Feasibility study

for Bogatic and Bijeljina

EUROPÄISCHES ZENTRUM
FÜR ERNEUERBARE ENERGIE
GÜSSING GMBH

by

European Center for Renewable Energy Güssing Ltd.

BIJELJINA & BOGATIĆ
cross border development

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1. GENERAL INFORMATION

Based on the cross border energy concept of Bogatić and Bijeljina, developed on the evaluated data of the energy demand from both municipalities as well as on the calculated data a feasibility study for both regions are going to be evolved. The feasibility study will go on the results and recommended measures to emerge a form of guideline how to implement the renewable energy in these regions.

These two concept regions and their municipalities do not very differ in the geographically, climatically conditions as well as in spatial distribution of settlements, which cause in nearly common conditions for biomass production and the use of solar energy are similar.

Graphic 1: The two concept regions and their municipalities. Bogatić on the left and Bijeljina on the right.

Bogatić is smaller in area and has fewer inhabitants than Bijeljina, so the method of comparing both regions is the use of key figures, mostly per-capita-values.

2. Energy demand and resources and potentials of Bogatic and Bijeljina

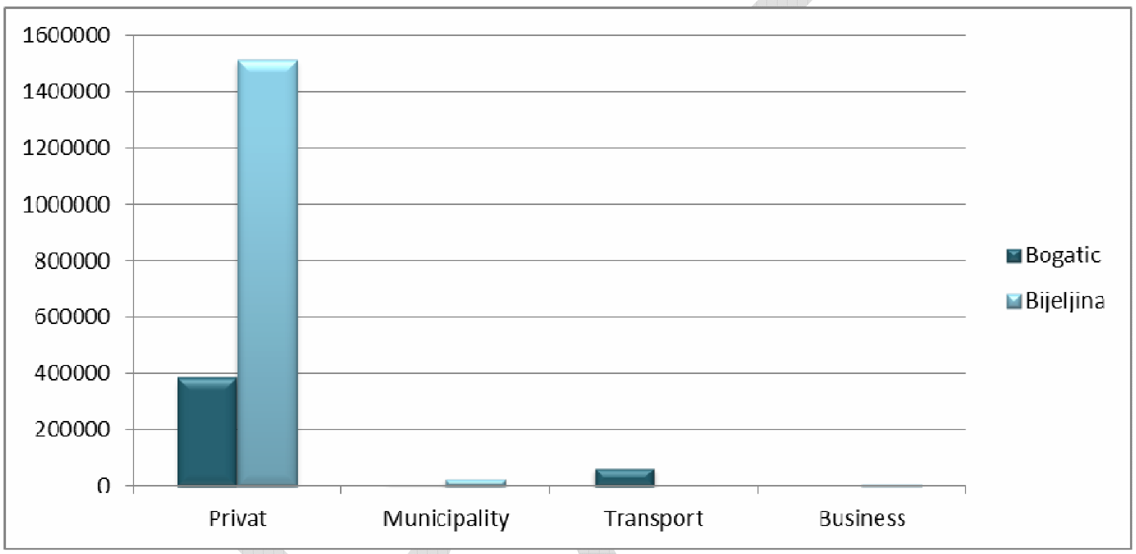
2.1 Energy demand

Even if there are huge difference of demographic and economic situation, the main groups of the energy demand in the municipalities is the private sector. In the previous energy concept was the energy demand calculated of the following sectors:

- Private

- Municipality
- Transport
- Business

The following graphic also shows, that the private sector has a very important part of both municipalities in the field of energy demand, based mainly on low electricity prices in Bogatic as well as heat supply in Bijeljina with an input material of lignite and coal.



Graphic 2: Distribution of energy demand in the two concept regions by energy demand groups (Source: Calculation EEE, 2014)

2.2 Energy resources and potentials

The renewable energy potentials were calculated in both municipalities based on the received data. The data are calculated for:

- Forestry
- Agriculture
- Geothermy
- Solar radiation

All potentials are also considered regarding their capacity to cover the energy demand or certain aspects of the demand. All calculated potentials do have theoretical values, because there are always economic and technical limitations for their use. In any case the results are showing chances and possibilities for the use of renewable resources and, on the other hand, limitations in their availability and practical use.

2. Evaluation of the geothermal energy in Bogatic

2.1 Geothermal electricity production and District heat supply

Many geothermal energy supply systems are based on a dependable sedimentary resource environment, and on the doublet concept of heat extraction.

In case of Bogatic there is no doublet drilling and the extracted water is not reinjected into the ground again. In case of BB2 this could lead to the problem which can already be observed in the case of BB1, where abundance of delivery has already dropped to more than 50%, according to the information received during a working meeting in Bogatic when also the wells have been visited.

The depletion of the wells´ abundance therefore is a threat to the economic viability of any installed geothermal facility, which needs always to be kept in mind and which has to be discussed with the respective experts in the initial planning phase of a facility.

The following accomplishment is made presuming that there is no change in the abundance and temperature levels of the geothermal wells.

2.2 District heat supply

Geothermal District Heating is the use of geothermal energy to heat individual and commercial buildings, as well as industry, through a distribution network.

Regarding the current temperature level and abundance of *BB1 (75°C and 17 l/s)*, a heat capacity of 1,3 MW can be provided for a district heating system. From *BB2 (78°C and 61 l/s)* the heat capacity is located at 5,1 MW. In both cases a temperature drop ΔT of 20°C in the course of building heating are presumed.

Because of the lack of reinjection of a possible return flow, the system can be considered as a one-way system, where water is dumped at a temperature level of about 55°C, if the remaining heat is not used further for greenhouse heating or any similar low-temperature application.

According to the information given at the project meetings in December 2013, the geothermal heat shall be used for heating municipal buildings. The heat load of the buildings which are currently not heated with electricity is about 2,4 MW. In case of the use of BB1, only selected buildings can be provided with heat because BB1 can only deliver 1,3 MW. In case of the use BB2 there is a surplus of energy of 2,7 MW heat load.

A pipeline for hot water transport from BB1 to the centre of Bogatic needs to have a length of 2.500 m and a pipeline from BB2 needs to be about 4.200 m long. A possibly needed extent of the pipeline for dumping the used water or for providing low-level heat for other applications is not the subject of considerations.

In the following paragraphs two main variants with 2 kinds of scenarios are discussed. The scenarios were introduced because of lacking information on possible subsidies for the facilities. The two – imaginary – scenarios of the variants are developed under the aspect of **0% subsidies** (1a, 2a) and the inverse aspect of **100% subsidies**. The real heat supply costs will be found between these upper and lower limits.

2.2.1 Variant 1: District heating from BB1

Variant 1 is considering the use of BB1 in a district heating system. The capacity could cover the heat load of, for example, the primary school and the kindergarten. The following tables are giving an overview on investments, annual costs and costs of heat supply, if the project is realized by use of 100% credit capital for investments (1a) and without any credit capital for investments (1b).

Cost estimation, regarding investments and annual costs, is considered on the basis of prices in Austria.

Table 1: Calculation of considering the district heating form BB1 with committed assessts (Source: Calculation EEE)

Variant 1a : District heat from BB1 – 100% credit capital	
Specification:	
Heat power (MW)	1,3
Heat production (MWh/a)	1.560
Investments:	***€***
Grid and building connections	330.000
Heat central	225.000
Amount of investments	**555.000**

Annual costs:	**€**
Maintenance costs	12.000
Capital costs	57.000
Personel expenditures	12.000
Auxiliary energy	1.404
Amount of annual costs	**82.404**
Costs of heat supply (€/MWh)	**52,8**

Table 2: Calculation of considering the district heating from BB1 without committed assessts (Source: Calculation EEE)

Variant 1b : District heat from BB1 - no credit capital	
Specification	
Heat power (MW)	1,3
Heat production (MWh/a)	1.560
Investments	**€**
Grid and building connections	330.000
Heat central	225.000
Amount of investments	**555.000**
Annual costs	**€**
Maintenance costs	12.000
Capital costs	1.500
Personel expenditures	12.000
Auxiliary energy	1.404
Amount of annual costs	**26.904**
Costs of heat supply (€/MWh)	**17,2**

2.2.2 Variant 2: District heating from BB2

Variant 2 is considering the use of BB2 in a district heating system. The capacity could cover the heat load of all buildings of municipal public service. If BB2 was harnessed completely, almost the double load could be covered by it. Variant 2 is referring only to the public buildings therefore the calculated heat load is lower than the capacity of the geothermal well. The first table shows costs in case of 100% credit capital (2a), the second table shows costs without credit capital (2b).

Cost estimation, regarding investments and annual costs, is considered on the basis of prices in Austria.

Table 3: Calculation of considering the district heating form BB2 with committed assessts (Source: Calculation EEE)

Variant 2a: District heat from BB2 – 100% credit capital	
Specification:	
Heat power (MW)	**2,8**
Heat production (MWh/a)	3.360
Investments:	**€**
Grid and building connections	536.000
Heat central	260.000
Amount of investments	**796.000**
Annual costs:	**€**
Maintenance costs	15.000
Capital costs	82.000
Personel expenditures	20.000
Auxiliary energy	3.000
Amount of annual costs	**120.000**
Costs of heat supply (€/MWh)	**35,7**

Table 4: Calculation of considering the district heating form BB2 without committed assessts (Source: Calculation EEE)

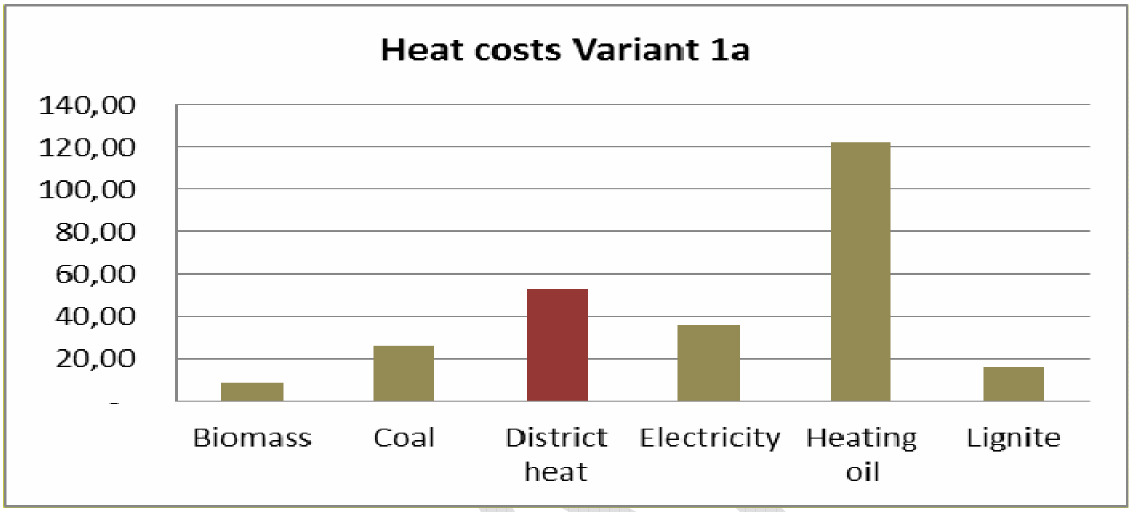
Variant 2b: District heat from BB2 – nocredit capital	
Specification:	
Heat power (MW)	**2,8**
Heat production (MWh/a)	3.360
Investments:	**€**
Grid and building connections	536.000
Heat central	260.000
Amount of investments	**796.000**
Annual costs:	**€**
Maintenance costs	15.000
Capital costs	6.500
Personel expenditures	20.000
Auxiliary energy	3.000
Amount of annual costs	**44.500**
Costs of heat supply (€/MWh)	**13,2**

2.2.3 Comparison of the variants

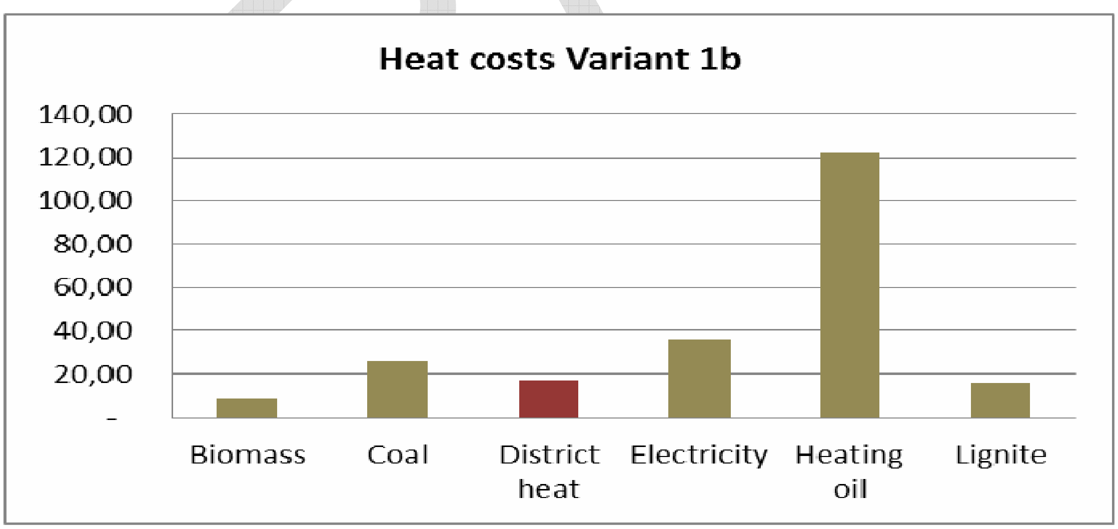
Investments in Variant 2 are by 30% higher than in Variant 1 (BB1), also annual costs are higher by 31% in Variant 2 (BB2).

The costs of heat supply, which means the amount of money, necessary to cover all costs, are by 32% lower in Variant 2.

