cooling energy	1.1	1,216,732.00	1,338,405.20	0.009	11,517.01 €
			4,270,759.70		36,750.00 €
Unit of all=	Total costs / Total Qty. Produced	36,750.00 € / 4,270,759.70	= 0.01		

Table 18: Labour costs

Divsion with equivalents for labour costs for the first year					
Total costs:			19,400.00 €		
Sort	1 Equivalent	2 Qty. Produces [kWh]	3 Units of account 1*2	4 Units costs [€/kWh] Unit of all * 1	5 Total costs per sort
Heat	0.5	1,738,189.00	869,094.50	0.002	3,947.88 €
Electricity	1.0	2,063,260.00	2,063,260.00	0.005	9,372.39 €
Cooling energy	1.1	1,216,732.00	1,338,405.20	0.005	6,079.73 €
			4,270,759.70		19,400.00 €
Unit of all=	Total costs / Total Qty. Produced	19,400.00 € / 4,270,759.70	= 0.00454		

Table 19: Additional costs

Divsion with equivalents for additional costs for the first year Total costs: 24,172.14 €					
Sort	1 Equivalent	2 Qty. Produces [kWh]	3 Units of account 1*2	4 Units costs [€/kWh] Unit of all * 1	5 Total costs per sort
Heat	0.5	1,738,189.00	869,094.50	0.003	4,919.00 €
Electricity	1.0	2,063,260.00	2,063,260.00	0.006	11,677.88 €
Cooling energy	1.1	1,216,732.00	1,338,405.20	0.006	7,575.26 €
			4,270,759.70		24,172.14 €
Unit of all=	Total costs / Total Qty. Produced	24,172.14 € / 4,270,759.70	= 0.00566		

Table 20: Financing costs

Divsion with equivalents for financing costs for the first year Total costs: 23,826.18 €					
Sort	1 Equivalent	2 Qty. Produces [kWh]	3 Units of account 1*2	4 Units costs [€/kWh] Unit of all * 1	5 Total costs per sort
Heat	0.5	1,738,189.00	869,094.50	0.003	4,848.60 €
Electricity	1.0	2,063,260.00	2,063,260.00	0.006	11,510.74 €
Cooling energy	1.1	1,216,732.00	1,338,405.20	0.006	7,466.84 €
			4,270,759.70		23,826.18 €
Unit of all=	Total costs / Total Qty. Produced	23,826.18 € / 4,270,759.70	= 0.00558		

The calculation of the equivalent financing costs has been carried out over the whole period of 16 years. To keep the overview, it is however not presented here but is included in the complete cost calculation, see Excel –File.

7.2 Addition of the costs and manufacturing costs for each product in the first 16 years

Heat

Table 21: Calculation of costs per kWh Heat for the first 16 years (without tax)

		1. Year	2. Year	3. Year	4. Year	5. Year	6. Year	7. Year	8. Year
Utilization of capacity %		50	100	100	100	100	100	100	100
Quantity [kWh/a]		869,094.50	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00
Costs	Costs per kWh								
Depreciation costs	0.005 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €
Raw material costs	0.004 €	3,739.29 €	7,478.58 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €
Labour costs	0.0023 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €
Additional costs	0.003 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €
Financing costs	0.003 €	4,848.60 €	4,733.20 €	4,571.53 €	4,409.92 €	4,248.30 €	4,086.68 €	3,925.06 €	3,763.44 €
Sum of costs		25,696.20 €	29,320.09 €	29,158.428 €	28,996.811 €	28,835.191 €	28,673.571 €	28,511.951 €	28,350.331 €
Cost per kWh heat	0.0169 €	0.0296 €	0.0169 €	0.0168 €	0.0167 €	0.0166 €	0.0165 €	0.0164 €	0.0163 €