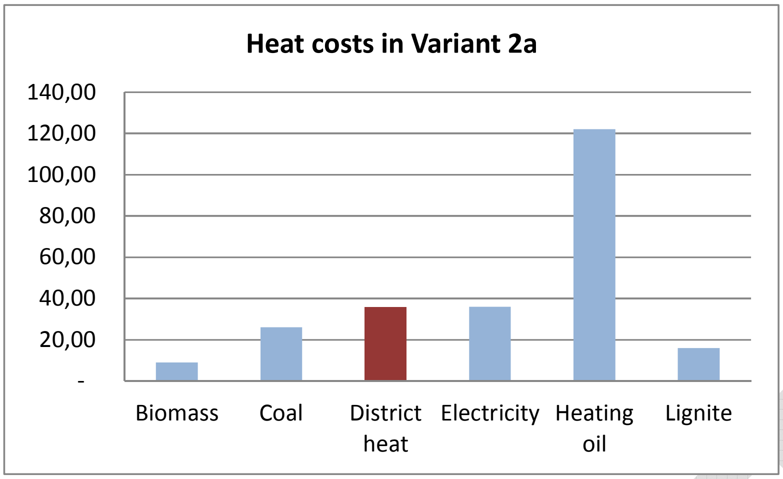
The following charts are showing the costs of heat supply in comparison of the respective examined variants and compared to the submitted prices of other energy sources.



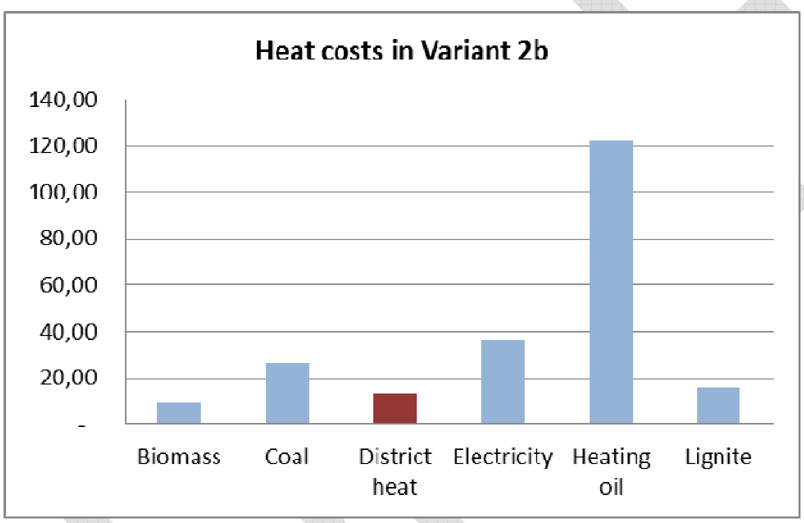
Graphic 3: Illustration of district heating costs of BB1 by 100% committed assessts (Source: Calculation EEE)



Graphic 4: Illustration of district heating costs of BB1 by no committed assessts (Source: Calculation EEE)



Graphic 5: Illustration of district heating costs of BB2 by 100% committed assessts (Source: Calculation EEE)



Graphic 6: Illustration of district heating costs of BB2 by no committed assessts (Source:Calculation EEE)

2.3 Electricity production

In order to generate electricity from low-to-medium temperature sources and to increase the utilization of thermal resources by recovering waste heat, binary technologies have been developed.

The binary plants utilize a secondary working fluid, usually an organic fluid that has a low boiling point and high vapour pressure at low temperatures, compared with steam. The secondary fluid operates through a conventional Rankine cycle: the geothermal fluid yields heat to the secondary fluid through heat exchangers, in which this fluid is heated and vaporizes; the vapour produced drives a normal axial flow turbine, is then cooled and condensed, and the cycle begins again. When suitable secondary fluids are selected, binary systems can be designed to utilize geothermal fluids in the temperature range of 80 to 170 °C.

The upper limit depends on the thermal stability of the organic binary fluid, and the lower limit on the technical-economic factors below this temperature the size of the heat exchangers required would render the project uneconomical. Apart from low-to-medium temperature geothermal fluids and waste fluids, binary systems can also be utilized where flashing of the geothermal fluids should preferably be avoided (for example, to prevent well scaling). In this case, down-hole pumps can be used to keep the fluids in a pressurized liquid state, and the energy can be extracted from the circulating fluid by means of binary units.

2.3.1 Application of Organic Rankine Cycles (ORC)

In a conventional steam power plant the thermal energy is converted to electricity as water passes through a sequence of state changes. To implement these state changes the components like a turbine with generator, condenser, feed pump and boiler are needed. The water steam cycle is suitable for turbine inlet temperatures above 350 °C. At lower temperatures the efficiency significantly decreases and the danger of erosion due to droplets increases because the expansion goes deep into the wet steam region.

ORC overcomes these problems by using an organic fluid, e. g. Pentane, instead of water (therefore it's called **Organic** Rankine Cycle). Organic fluids have lower boiling temperatures than water which make them suitable to explore heat potential with temperatures below 350 °C. By adoption of the working fluid to an existing waste heat temperature higher efficiencies can be achieved than with a conventional steam cycle. Many organic working fluids have an "overhanging" saturated vapour curve with the advantage that die expansion always ends within the superheated and therefore dry region. This way the danger of blade erosion is excluded and a low maintenance operation is assured. In general, the ORC technique is characterized by its robustness, compact design, high ability for automation and the comparatively high efficiency.

The only applicable working fluids for temperature levels around 80°C, as in the case of Bogatic, are perfluoropentane and n-pentane, the first one has its boiling point at 30°C and the second one at 36°C. Perfluoropentane is used at the geothermal power plant in Neustadt-Glewe, Germany.

One problem of the working fluids is, that perfluoropentane is relevant to climate change and n-pentane can be explosive, if handled improperly. A further problem of the use of fluids with low temperature boiling points is, that during the cycle they need to be cooled down to this condensation temperature level in order to keep the process working. The cooling of the working fluid needs to be carried out in two steps. The first step is air cooling or evaporative cooling and the second step is cooling the fluid to condensation temperature by means of a cryocooler. The second step will be necessary in the warm season.

The cooling process can consume considerable amounts of the generated electricity and have a negative impact on the economic viability of the project. Therefore, for economic reasons, it is recommended, to feed the whole generated electricity into the grid and to buy the necessary auxiliary energy from the grid, because this is considerably cheaper than to use the own produced energy.

The electric efficiency of the ORC-process at the given temperature level is located at about 8-10% of the energy input.

The cost estimation for investments and annual costs is based on average prices and values in Austria. For the calculation of revenues the feed in tariffs for Serbia, as submitted by the project partner have been used.

Similarly to the considerations for a geothermal district heating system, two scenarios have been developed. One scenario is based on the consideration of 100% credit capital and one on 0% credit capital.

Table 5: Calculation of the power generation by geothermy with committed assessts (Source: EEE)

Geothermal power generation – Scenario 1: 100% credit capital		
Thermal input	5.100	kW
Electric power installed	500	kW
Electricity production	3.750.000	kWh
Internal consumption	1.500.000	kWh
Net production of electricity	2.250.000	kWh
Constructional investments	561.000	€
Investment ORC	950.000	€
Investment cooling system	765.000	€
Investment total	**2.276.000**	**€**
Feed- in tariff	0,097	€/kWh
Annual revenues	**363.750**	**€/a**
Capital costs	-260.000	€

Maintenance	-56.900	€
Personnel expenditures	-11.250	€
Other (Auxiliary energy, maintenance,	-56.380	€
Total annual expenditures	**-384.530**	**€**
Result	**-20.780**	**€**

Table 6: Calculation of power generation by geothermy without committted assessts (Source: EEE)

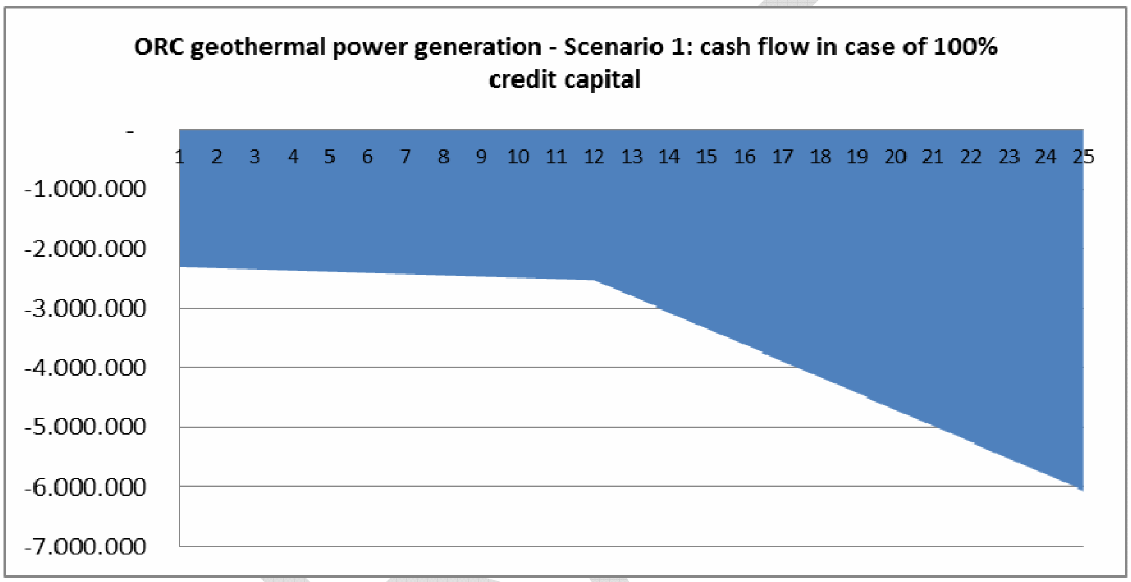
Geothermal power generation – Scenario 2: 0% credit capital		
Thermal input	5.100	kW
Electric power installed	500	kW
Electricity production	3.750.000	kWh
Internal consumption	1.500.000	kWh
Net production of electricity	2.250.000	kWh
Constructional investments	561.000	€
Investment ORC	950.000	€
Investment cooling system	765.000	€
Investment total	**2.276.000**	**€**
Feed- in tariff	0,097	€/kWh
Annual revenues	**363.750**	**€/a**
Capital costs	-2.000	€
Maintenance	-56.900	€
Personnel expenditures	-11.250	€
Other (Auxiliary energy, maintenance,	-56.380	€
Total annual expenditures	**-126.530**	**€**
Result	**237.220**	**€**

2.3.2 Comparison of scenarios

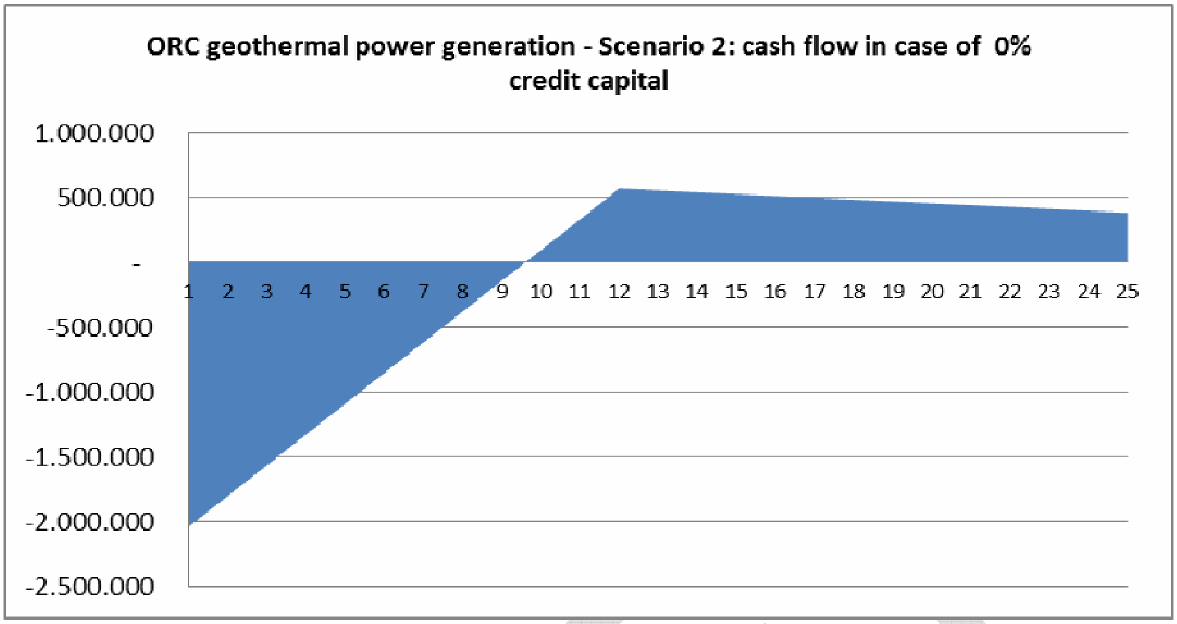
The following two images are giving an overview on the two scenarios in a more dynamic way, modelling the cash flow of both scenarios. This method allows to estimate, how long the facility will take to recoup investment costs and if the economic viability is given through the period of the guaranteed incentive purchase price, which is currently c€ 9,67/kWh for 12 years. In case of a combination of geothermal energy and biomass a mixed feed-in tariff of c€ 11,48 - was used. For the time after the funded period, a tariff of c€ 3,00 - was assumed.

As can be seen in the graphs, the development is depending mainly on the use of credit capital. Scenario 1 (100% credit capital) is taking a negative development and scenario 2 (0% credit capital) does pay back within 10 years.

The cashflow models are sketches which line out the economic development in a stable framework of conditions. One important aspect of the models is to show, if the payback period equals at least the period of funded feed-in-tariffs or the credit period.



Graphic 7: Illustration of cashflow by 100% committed assessts (Source: Calculation EEE)

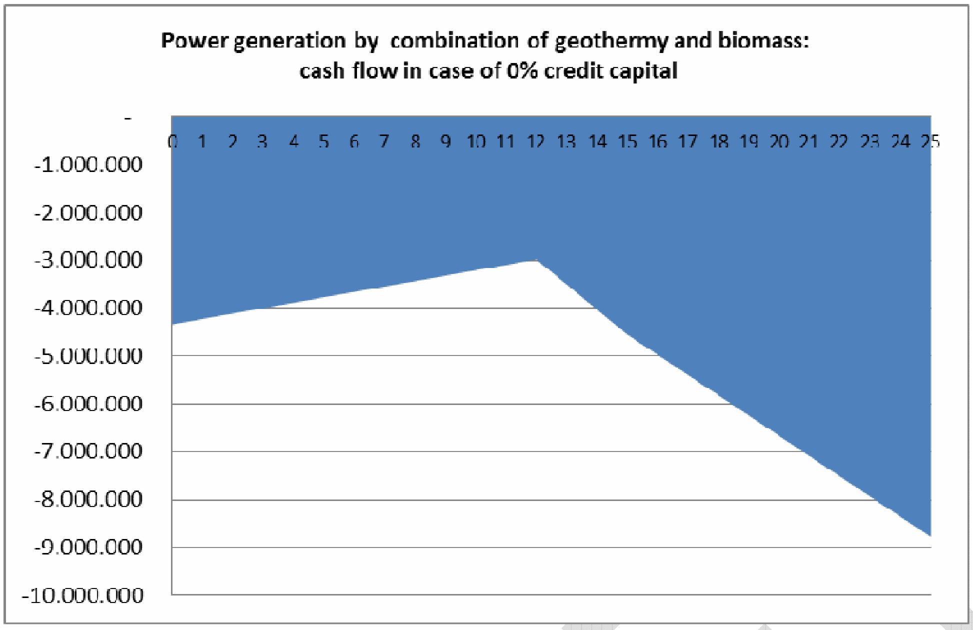


Graphic 8: Illustration of cashflow by no committed assessts (Source: Calculation EEE)

A probable power generation from geothermal water is only possible, because the well already exists. If drillings for water was necessary, the facility would not be economically viable.

During the working meeting in December 2013 also a combination of biomass and geothermy was discussed. This variant would have a higher output of electricity, but would require also higher investments for the biomass related components. Therefore, the investment would be including higher annual costs for fuel and maintenance.

In the case of the discussed combination, the annual payback would be reduced to about € 112.000,- and the facility would never pay back, as sketched out in the cash-flow modelling below.



Graphic 9: Illustration of power generation by comibination of geothermy and biomass by no committed assesstes (Source: Calculation EEE)

2.4 Evaluation of variants and scenarios regarding the use of geothermal energy in Bogatic

In Bogatic, developed geothermal wells already exist. Regarding the temperature level, the wells BB1 and BB2 are the most interesting ones. Regarding the delivery in litres per second, BB2 is the most abundant one. The delivery of BB1 has been decreasing in the course of the years.

The two possibilities of use, power production and district heat, have been examined with respect to their economic feasibility and viability.

The variant of geothermal power generation turned out to be not feasible if credit capital is used, because the investments will not pay back within the period of the incentive feed in tariff payment. A combination with biomass is only risen investments and annual costs and the payback is even reduced.

A possibility to generate geothermal electricity at a viable level would be to avoid credit capital (which is hardly possible) and additionally to sell the heat to a facility operating on low temperature levels. Since there is no such facility at the moment, this possibility could not be examined.

The variants of district heating by geothermal water turned out to be a possible and even economically viable solution, yet depending on the share of credit capital in the investments.

The hot water would be used only during the heating period and the well would be shut during the warm season. If a use for the heat could be found even beyond the heating period, such as drying crops, wood chips etc. the geothermal heat could even provide noticeable income for the running company (or the municipality).

Thus, the use of geothermal heat should preferably be carried out in the form of a district heating system, even if only the municipal and public buildings are supplied.

3. Bijeljina

Referring to the submitted documents, the pre-conditions for the use of geothermal energy in Bijeljina are very promising.

The common annotations concerning the use of heat and power generation have already been given in the chapters regarding geothermal energy for the municipality of Bogatic.

The situation in Bijeljina, however is different from the one in Bogatic, because only smaller wells are developed, which are not suitable for energy supply on a larger scale or for electricity production. Nevertheless, the conditions for such types of energy supply are very positive and the development of the potential is very promising.

3.1 Geothermal power generation

The following considerations are focussed on the generation of electricity from hydro-geothermal sources. The purpose of the investigations in the case of Bijeljina, is to find out the minimum needed frame conditions for an economical viable facility.

These minimum needed frame conditions are:

- Depth of the geothermal resource
- Water temperature
- Water delivery
- Investments
- Capital costs
- Operating costs
- Feed-in-tariffs
- Investment subsidies
- Possibilities and costs for heat sale

Water temperature and water delivery are defining the capacity of the power plant. The capacity then determines the necessary investments. Produced energy, capital costs, operating costs and feed-in tariffs finally are the parameters for the economic viability.

The first step is to determine the needed drilling depth in order to achieve reasonable water temperatures. According to the information submitted, 120 to 150 °C can be achieved at depths around 2.000 meters. For the calculation was used a temperature level of 130°C.

The drilling of the doublets for extraction and reinjection of the necessary amount of thermal water including the pipework is expected to create costs of € 5.000.000,-. In this case, the power plant needs to have a minimum power capacity in order to legitimate the investment and to deliver enough energy for an economical viable operation of the facility.

3.1.1 Modelling of variants

The modelling of different variants of a geothermal power plant has the purpose to determine the minimum determining factors required for economic viability.

The factors are:

Feed in tariff for electricity, sale price for district heat, share of credit capital, share of investment subsidies.

The feed in tariffs for electricity are taken into calculation according to the documents submitted, regarding governmental regulations.

It turned out, that geothermal electric power generation is not viable without selling also the excess heat, except. The current average heat price is € 15,8 /MWh and is based on the main heat energy carriers: ***biomass and lignite***. The sale price for district heat was estimated slightly higher than the average household price for lignite, which corresponds to about € 20.- / MWh

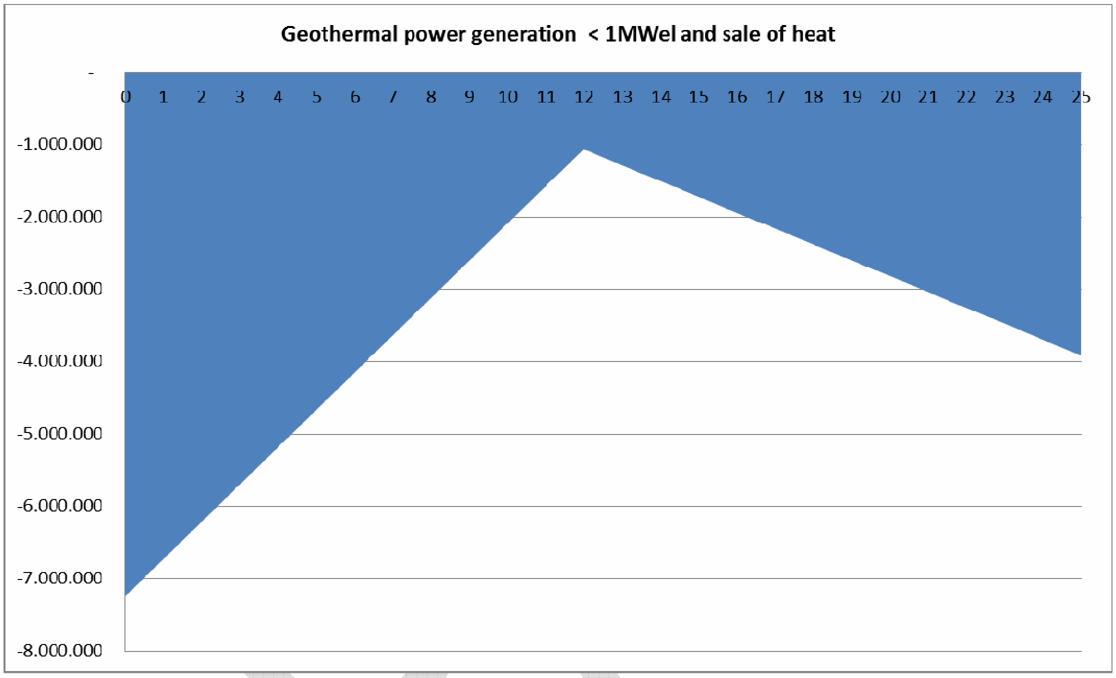
The shares of credit capital and possible investment subsidies can vary in a wide range. Almost all variants turn out to be viable, if no credit capital is used. If credit capital is used, the grant of investments subsidies from public funding is almost indispensable.

Credit capital is regarded with an interest rate of 5% and a credit period of 12 years.

3.1.2 Variant 1: power capacity 1 MW or below

A capacity of 1 MW or below is not viable, even when no credit capital is used and all the co-produced heat is sold as district heat. This situation is simulated in the cash flow model below.

The main influence factor for viability is the feed in tariff for electricity. The break-even point is not reached. As soon as the incentive tariff finishes after 12 years, the facility has to bear increasing losses.

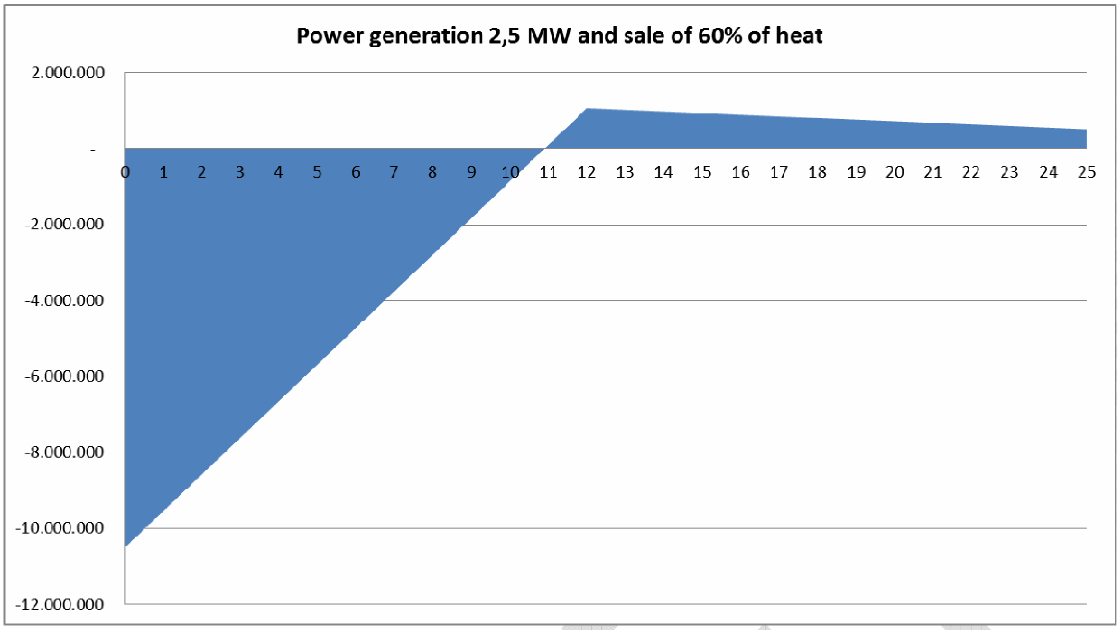


Graphic 10: Illustration of the break-even point by a power generation by an amount <1 Mwel. (Source: Calculation EEE)

3.1.3 Variant 2: power capacity 2,5 MW

In variant 2 an electric power capacity of 2,5 MW is analysed. The share of credit capital is 30%. In order to have a positive development, 60% of the produced heat has to be sold. In this case the facility has to operate 60 l/sec at a temperature level of 130 °C. The cooling circuit is assumed as a district heating system with the length of 8 km, operating a heat load of 5 MW. The costs of the heat grid are included in the model.

The break-even point is reached after 11 years, there is a stable outlook on viability and development.

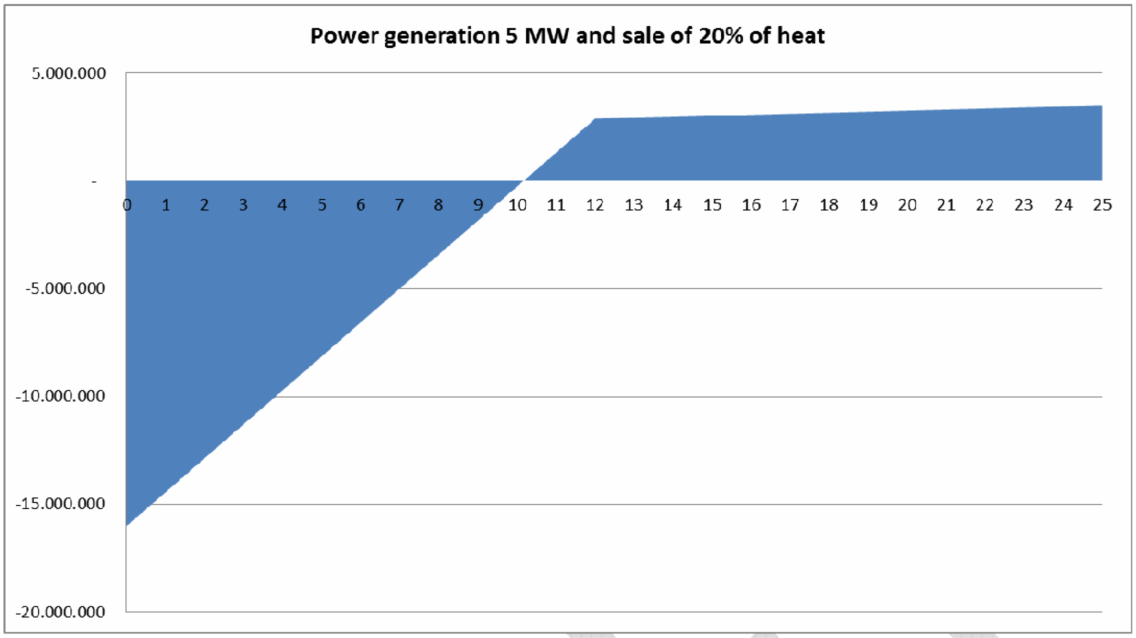


Graphic 11: Illustration of a break-even point by a power generation by an amount of 2,5 MW (Source: Calculation EEE)

3.1.4 Variant 3: power capacity 5 MW

In variant 3 an electric power capacity of 5 MW is analysed. The share of credit capital is 30%, as in the precedent variant. In order to have a positive development, only a share of 20% of the produced heat has to be sold. In this case the facility has to operate 120 l/sec at a temperature level of 130 °C. The cooling circuit is assumed as a district heating system with the length of 17 km, operating a heat load of 10 MW. The costs of the heat grid are included in the model. It has to be made sure, that the grid is operating all over the year

The break-even point is reached after 10 years, the outlook on viability and development is more stable than in variant 2.