		9. Year	10. Year	11. Year	12. Year	13. Year	14. Year	15. Year	16. Year
Utilization of capacity %		100	100	100	100	100	100	100	100
Quantity [kWh/a]		1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00	1,738,189.00
	Costs per kWh								
Depreciation costs	0.005 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €	8,241.44 €
Raw material costs	0.004 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €	7,478.581 €
Labour costs	0.0023 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €	3,947.88 €
Additional costs	0.003 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €	4,919.00 €
Financing costs	0.003 €	3,601.82 €	3,440.20 €	3,278.58 €	3,116.96 €	2,955.34 €	2,793.72 €	2,632.10 €	2,470.48 €
Sum of costs		28,188.711 €	28,027.091 €	27,865.471 €	27,703.851 €	27,542.231 €	27,380.611 €	27,218.991 €	27,057.371 €
Cost per kWh heat	0.0169 €	0.0162 €	0.0161 €	0.0160 €	0.0159 €	0.0158 €	0.0158 €	0.0157 €	0.0156 €

Electricity

Table 22: Calculation of cost per kWh electricity for the first 16 years (without tax)

		1. Year	2. Year	3. Year	4. Year	5. Year	6. Year	7. Year	8. Year
Utilization of capacity %		50	100	100	100	100	100	100	100
Quantity [kWh/a]		1,031,630.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00
Costs	Costs per kWh								
Depriciation costs	0.009 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €
Raw material costs	0.009 €	8,877.20 €	17,754.41 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €
Labour costs	0.0045 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €
Additional costs	0.006 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €
Financing costs	0.006 €	11,510.74 €	11,236.77 €	7,040.16 €	10,469.29 €	10,085.60 €	9,701.91 €	9,318.22 €	8,934.53 €
Sum of costs		61,003.66 €	69,606.90 €	65,410.287 €	68,839.419 €	68,455.728 €	68,072.036 €	67,688.345 €	67,304.654 €
Cost per kWh electricity	0.0339 €	0.0591 €	0.0337 €	0.0317 €	0.0334 €	0.0332 €	0.0330 €	0.0328 €	0.0326 €

		9. Year	10. Year	11. Year	12. Year	13. Year	14. Year	15. Year	16. Year
Utilization of capacity %		100	100	100	100	100	100	100	100
Quantity [kWh/a]		2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00	2,063,260.00
	Cost per kWh								
Depriciation costs	0.009 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €	19,565.45 €
Raw material costs	0.009 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €	17,754.407 €
Labour costs	0.0045 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €	9,372.39 €
Additional costs	0.006 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €	11,677.88 €
Financing costs	0.006 €	8,550.84 €	8,167.14 €	7,783.45 €	7,399.76 €	7,016.07 €	6,632.38 €	6,248.69 €	5,865.00 €
Sum of costs		66,920.962 €	66,537.271 €	66,153.580 €	65,769.888 €	65,386.197 €	65,002.506 €	64,618.814 €	64,235.123 €
Cost per kWh electricity	0.0339 €	0.0324 €	0.0322 €	0.0321 €	0.0319 €	0.0317 €	0.0315 €	0.0313 €	0.0311 €

Cooling Energy

Tabelle 23: Calculation of cost per kWh cooling energy for the first 16 years (without tax)

		1. Year	2. Year	3. Year	4. Year	5. Year	6. Year	7. Year	8. Year
Utilization of capacity %		50	100	100	100	100	100	100	100
Quantity [kWh/a]		608,366.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00
Costs	Costs per kWh								
Depreciation costs	0.010 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €
Raw material costs	0.009 €	11,517.01 €	11,517.01 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €
Labour costs	0.0050 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €
Additional costs	0.006 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €
Financing costs	0.006 €	7,466.84 €	7,289.12 €	7,040.16 €	6,791.27 €	6,542.37 €	6,293.48 €	6,044.59 €	5,795.69 €
Sum of costs		45,330.65 €	45,152.93 €	44,903.968 €	44,655.08 €	44,406.183 €	44,157.29 €	43,908.394 €	43,659.50 €
Cost per kWh cooling energy	0.0373 €	0.0745 €	0.0371 €	0.0369 €	0.0367 €	0.0365 €	0.0363 €	0.0361 €	0.0359 €