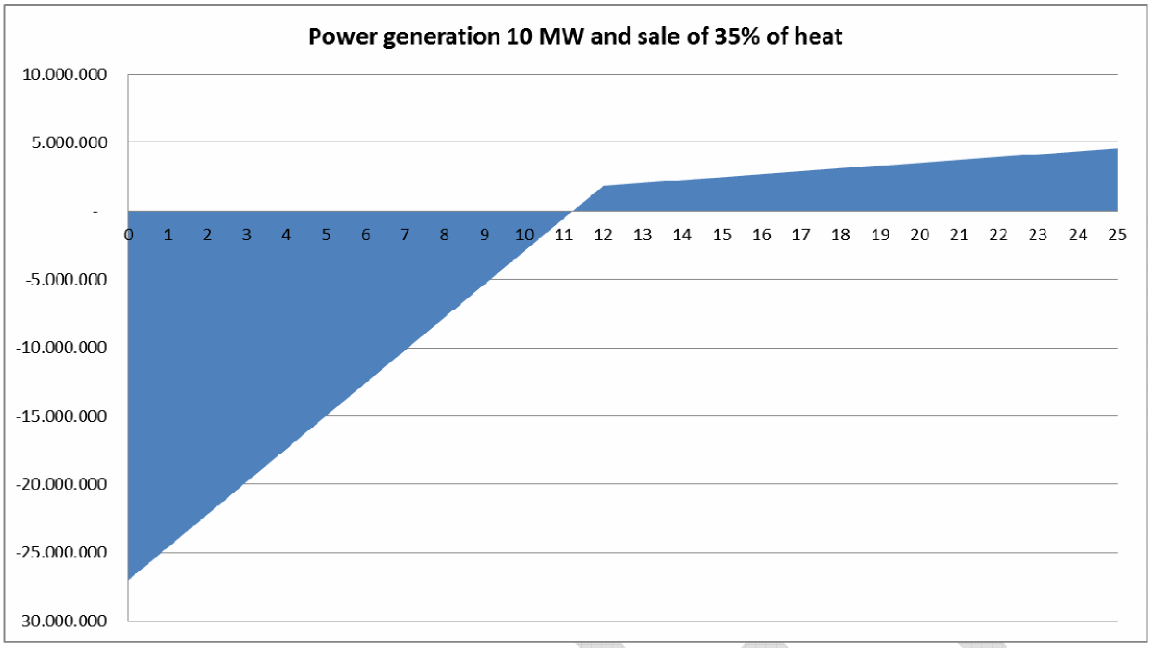


Graphic 12: Illustration of a break-even point by a power generation by an amount of 5 MW (Source: Calculation EEE)

3.1.5 Variant 4: power capacity 10 MW

In variant 3 an electric power capacity of 10 MW is analysed. The share of credit capital is, once more, 30%. In order to have a positive development, the share of the produced heat to be sold needs to be 35% since the feed-in tariff in this power range is considerably lower than for facilities up to 5 MW. In this case the facility has to operate 250 l/sec at a temperature level of 130 °C. The cooling circuit is assumed as a district heating system with the length of 17 km, operating a heat load of 20 MW. The costs of the heat grid are included in the model. It has to be made sure, that the grid is operating all over the year. If the grid is not operable all the time, because the heat load to dump is too high, additional cooling systems need to be installed, which would raise the investment costs considerably, and the facility is not viable anymore and does not break even.

The break-even point, in case of 35% heat sale, is reached after 11,5 years, the outlook on viability and development then is stable.



Graphic 13: Illustration of a break-even point by a power generation by an amount of 10 MW (Source: Calculation EEE)

3.2 Evaluation of variants regarding the use of geothermal energy in Bijeljina

The comparison of the considered variants for geothermal power generation is made in order to find out the most favourable variant of power plant.

The evaluation is done by some key-figures, by which the variants become comparable.

Table 7: The evaluation of efficiency of geothermal energy (Source: Calculation EEE)

	Variant			
	1 MW	**2,5MW**	**5 MW**	**10 MW**
Heat load to dump	*4,2*	*10*	*20*	*40*
Years to break even	*-*	*11*	*10*	*11*
Investment €/kW	*7.244*	*4.200*	*3.200*	*2.700*
Annual costs €/kW	*1.225*	*443*	*393*	*361*
Annual revenues €/kw	*960*	*828*	*708*	*602*
Revenues €/ cost	*0,78*	*1,87*	*1,80*	*1,67*
Electricity share in revenues	*68%*	*78%*	*92%*	*83%*

The variant regarding 1 MW or less has to drop because it does not pay back.

The variants regarding the range between 2,5 and 5 MW are the ones with the highest revenues. Also the dumping of the heat loads by a district heating system seems to be manageable, because the loads are not too high and the amount of heat which needs to be sold for economic viability can be managed easier.

The variant regarding 10 MW has lower revenues than the two precedent variants. It has also to be considered, that a heat load of 40 MW has constantly to be dumped all over the year.

The recommendation therefore is, to focus on a facility with a power capacity of 2,5 to 5 MW.

The following table is giving an overview of the basic data used for the rentability calculation in case of the 5 MW variant:

Table 8: Return on invest for a geothermal power plant of 5 Mwel (Source: Calculation EEE)

Geothermal power plant 5 MWel			
Specification			
Thermal Input		*25.000*	*kW*
Electric power installed		*5.000*	*kW*
Electricity production		*36.000.000*	*kWh*
Internal consumption		*9.000.000*	*kWh*
Net production of electricity		*27.000.000*	*kWh*
Minimum required heat sale		*15.000.000*	*kWh*
Investment			
Drilling		*5.000.000*	*€*
Constructional investments		*2.500.000*	*€*
Investment ORC		*5.500.000*	*€*
Investment cooling system		*3.000.000*	*€*
Investment total		*16.000.000*	
Revenues			
Feed in tariff		*0,090*	*€/kWh*
Heat price		*0,020*	
Annual revenues		*3.540.000*	*€/a*
Annual costs			
Capital costs	-	*541.562*	*€*
Maintenance	-	*400.000*	*€*
Personel expenditures	-	*108.000*	*€*

Reinvestment reserve	-	*566.667*	*€*
Other (Auxiliary energy, maintenace contract, insurance etc)	-	*350.000*	*€*
Total annual expenditures	-	*1.966.229*	*€*
***Annual result** (within the first twelve years)*		***1.573.771***	***€***

4. Biogas

4.1 Definition and overview

Biogas typically refers to a mixture of gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from regionally available raw materials. It is a renewable energy source and in many cases exerts a very small carbon footprint.

Biogas is produced by anaerobic digestion with anaerobic bacteria or fermentation of biodegradable materials. It is primarily methane (CH4) and carbon dioxide (CO2) and may have small amounts of hydrogen sulphide (H2S), moisture and siloxanes.

The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.

Biogas can be compressed in the same way as natural gas is compressed, and used to power motor vehicles.

4.2 Types of resources

The possible substrates for anaerobic digestion can roughly be categorized into:

- Agricultural residues
- Energy crops for biogas
- Animal manure
- Organic waste

The project regions are very rich in agricultural residues, which partly can be used for the production of biogas. Maize straw is the main agricultural residue in the project regions. If shredded thoroughly, it can be added up to a share of 20% in the digestion process and it is causing a very good biogas output.

Anaerobic digesters or biogas plants can be directly supplemented with energy crops once they have been ensiled into silage. The most common energy crop for biogas is maize silage, but also other crops, like sorghum silage, grass silage or silage of catch crops can be used. Since there is enough farmland in the regions to ensure the nutrition of the population from regional agriculture (which is an important criterion for sustainability), there is enough space for cultivating energy crops.

Manure produced on farm is generally used as a fertilizer on farm land. Most farmers value their manure and would not give it away. The exceptions are poultry farms and large hog operations that need to dispose their manure because they produce more manure nutrients than their landbase can handle sustainably. There are some potentials in the project regions, but the amount of manure is not sufficient to run a facility solely on this substrate. However, it can be used as co-substrate.

Organic waste is a broad claim term which includes all kinds of kitchen waste (private, restaurants, hospitals etc.), waste from food industry (grain, vegetable, meat and dairy processing industry, breweries etc.) but also waste from private and public areas (lawn mowing etc.). In some publications also sewage is considered as organic waste, whereas here, in the present study, it is regarded not as such.

In the project regions there is a potential for centralized biogas plants to be established in dense rural communities, especially in the cities of Bogatic and Bijeljina. However, trucking of manure and other substrates to and from centralized biogas plants may increase cost, social and environmental issues that would outweigh any economy of scale benefits. Manure pipelines are technical alternatives but may not be economically feasible for the distances involved.

4.3 Biogas systems

Biogas systems are composed of anaerobic digesters which convert organic materials into biogas and biogas conversion systems which convert biogas into useful energy forms.

4.3.1 The digester

An anaerobic digester is a sealed vessel in which waste is fed, heated and mixed. In the absence of oxygen, anaerobic bacteria thrive by consuming the solid fraction of the waste and releasing methane and carbon dioxide (biogas). Anaerobic digester efficiency is maintained by providing the right environment and right nutrients for bacterial population growth. Since bacteria cannot readily move, mixing is a very important component of digester design to ensure that bacteria get to the organic materials (feedstock). The quality and application rate of the feedstock are also very important.

The main types of digesters are the liquid substrate digester and the solid substrate digester.

Liquid systems are digesters in which the substrate inside the digester is adequately fluid to be pumped (less than 15% dry matter). These digesters can accept solid input, via a solid materials feeding device; bacterial breakdown of these solids ensures that the substrate inside the digester remains liquid

Solid digesters are systems where the material inside the digester remains solid and is expelled in a solid form. Solid digesters may run in batches or continuously.

The most common form is the liquid digester.

4.3.2 The conversion technologies

- *Direct combustion*

Biogas can be burned using a modified natural gas burner to generate hot air for heating and drying applications. Boilers are used to generate hot water or steam for industrial applications. Any natural gas boiler or burner may be modified to burn biogas; however, the equipment must be made resistant to the sulphuric acid released by the combustion of biogas containing H_2S.

- *Electricity generation*

Internal combustion engines can be used to burn biogas and power an electrical alternator to generate electricity that can be sold on the power grid. Two types of biogas engines are available: diesel and gas. Gas engines are designed to burn a gaseous fuel instead of liquid. In a diesel biogas engine 5% of the produced energy will come from diesel oil which will be used as a pilot fuel to ignite biogas during combustion.

The turbine is a robust technology used for the conversion of natural gas into electricity; however, biogas, which has a lower BTU value than natural gas, is wet and corrosive and thus not an ideal fuel for the turbine. To ensure reliable operation of biogas turbines, the gas requires considerable conditioning which is often not economically viable.

Biogas generators are relatively simple systems; however, efficiency of conversion from biogas energy to electrical energy is only 40% at best. The rest of the biogas energy is converted to heat and noise. Heat from the exhaust and jacket can be recovered but needs to be used immediately or else it is lost to the atmosphere.

This is the most common and mature technology for the conversion of biogas. Equipment robustness and efficiency are constantly being improved.

- *Biogas upgrading*

Biogas is typically composed of 60% methane and 40% CO_2. Natural gas as we know it is composed of 97% methane. Technologies such as pressure swing absorption and water-scrubbing are used to remove CO_2 from the biogas stream, converting it to renewable natural gas (RNG). This gas can be injected into a natural gas pipeline for resale to residential and industrial consumers.

Biogas upgrading technology is becoming increasingly attractive as it does not have the heat lost and emission issues related to the internal combustion engine and electrical energy generation. Moreover, the final product is identical to natural gas and can be transported efficiently using the existing natural gas grid. Unlike natural gas, which contributes greenhouse gas emissions to the atmosphere, the combustion of upgraded biogas actually reduces greenhouse gas emissions to the atmosphere by displacing natural gas.

4.3.3 Biogas production and utilization in the project regions

The technology for biogas production, considered in the following variants is fermentation in the liquid substrate digester.

Regarding the usable feedstock for the anaerobic digestion process, the following annotations need to be made:

- *Animal manure*
  Due to the (currently) dispersed livestock in the regions, animal manure cannot contribute much to the production and utilization of biogas from it and its potential, at the moment, is rather theoretical. Therefore, preferably silages in combination with agricultural residues should be used. In any case, if available in a simple way at the facility´s location, it should be added to the process

- *Silage*
  Silage from maize, sorghum, green grains or grass can be used for co-fermentation with animal manure or as single and mix substrates for biogas production. They are commonly used in many biogas plants and their use is state of the art.

- *Agricultural residues*

Straw has a high biogas output but is not easy to handle in the anaerobic fermentation process. In order to work properly, it needs to be shredded to small particles before being added to the fermentation process. In the biogas plant in Strem, Austria, the use of maize straw has been tested. Maize straw is a low-cost substrate and can be added to the maximum of 20% to the fermentation process, thus, reducing the costs of feedstock.

4.4 Variants of biogas use

To examine the viability of the different variants for biogas, the model of a facility with an output of 500 m³/h was used.

The basic technical data are:

Table 9: The basic technical data of biogas utilisation (Source: EEE)

Gas output:	**500**	***m³/h***
Primary energy content	2.720	*kWh*
Electric power	1.034	*kW*
Thermal power	1.224	*kW*
Operation hours fermenter	8.000	*h/a*
Operation hours CHP	8.000	*h/a*
Net gas production	18.496	*MWh net*
Gross gas production	21.760	*MWh*
Electricity production	8.269	*MWh*
Heat production	9.792	*MWh*
Annual demand silage	15.059	*t/a*
Annual demand maize straw	3.765	*t/a*
Total demand substrate mix	18.824	*t/a*
Daily substrate demand	56,1	*t/d*

The main elements of the calculation are listed below:

- *Substrate: Scenario with 100% of maize (or similar) silage, scenario with 80% maize silage and 20% of maize straw. The 80/20 scenario is used for the further calculations.*
- *Electricity feed-in tariff for the first 12 years: 157 €/MWh*
- *Electricity feed-in tariff for the following years: 30 €/MWh*
- *Sales price of co-generated heat: 20 €/MWh (equalling heat costs of lignite)*
- *Sales price of desulfurized crude biogas: 25 €/MWh (equivalent to current natural gas wholesale price)*
- *Sales price of up-graded biogas: 25 €/MWh (equivalent to current natural gas wholesale price)*
- *Investments and annual costs: as common in Austria*
- *Labor costs: 3 €/h*
- *Credit capital share: 30%*
- *Credit interest rate: 5%*
- *Credit period: 12 years*

4.4.1 Pre- examination: maximum limit for substrate purchase

Biogas substrate is the most important cost factor for running the facility. If the substrate is too expensive, the facility will not be viable. As a criterion for the maximum limit of substrate purchase costs was assumed, that the cumulated cash-flow of the facility enters into the positive sector after 6 years (half of the subsidized feed-in tariff period) and thus also investment reserves for the period after the subsidized 12 years can be accumulated.

For avoiding any substrate costs, a livestock unit 10.500 is needed. This equals the same number of cattle or 86.000 pigs, concentrated in one production unit.

Most biogas facilities using manure are processing a substrate mix of 20% animal manure and 80% (maize-) silage. In this case, the maximum purchase price of green maize for silage is € 33.-/t

If 100% silage is used, the price limit is located at € 26.-/t.

An alternative for manure is, as stated before, maize straw, as a by-product of corn production. Also the provision and pre-processing of the straw are creating costs, but at the end it is a cheaper substrate component than maize silage. The costs have been calculated and are almost equal to grass silage, which is located around € 15.- / t. The biogas output of maize straw is about 350 m³/t and thus, roughly the double of maize silage. In this case, the price limit for green maize purchase is around € 30.-/t.

The further calculations are based on costs of € 30.-/t for maize silage and € 15.-/t for maize straw. These are the upper cost limits for substrate. Higher costs are causing a shift of the point in time, when the facility is breaking even, towards the end of the 12 year period of subsidized feed-in tariff. This shift is raising the risk of not being able to continue in an economic viable way after the 12 year period.

If the costs are referred to the primary energy content of the substrate, the limiting costs of the input energy must not exceed € 23,30/MWh.

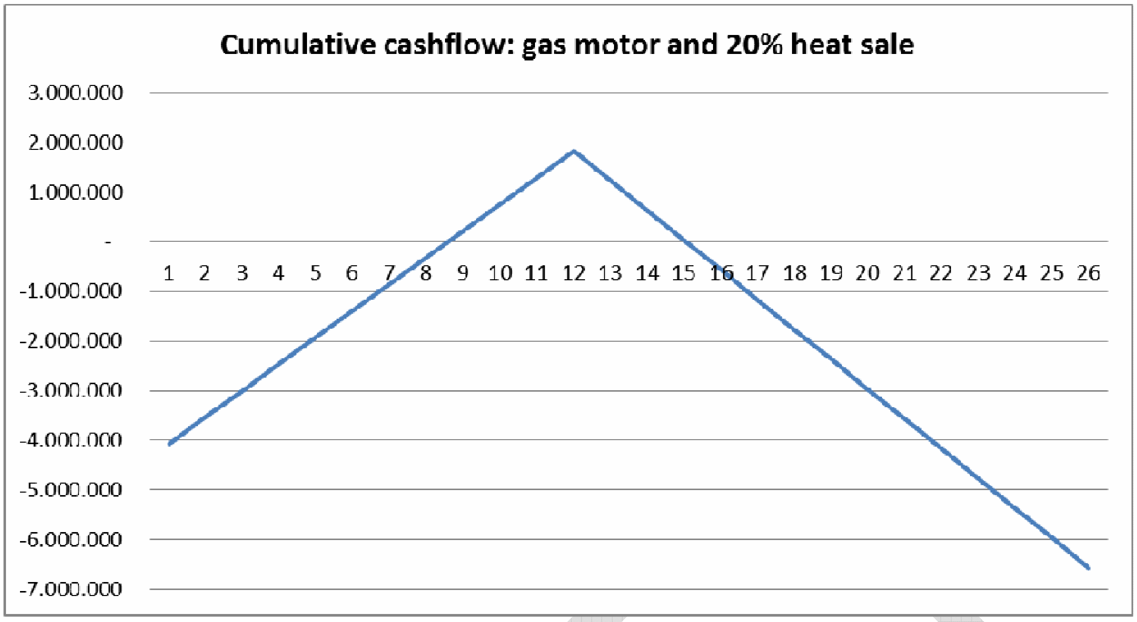
4.4.2 Variants of combined heat and power generation (CHP) from biogas

Regarding the generation of energy by combustion in a gas motor, two variants have been examined. The first variant is electricity generation and sale of the co-generated heat, the second one is electricity generation by a gas motor and feeding the excess heat into a downstream ORC generator, leaving low level heat which might be used or not.

4.4.3 CHP generation with gas motor

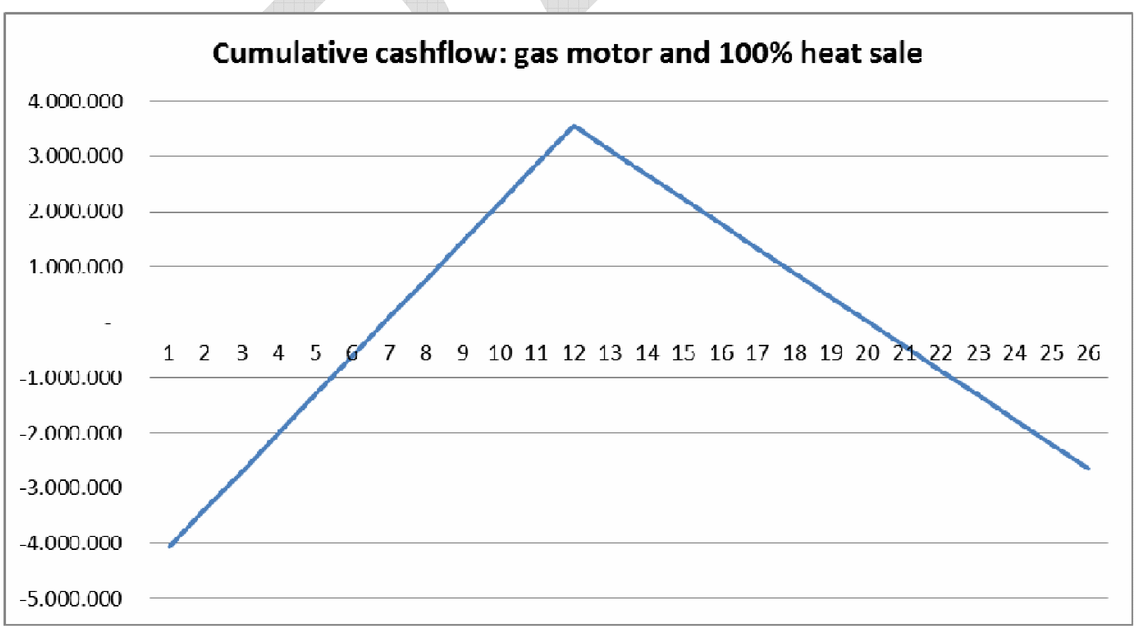
In the first scenario, the biogas from the digester is combusted in a gas motor. The produced electricity is fed into the grid, the produced heat is sold. In this case, also an investment into a heat grid is necessary, if such does not exist. For the calculation a heat grid with the length of 5.000 m was assumed.

The cumulative cashflow of this variant is sketched out in the following image, which refers to a scenario of selling 20% of the generated heat, an approximate amount which can be sold during an average heating period. It can clearly be seen, that the main factor for the viability of the power-plant is the sale of electricity.



Graphic 14: Illustration of cumulative cashflow by 20% of heat sale (Source: Calculation EEE)

The main characteristic of the performance does not change, even if 100 % of the excess heat can be sold, as shown in the next image:



Graphic 15: Illustration of cumulative cashflow by 100% of heat sale (Source: Calculation EEE)

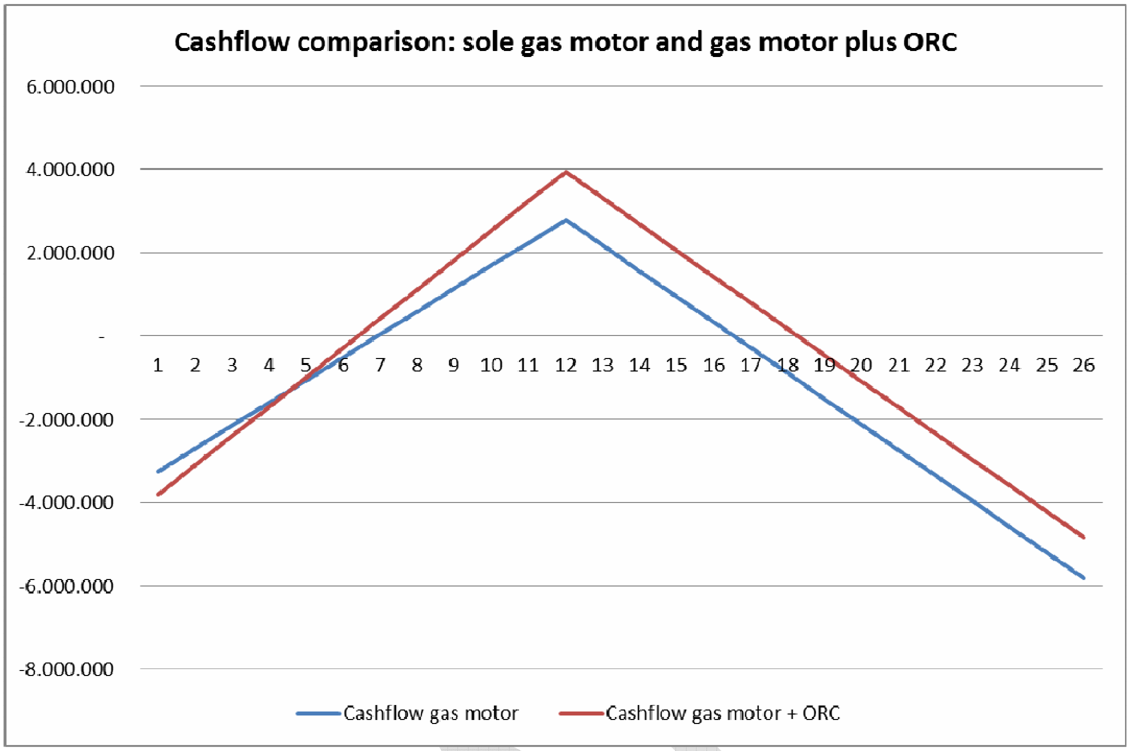
Both scenarios of the variant are not leading to a sustainable viability. The level of viability would be reached at a heat sale price level of € 68.-/ MWh and a sales rate of 100% of heat. Since the average price for heat in the regions is between € 16-18.-/MWh, the needed minimum heat price is not competitive.

After the 12 year period the facility is no more viable.

4.4.4 CHP generation with gas motor and downstream electricity generation from excess heat with ORC process

Power generation with a gas motor is a very efficient way to generate electricity from biogas. Nevertheless, slightly more than the amount of electricity, also heat is generated. If this heat cannot be sold, it can be fed into a downstream ORC process, to generate electricity from the motor´s excess heat. About 60% of this excess heat is going through the exhaust and 40% are from motor´s water cooling system. The heat from the exhaust is at a level of approximately 500 °C and can be used for the ORC process. The heat from the water cooling system is at about 80-90 °C and can be used for heating the fermenters. Thus, additional electricity can be generated and the efficiency can be raised, leading to approximately 15% higher efficiency. This process is making sense in biogas power-plants equal or greater 1 MW electric power.

The sketch of the cumulative cashflow is showing the performance of such a power-plant. This variant does not consider the sale of heat, for the same reason as stated in the precedent variant.



Graphic 16: Illustration of cashflow by comparison of sole gas motor and gas motor plus ORC (Source: Calculation EEE)

The downstream ORC generator is increasing the efficiency of the electricity generation by 15% and the economic performance by 28% compared to the sole conversion in a gas motor (without heat sale) and a 6% better performance compared to the precedent variant of electricity generation and heat sale.