		9. Year	10. Year	11. Year	12. Year	13. Year	14. Year	15. Year	16. Year
Utilization of capacity %		100	100	100	100	100	100	100	100
Quantity [kWh/a]		1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00	1,216,732.00
	Costs per kWh								
Depreciation costs	0.010 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €	12,691.81 €
Raw material costs	0.009 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €	11,517.012 €
Labour costs	0.0050 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €	6,079.73 €
Additional costs	0.006 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €	7,575.26 €
Financing costs	0.006 €	5,546.80 €	5,297.90 €	5,049.01 €	4,800.11 €	4,551.22 €	4,302.32 €	4,053.43 €	3,804.53 €
Sum of costs		43,410.605 €	43,161.71 €	42,912.815 €	42,663.92 €	42,415.026 €	42,166.13 €	41,917.236 €	41,668.34 €
Cost per kWh cooling energy	0.0373 €	0.0357 €	0.0355 €	0.0353 €	0.0351 €	0.0349 €	0.0347 €	0.0345 €	0.0342 €

The following diagram visualizes the evolution of the prices for each product.

Diagram 1: Prices changes for each product in the first 16 years

7.3 Selling price calculation and calculation of the sales profits for each product in the first 16 years

Tabelle 24: Heat

Heat				
Year	Output	Cost per kWh	Selling price per kWh	Turnover
1	869,094.50	0.0296 €	0.040 €	34,763.78 €
2	1,738,189.00	0.0169 €	0.040 €	69,527.56 €
3	1,738,189.00	0.0168 €	0.040 €	69,527.56 €
4	1,738,189.00	0.0167 €	0.040 €	69,527.56 €
5	1,738,189.00	0.0166 €	0.040 €	69,527.56 €
6	1,738,189.00	0.0165 €	0.040 €	69,527.56 €
7	1,738,189.00	0.0164 €	0.040 €	69,527.56 €
8	1,738,189.00	0.0163 €	0.040 €	69,527.56 €
9	1,738,189.00	0.0162 €	0.040 €	69,527.56 €
10	1,738,189.00	0.0161 €	0.040 €	69,527.56 €
11	1,738,189.00	0.0160 €	0.040 €	69,527.56 €
12	1,738,189.00	0.0159 €	0.040 €	69,527.56 €
13	1,738,189.00	0.0158 €	0.040 €	69,527.56 €
14	1,738,189.00	0.0158 €	0.040 €	69,527.56 €
15	1,738,189.00	0.0157 €	0.040 €	69,527.56 €
16	1,738,189.00	0.0156 €	0.040 €	69,527.56 €

Tabelle 25: Electricity

Electricity				
Year	Output	Cost per kWh	Selling price per kWh	Turnover
1	1,031,630.00	0.0591 €	0.070 €	72,214.10 €
2	2,063,260.00	0.0337 €	0.070 €	144,428.20 €
3	2,063,260.00	0.0317 €	0.070 €	144,428.20 €
4	2,063,260.00	0.0334 €	0.070 €	144,428.20 €
5	2,063,260.00	0.0332 €	0.070 €	144,428.20 €
6	2,063,260.00	0.0330 €	0.070 €	144,428.20 €
7	2,063,260.00	0.0328 €	0.070 €	144,428.20 €
8	2,063,260.00	0.0326 €	0.070 €	144,428.20 €
9	2,063,260.00	0.0324 €	0.070 €	144,428.20 €
10	2,063,260.00	0.0322 €	0.070 €	144,428.20 €
11	2,063,260.00	0.0321 €	0.070 €	144,428.20 €
12	2,063,260.00	0.0319 €	0.070 €	144,428.20 €
13	2,063,260.00	0.0317 €	0.070 €	144,428.20 €
14	2,063,260.00	0.0315 €	0.070 €	144,428.20 €
15	2,063,260.00	0.0313 €	0.070 €	144,428.20 €
16	2,063,260.00	0.0311 €	0.070 €	144,428.20 €

Tabelle 26: Cooling energy

Cooling energy				
Year	Output	Cost per kWh	Selling price per kWh	Turnover
1	608,366.00	0.0745 €	0.060 €	36,501.96 €
2	1,216,732.00	0.0371 €	0.060 €	73,003.92 €
3	1,216,732.00	0.0369 €	0.060 €	73,003.92 €
4	1,216,732.00	0.0367 €	0.060 €	73,003.92 €
5	1,216,732.00	0.0365 €	0.060 €	73,003.92 €
6	1,216,732.00	0.0363 €	0.060 €	73,003.92 €
7	1,216,732.00	0.0361 €	0.060 €	73,003.92 €
8	1,216,732.00	0.0359 €	0.060 €	73,003.92 €
9	1,216,732.00	0.0357 €	0.060 €	73,003.92 €
10	1,216,732.00	0.0355 €	0.060 €	73,003.92 €
11	1,216,732.00	0.0353 €	0.060 €	73,003.92 €
12	1,216,732.00	0.0351 €	0.060 €	73,003.92 €
13	1,216,732.00	0.0349 €	0.060 €	73,003.92 €
14	1,216,732.00	0.0347 €	0.060 €	73,003.92 €
15	1,216,732.00	0.0345 €	0.060 €	73,003.92 €
16	1,216,732.00	0.0342 €	0.060 €	73,003.92 €

7.4 Computation of cash-flow for 16 years

Tabelle 27: Cashflow

Cash flow calculation: 16 years

	1. Year	2. Year	3. Year	4. Year	5. Year	6. Year	7. Year	8. Year
Turnover	143,479.84 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €
Depreciation costs	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €
Raw material costs	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €
Labor costs	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €
Additional costs	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €
Financing costs	23,826.18 €	47,884.45 €	46,249.37 €	44,614.29 €	42,979.21 €	41,344.13 €	39,709.05 €	38,073.97 €
Brutto	-1,167.17 €	118,254.40 €	119,889.48 €	121,524.56 €	123,159.64 €	124,794.72 €	126,429.80 €	128,064.88 €
Corporate tax (50%)	0.00 €	59,127.20 €	59,944.74 €	60,762.28 €	61,579.82 €	62,397.36 €	63,214.90 €	64,032.44 €
Netto	0.00 €	59,127.20 €	59,944.74 €	60,762.28 €	61,579.82 €	62,397.36 €	63,214.90 €	64,032.44 €
Cash flow (net+depr.)	39,331.52 €	99,625.89 €	100,443.43 €	101,260.97 €	102,078.51 €	102,896.05 €	103,713.59 €	104,531.13 €
Repayment credit	0.00 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €
DIVIDEND	39,331.52 €	76,934.29 €	77,751.83 €	78,569.37 €	79,386.91 €	80,204.45 €	81,021.99 €	81,839.53 €

Cash flow calculation: 16 years

	9. Year	10. Year	11. Year	12. Year	13. Year	14. Year	15. Year	16. Year
Turnover	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €	286,959.68 €
Depreciation costs	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €	40,498.69 €
Raw material costs	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €	36,750.00 €
Labor costs	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €	19,400.00 €
Additional costs	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €	24,172.14 €
Financing costs	36,438.90 €	34,803.82 €	33,168.74 €	31,533.66 €	29,898.58 €	28,263.50 €	26,628.42 €	24,993.35 €
Brutto	129,699.95 €	131,335.03 €	132,970.11 €	134,605.19 €	136,240.27 €	137,875.35 €	139,510.43 €	141,145.50 €
Corporate tax (50%)	64,849.98 €	65,667.52 €	66,485.06 €	67,302.60 €	68,120.13 €	68,937.67 €	69,755.21 €	70,572.75 €
Netto	64,849.98 €	65,667.52 €	66,485.06 €	67,302.60 €	68,120.13 €	68,937.67 €	69,755.21 €	70,572.75 €
Cash flow (net+depr.)	105,348.67 €	106,166.21 €	106,983.75 €	107,801.29 €	108,618.82 €	109,436.36 €	110,253.90 €	111,071.44 €
Repayment credit	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €	22,691.60 €
DIVIDEND	82,657.07 €	83,474.61 €	84,292.15 €	85,109.69 €	85,927.22 €	86,744.76 €	87,562.30 €	88,379.84 €