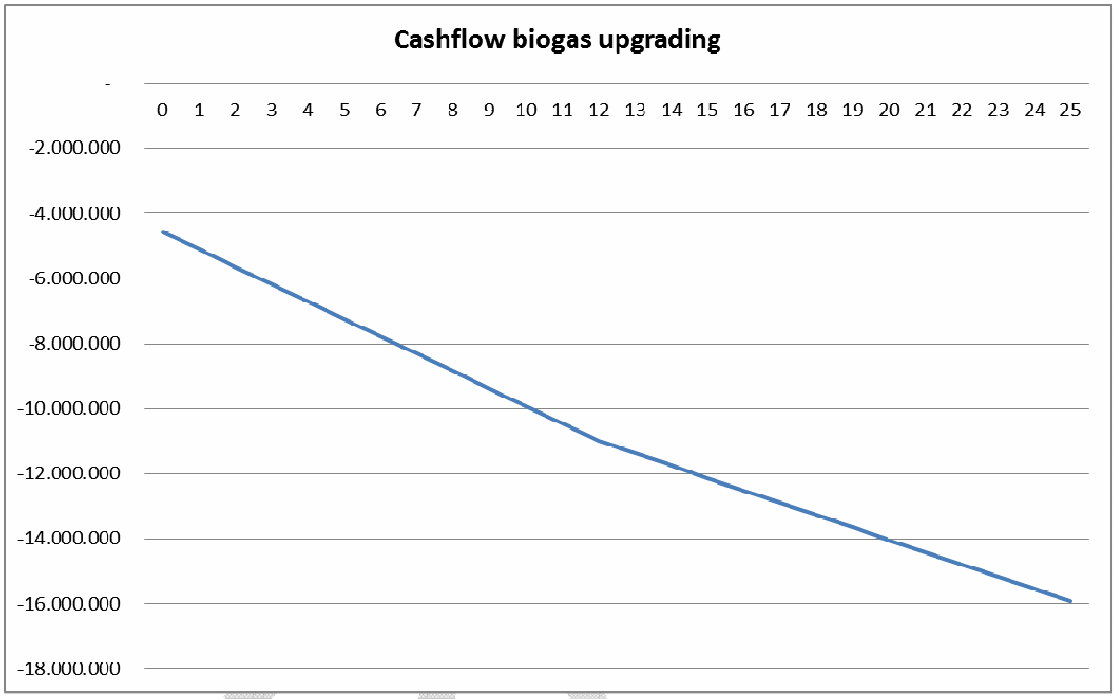
Nevertheless, also this variant of power plant ceases to be viable after the 12 year period of the subsidized feed-in-tariff.

4.4.5 Variant of biogas upgrading

The most prevalent method for biogas upgrading is water washing where high pressure gas flows into a column where the carbon dioxide and other trace elements are scrubbed by cascading water running counter-flow to the gas. This arrangement could deliver 98% methane with manufacturers guaranteeing maximum 2% methane loss in the system.

Another, very efficient, method commonly used for upgrading is the pressure swing adsorption (PSA). A PSA system for biogas will have four stages, one each for water vapor, carbon dioxide, nitrogen and oxygen. Gas to be upgraded enters each vessel, is compressed to a high pressure whereby the gas to be removed is adsorbed on to the surface of the adsorbent, and is then decompressed allowing the methane to leave. The adsorbent is then regenerated. For oxygen, molecular sieve is used, for nitrogen a zeolite, for carbon dioxide and water a zeolite or activated carbon.

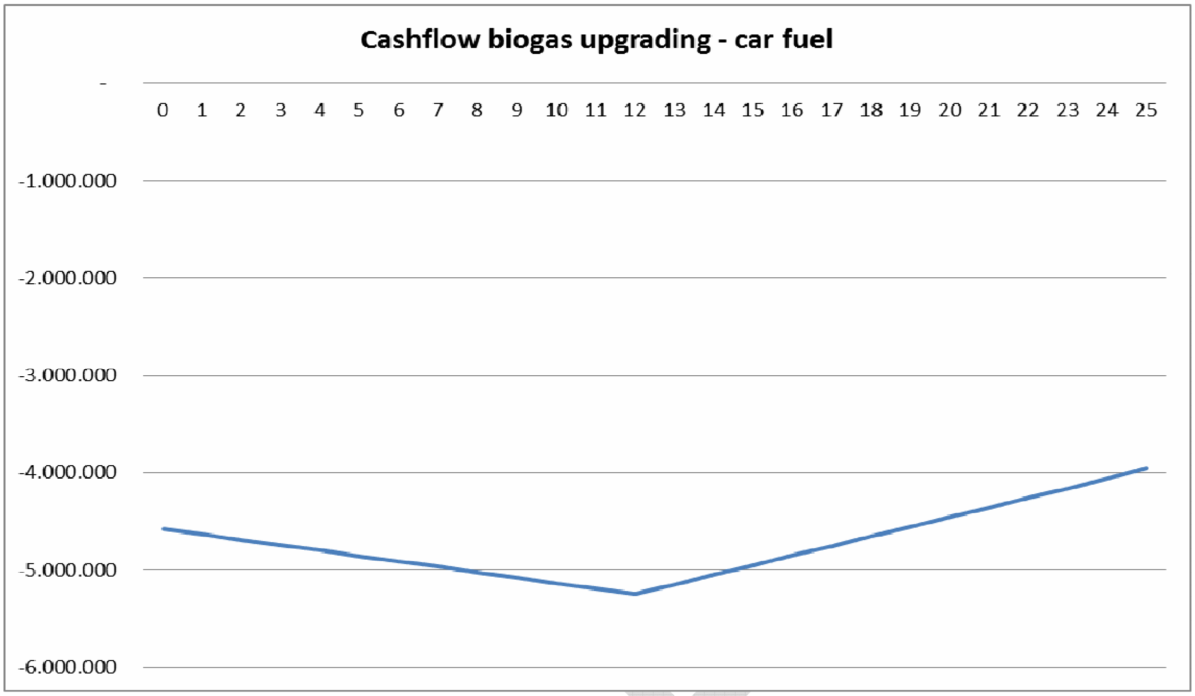
The method used for the calculation is water washing of the biogas. The cumulated cashflow of the facility is sketched out on the following chart.



Graphic 17: Illustration of cashflow by biogas upgrading (Source: Calculation of EEE)

The performance of the facility is negative, because the production costs for the upgraded biogas are € 65,6 / MWh. These costs are not competitive with the current trade price for natural gas, which is around € 25.-/MWh.

Upgraded biogas can also be used in gas cars as traffic fuel. Since fuel costs have increased constantly within the last decade, also the demand for gas cars is increasing, because gas cars are currently causing only about half of the fuel costs of a comparable, gasoline or diesel based car. Particularly in Italy, the share of gas based cars is already at 3,6% with the same increasing trend as in other European countries (which have, currently, lower shares of gas cares in comparison with Italy). This can lead to a possible variant of use of the facility after the 12 year electricity generation. The following chart is sketching out the cashflow if the upgraded biogas can be sold as fuel at a price of € 65.-/MWh.



Graphic 18: Illustration of cashflow by biogas upgrading for car fuel (Source: Calculation EEE)

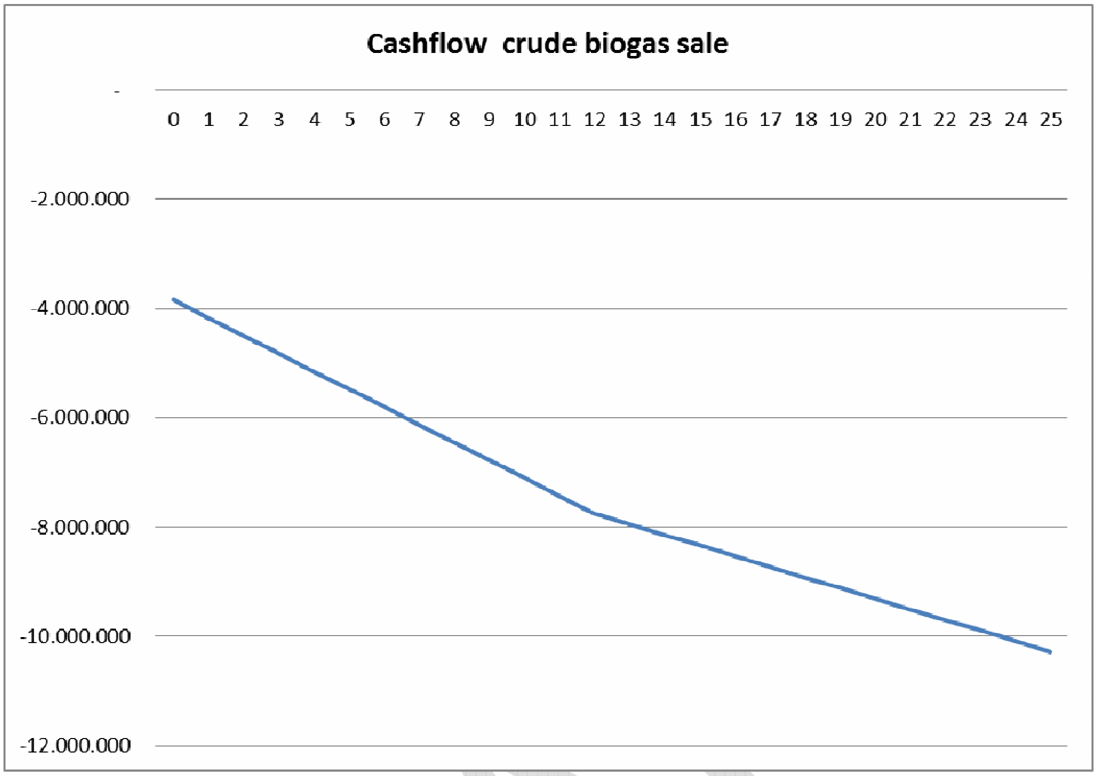
Also this variant is not performing very well, but is showing a different tendency of viability trend and gives an outlook on a later use.

4.4.6 Variant of direct sale of Biogas

Biogas for direct combustion, distributed via a biogas grid needs some processing before use. The two main steps of processing are the removal of the corrosive hydrogen sulphide (H2S) and the removal of water vapour. Furthermore a constant concentration of methane is desirable.

The investment for processing and conditioning is lower than the investment for upgrading to natural gas quality.

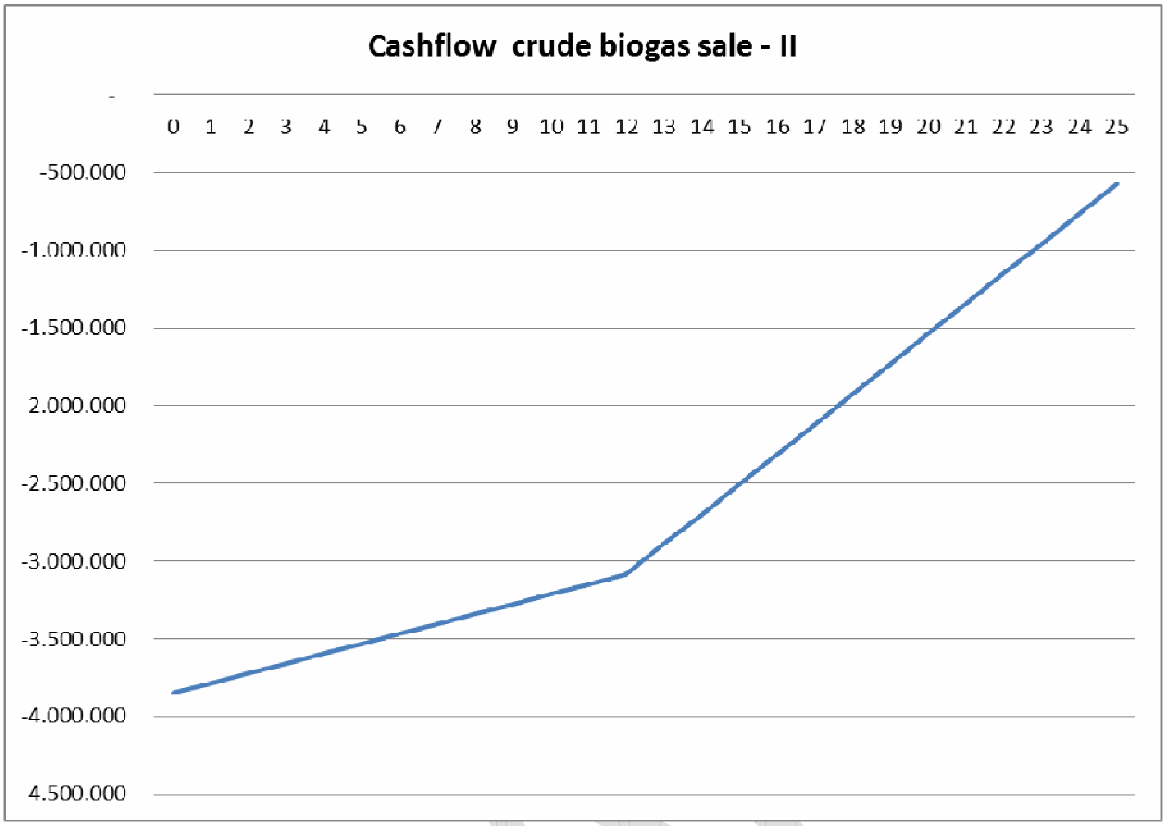
The cashflow for this kind of facility, including 10.000 m of a low pressure biogas grid is sketched out in the chart below.



Graphic 19: Illustration of cashflow by crude biogas sale (Source: Calculation EEE)

Also the performance of this variant is negative, if compared with the current wholesale price for natural gas.

A different scenario is the sale of the biogas in an own operated biogas grid. The current price in the region for natural gas for households and small industry is about € 58.-/MWh. If the whole amount of gas could be sold at a level of 20% below this price, the performance of the facility would turn into positive, but only in long term dimensions, as sketched out in the next chart.