7.5 Equity profitability

Table 28: Equity profitability

Equity profitability			
	1. Year	2. Year	3. Year
Partners equity	300,100.00 €	300,100.00 €	300,100.00 €
Net-profit	0.00 €	59,127.20 €	59,944.74 €
Total	300,100.00 €	359,227.20 €	360,044.74 €
Dividend	39,331.52 €	76,934.29 €	77,751.83 €
Profit made in % Partners equity	13.11	21.42	21.60

It can be derived from table 28 that our profit due to the equity is about 22% in the second year, after reaching the 100% efficiency of the facility. Diagram 1 shows the trend of it during the first 16 years.

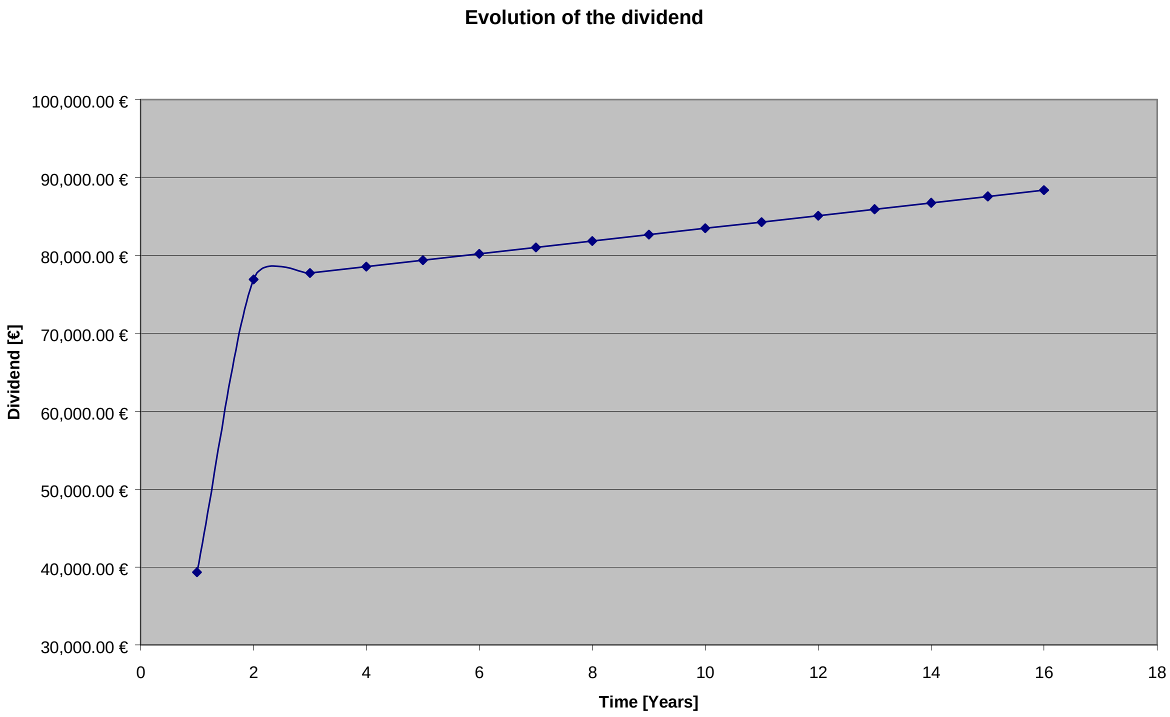

Diagram 2: Trend of the profit in percent due to the shareholders equity

8 Risks

Liability of the Limited company is limited to the investor's investments. The partners cannot lose more money than the value of their shares if the corporation runs into dept, as they are not responsible for the corporation's obligations.

9 Conclusion

The overall costs and profit calculation shows that the company Biogas Technology GmbH is a profitable organisation. The evaluated prices for the products heat, electricity and cooling energy give enough space to set a price for them which is deep enough to be remunerative for the purchasing companies and high enough to give the Ltd itself a good economical income. For all involved associations exists a “win-win-Situation”, which will help them to stabilize their companies in the national and in the international market which is necessary, especially with respect to their entry in the EU.

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