Graphic 20: Illustration of crude biogas sale variant 2 (Source: Calculation EEE)

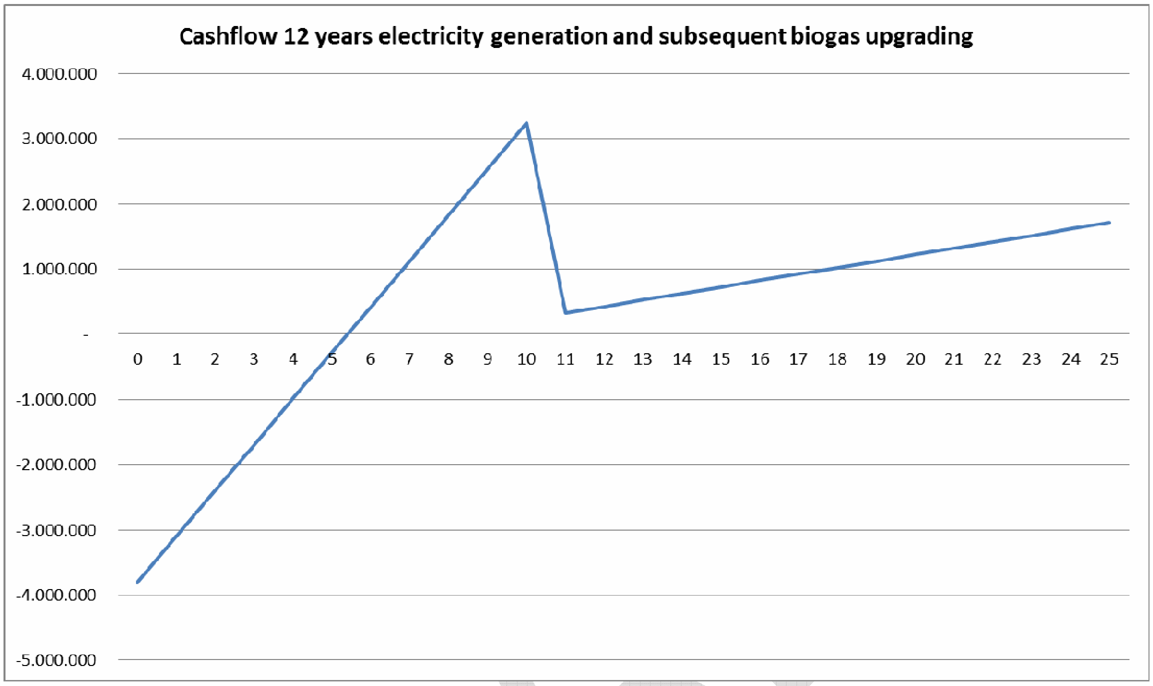
This also leads to another variant, which is discussed in the following paragraph.

4.4.7 Combined variant of power generation for 12 years and subsequent biogas sale or upgrading

The average life-span of the fermenters is about 25-30 years, but, as shown in the variants above, only electricity generation has a positive performance in the first 12 years. After that period, the facility will perform in a negative way, if no other use for the still existing gas production capacity can be found. The main condition in this case is that the substrate costs do not rise dramatically and if they do so, alternatives to the used substrate mix can be found to reduce the costs.

The variant, at the moment is surely rather speculative, but if the current development trends for electricity, natural gas and traffic fuels are prolonged, the price for electricity should decrease, whereas the price for natural gas and traffic fuel should rise. If this trend is continuing in the next decade, the variant can still be considered as a valuable option.

The following chart is showing the cashflow of the variant with 12 years of electricity generation and subsequent change in production to biogas upgrading for traffic use, selling the upgraded biogas for € 65.-/MWh.

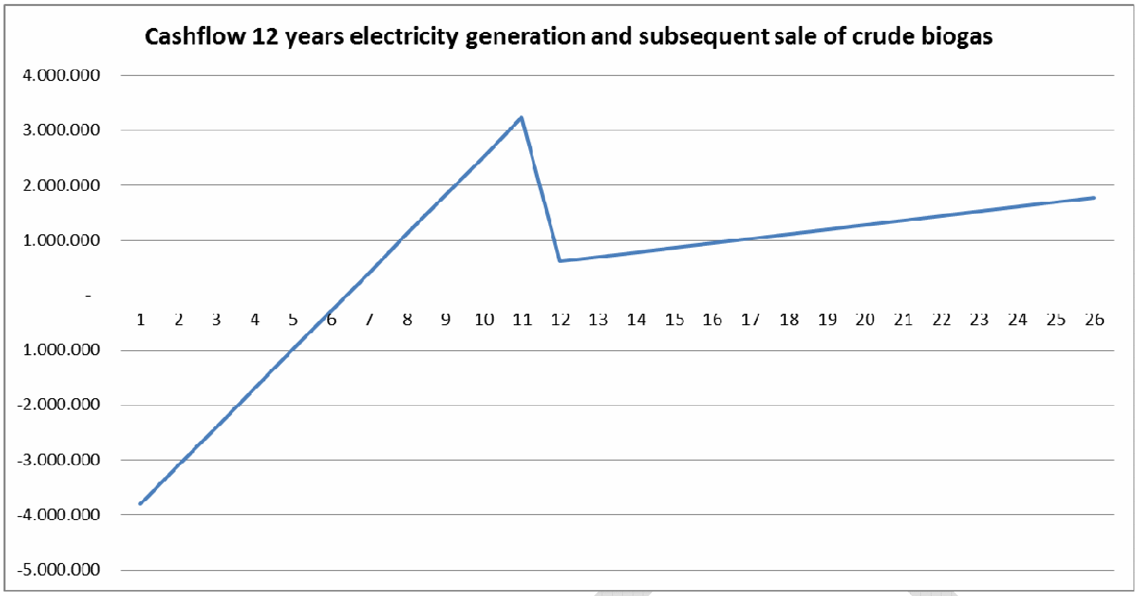


Graphic 21: Illustration of cashflow by a period of 12 years for electricity production and biogas upgrading (Source: Calculation EEE)

Under the given circumstances, this variant is performing positively.

Another version of the variant with firstly generating electricity for 12 years is the subsequent construction of a biogas grid and the sale of roughly purified crude biogas for heat applications. This version includes the assumption, that all produced gas can be sold over the year and therefore this would be requesting customers from heat consuming industry rather than private households.

The cashflow of this version of variant is shown in the following chart. It is very similar to the variant of upgrading, despite the necessary investment between the years 10 – 12, which is not as big as for the upgrading unit.



Graphic 22: Illustration of cashflow by a period of 12 years for electricity production by subsequent sale of crude biogas (Source: Calculation EEE)

4.5 Evaluation of variants regarding the use of biogas in the project regions

Among the examined variants only the ones including electricity production are performing in a positive way – at least in the first 12 years of the facility´s life span (which is commonly between 25-30 years). After these 12 years the performance turns into negative, if no subsequent use for the biogas produced in the facility can be found. This is requiring investments in the years 10-12, not for the silos and fermenters, but for the energy supply technology. From the present point of view the switch from electricity generation to direct gas applications seems to be a viable alternative.

The following tables are giving an overview on the needed investments, annual costs and revenues of biogas use.

The time span from year 1 to year12 is defined as "first period", the time span from year 13 and beyond is defined as "second period".

4.5.1 First period: Electricity generation from gas motor and downstream ORC unit

The following table is giving an overview on the basic data for the economic performance of the variant of maximum electricity production:

Investment	***€***
Constructional investments	***2.621.723***

Power generation units	*1.050.411*
Development	*127.374*
Total investment	***3.799.509***
Annual costs	
Capital bound costs	*128.604*
Depriciation and impairments	*316.626*
Maintenance	*113.985*
Personel expenditures	*27.659*
Insurance etc.	*6.369*
Biogas substrate	*508.235*
Total annual costs	***1.101.478***
Annual revenues	***1.488.832***
Result from year 1 to 12	***387.354***
Result from year 13 on	***- 944.425***

4.5.2 Second period: Variant of biogas upgrading

The following table is giving an overview on additional investments for biogas upgrading and the basic data for the economic performance:

Investment	***€***
Constructional investments	*900.000*
Upgrading unit	*937.344*
Development	*115.795*
Total investment	***3.799.509***
Annual costs	
Capital bound costs	*66.109*
Maintenance	*58.594*
Personel expenditures	*27.659*
Insurance etc.	*5.790*
Biogas substrate	*508.235*
Total annual costs	***666.387***
Annual revenues	***777.920***
Result from year 13 on	***111.533***

4.5.3 Second period: Variant of crude biogas sale

The following table is giving an overview on additional investments for crude biogas minimum processing, 10.000 m of low pressure gas grid and the basic data for the economic performance

Investment	***€***
Constructional investments	*1.100.000*
Desulfurization unit	*211.163*
Development	*115.795*
Total investment	***1.426.957***
Annual costs	
Capital bound costs	*48.299*
Maintenance	*42.809*
Personel expenditures	*27.659*
Insurance etc.	*14.270*
Biogas substrate	*508.235*
Total annual costs	***641.272***
Annual revenues	***850.816***
Result from year 13 on	***209.544***

4.6 Annex: Use of digestate

The annual amount of incidental digestate is 15.600 tons, of which 3.200 tons are solid and 12.400 tons liquid. After the optional separation of excess water in total about 7.900 tons of solid material are remaining.s

Using the digestate as a fertilizer about 50% of nitrogen, 65% of phosphor and 150% of kalium can be brought back to the arable land. These amounts can reduce the costs for mineral fertilizers by about 60%. Since fertilizers have a share of around 40% of the variable costs in agricultural production, the effect of the use of biogas digestate is a reduction of variable costs by approximately 25%.

If the fields for substrate cultivation are not in the surrounding of the facility, the expenditure for digestate logistics can become rather high, because of the low nutritient density in the liquid part of it. Therefore, it seems to be reasonable to bring down the water content of the liquid until the digestate is in a dense and solid form.

Bringing down the water content of the whole digestate of a biogas plant of this size down to a rate of 50%, in order to have it all in a solid form would create additional costs of € 23,7 / t and, in case, drying and pelletizing another € 54,0 / t, which is in total an amount of production costs of € 77,70 .
These are rather high costs for agricultural use, but there is a demand for high quality organic fertilizers for small scale private gardening in the EU, which probably could be interesting, if additional, similar material could be found, or if the facility is realized on a bigger scale, such as 2,5 – 3 MW electric. In this case, the specific costs for digestate processing are much lower.

4.7 ENVIRONMENTAL PROTECTION

One of the best solutions for the utilization of the damaging waste products being generated during livestock breeding and protects environment, which is setting up of the biogas plant. Biogas plants are important because they reduce emissions of CO_2 into the air, of which cattle husbandry is the main producer in the world. Fresh animal manure is immediately sent to biogas to be fermented and thus CO_2 is not released into the air and into subsoil water.

All the construction units are made in waterproof version. The pool and collection channels have the appropriate volume and can take reserve slurry in advance. The consumption of fermented slurry on agricultural land is in consistence with regulations and does not pollute the groundwater and the nitrogen content is below three percent, which is not considered as a disturbance to the environment.

The plant's residues have high-quality and low-nitrogen liquid and solid fertilizers as well as optional heating pellets, which can be utilized in all conventional pellet heating systems.

5. Solid biomass

Solid fuels have a share of 83% in the heat supply within the project regions. Two thirds of the demand for solid fuels is covered by biomass and one third by lignite.
The current annual demand for solid biomass in the project regions is 757.000 MWh (76.000 in Bogatic and 681.000 in Bijeljina). Only roughly 20% of this demand can be covered from the regional forests.
The current demand for lignite in the project regions is about 390.000 MWh/a (340.000 in Bijeljina and 50.000 in Bogatic).
The energy development plan for the project region has carried out a massive potential of biomass, mainly from agricultural residues, which could be used.

5.1 Substitution of lignite by local biomass

The combustion of lignite, mainly in single stoves with low efficiency, is a source for SO_2 in the atmosphere, reacting with H_2O to sulphuric acid. Sulfuric acid is a highly corrosive strong mineral acid with the molecular formula H_2SO_4. Sulfuric acid is having negative impacts on health, soils and water. Furthermore lignite, due to the low efficiency of the stoves, is a source for carbon monoxide (CO), which is a very toxic substance.

Replacing lignite by biomass could contribute to avoiding negative environmental impacts and contribute to secure income for farmers and thus raising regional added value.

As a main criterion for substituting lignite, the costs for 1 MWh of the substitute must not exceed the current price level for lignite.

For lignite substitution the following variants shall be examined:

- Agricultural residues
- Wood from short rotation coppices (SRC)
- A compound of residues and SRC-wood

5.2 Agricultural residues

Agricultural residues carry a high potential for energy use, but are tricky to handle because of some important properties regarding combustion. These are higher emissions of nitrogen oxides and chlorine compared to firewood and a low melting point of the ashes around 900 °C (wood: 1.300 °C). A low melting point of ash carries high risks of damaging the combustive unit by causing adhesive layers.

The straw of rapeseed, soybean and maize has higher melting points, which are around 1.100 °C.

In any case, the straw, if not combusted in a facility greater than 1 MW, needs to be processed before use because of the low storage density. This problem can be solved by briquetting or pelletizing, raising the storage density (kg/m³) by the factor 2 – 3.
The preparation of the straw based fuel is characterized by 4 main steps:

- Gathering / purchase
- Grinding
- Compaction

- Storage

In order to substitute lignite by agricultural residues in both regions, a facility with an annual output of approximately 100.000 t in the form of briquettes is needed. As a feedstock for it, the straw (as a co-product of existing corn-maize production) of 12.500 ha is required, which is roughly 1/3 of the current maize production area in both regions.

The most suitable resource in this case is maize straw, because it has acceptable combustion properties and can be found in abundant amounts. In contrary to grain straw it has almost no potential for sale or export, because there is no market for maize straw, which could push the prices to high level.

If the straw is retrieved from cultures grown with high amounts of mineral fertilizers, its content of chlorine, sulphur and nitrogen needs to be checked. Adding 2% of fine limestone is equilibrating the disadvantages of these substances contained.
Furthermore it has to be regarded, that the compacted straw expands during combustion, as also wood pellets and wood briquettes do and that about 5,5% of the pellet/briquette remains as ashes. Firewood leaves about 1% of ashes and lignite around 6%. Contrarily to lignite, the ashes are not sour and can be used similar to wood ashes.

Investments and costs for a straw briquetting facility with a capacity of 100.000 t/a are listed in the table below. The frame conditions for the calculation table are:

- Straw purchase price: € 15.-/t (dry matter)
- Heat purchase price: € 20.-/MWh
- Electricity purchase price: € 30.-/MWh
- Number of employees: 30
- Labour costs: € 4,5.-/hour
- Credit interest rate: 5%
- Credit period: 10 years
- Share of credit capital: 30%

Table 10: Investment costs for a straw briquetting facility (Source: Calculation EEE)

Investment		
Constructional	*2.094.000*	*€*
Grinding	*2.520.000*	*€*
Compaction	*3.930.000*	*€*
Technical installations	*3.930.000*	*€*
Total investment	***10.140.000***	***€***

Annual costs		
Acquisition of straw	*1.500.000*	*€/a*
Maintenance	*42.809*	*€/a*
Capital related costs	*293.073*	*€/a*
Depriciation and impairments	*845.000*	*€/a*
Maintenance	*304.200*	*€/a*
Personel expenditures	*284.639*	*€/a*
Auxiliary energy and materials	*1.557.444*	*€/a*
Insurance etc.	*101.400*	*€/a*
Total annual costs	***4.885.756***	*€/a*
Production costs per ton	***48,86***	***€/t***
Production costs per MWh	***10,86***	***€/MWh***

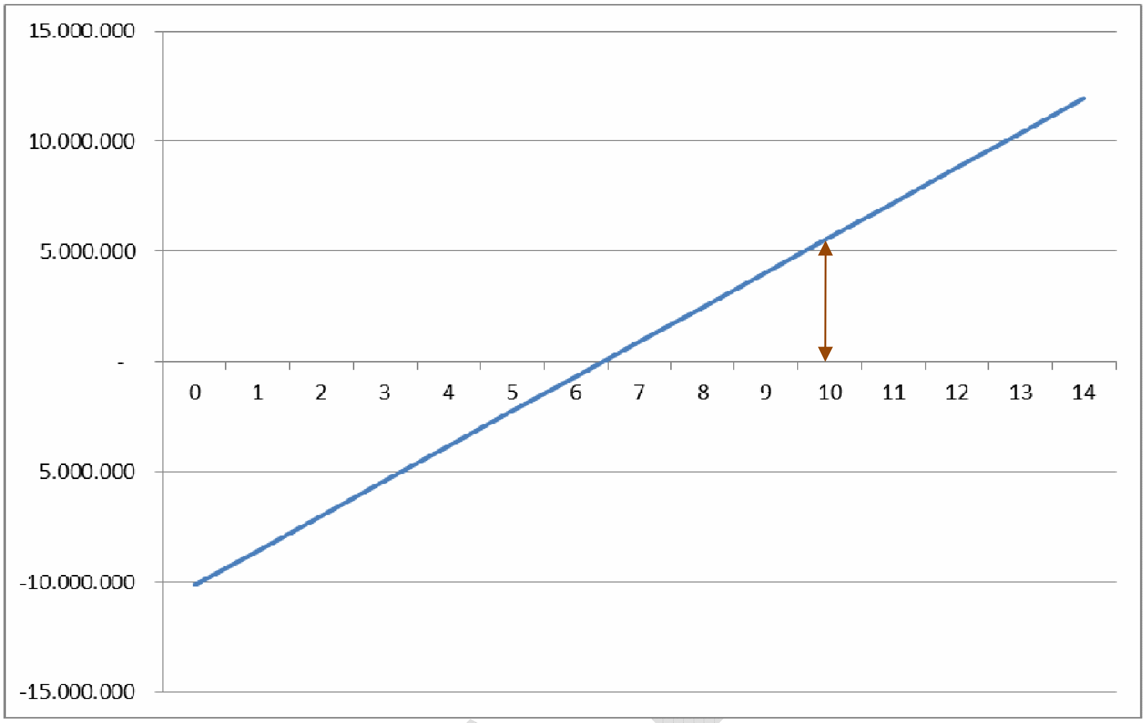
The next table is giving an overview on the performance of the facility. The sales factor is determining the sales price based on the production costs. A factor of 1,15 signifies a sales price which is the production costs plus 15%.

Table 11: Performance of a facility of straw briquetting (Source: Calculation EEE)

Sales factor: 1,15		
Sales price	56,19	€/t
	12,49	€/MWh
Annual revenue	5.618.620	€/a
Annual result	**732.863**	**€/a**

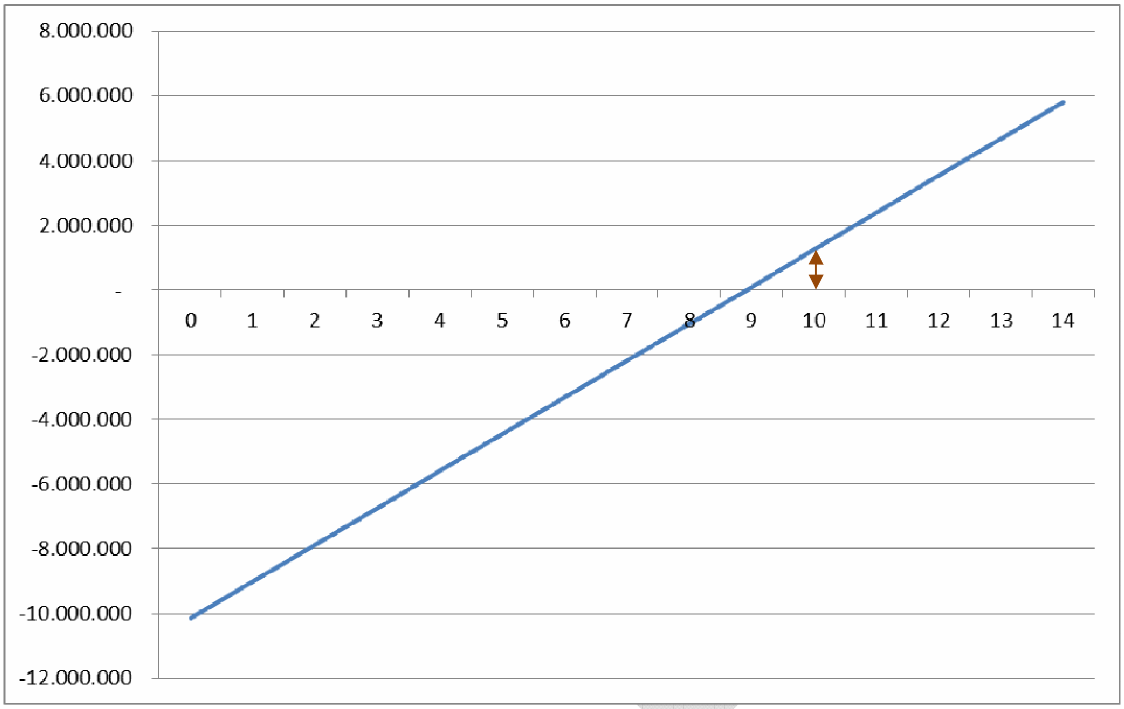
In this case, the sales price is approximately € 12,50 / MWh, which is about € 1,0 above the current customer´s price for hardwood (€ 11,50/ MWh) and € 3,00.- above the price for softwood (€ 9,01 /MWh).

The cashflow performance of the facility is sketched out in the following chart.



Graphic 23: Illustration of cashflow of a performance of straw briquettig facility (Source: Calculation EEE)

To be competitive, at least with hardwood, the sales factor would need to be reduced down to 1,06. In this case, the facility would still perform positively, but the break-even point would move from year 6 to year 9. The necessary reinvestments, occurring from year 10 on, would, in this case, hardly be covered by the performance, as can be seen in the next chart.



Graphic 24: Illustraton of cashflow of a performance of straw briquetting facility by reducing of the sales factor (Source: Calculation EEE)

5.3 Short rotation coppices (SRC) – production of logwood and wood chips

Among the different fast-growing broad leaf woods proposed for energy uses, willow (Salix) is one of the few that has been planted commercially to a significant extent in Europe. It is characterized by high productivity. Furthermore, it uses practices that are familiar to most farmers, presents winter harvests, thus reducing the impact on other agricultural operations, and demands low economic investments after the establishment is made.

Harvests take place on a two to five year cycle, and are carried out in winter after leaf fall when the soil is frozen. The established root system and the nutrients stored in the roots and stumps guarantee vigorous growth for the shoots. A plantation will yield from 8 to 18 tonnes of dry woodchip per hectare and year. A plantation can be harvested for up to thirty years before needing to be replanted.

When willow or poplar shoots are harvested as whole stems they are easy to store. The stems can be dried for combustion in a pile outdoors; the moisture content of the wood will decrease to about 30% on average until the next autumn. The stems can be cut further into billets that may not need to be chipped depending on use.

Where wood chip is being produced it is most efficient to use direct-chip harvesters. These are heavy self-powered machines that cut and chip the shoots on a loading platform. Some can be attached to a normal tractor and a hectare can be harvested in around 3 hours. Direct chipping reduces costs as a separate chipping in the store will not be needed; however, the wood chip needs to be well stored to avoid it composting. Harvesting Poplar requires heavier machinery as it produces fewer and heavier stems.

The price of dry willow as a heating fuel is currently around 45 euro per tonne in most of Europe. This is not a relatively high-return crop, but it is low-maintenance and is a way of utilising difficult fields. Small-scale production can be combined with the production of material for wicker work. Correctly managed, there is little need for pesticides or treatments.

The following table is giving an overview on the production costs on one hectare of SRC, also regarding a standard statistical difference in agricultural production costs between Austria and Serbia/Bosnia-Herzegowina, referring to the Monograph - AGRICULTURE IN LATE TRANSITION - EXPERIENCE OF SERBIA, published by the Serbian Association of Agricultural Economists – DAES (SAAE), Belgrade, Republic of Serbia, 2010.

Table 12: Production cost on 1 ha of SRC (Source: Calculation EEE)

SRC production Costs		
Yield (average-dry weight)	*11*	*t/a*
Yield (average-fresh weight)	*23*	*t/a*
Turnover period	*4*	*a*
Number of turnovers	*6*	
Total lifespan of coppice	*24*	*a*
Total yield (dry weight)	*264*	*t*
Total yield (fresh weight)	*554*	*t*
Investment	***2.314***	***€***
Capital related costs	*358*	*€*
Maintenance costs	*2.254*	*€*
Harvest costs	*2.035*	*€*

Chipping, transport and storage costs	*1.071*	*€*
Costs per turnover	***953***	***€***
Costs per ton fresh weight	*14,49*	*€/t*
Costs per ton dry weight	*30,43*	*€/t*
Costs per MWh	***5,97***	***€/MWh***

The next table is giving an overview on the sales volume for various common units, assuming a minimum sales factor of 1,3 regarding the production costs per unit. This means that the amount of money invested equals the total surplus earned until the end of the coppice and the money can be reinvested. This scenario assumes of course, that the periodical increase of costs and income are correlated equally.

Table 13: Sales volume for various common units (Source: Calculation EEE)

Sales price factor: 1,30		
Sales price fresh weight	18,84	€/t
Sales price dry weight	39,56	€/t
Sales price energy	**7,76**	**€/MWh**
Sales price 1 m³ (water content 25%)	11,79	€/m³

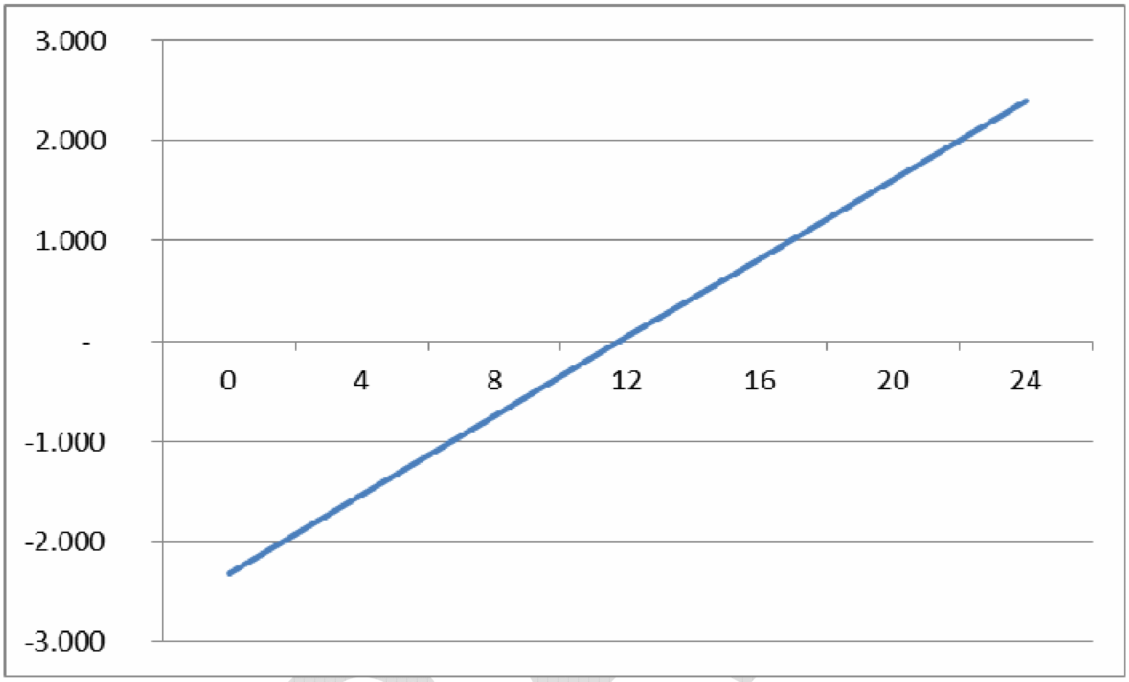
The key figures for economic viability are given in the next table.

Table 14: Economic viability of SRC (Source: Calculation EEE)

Total lifespan costs	**8.034**	**€**
Lifespan variable costs	5.361	€
Total income from coppice	10.444	€
Total contribution margin	**5.083**	**€**

The sales (no tax regarded in the calculation) price per MWh of SRC-wood is located at firewood level (€ 8,10 to 11,50 per MWh) and the heating value per m³ is about 60 % of the heating value of oak wood.

This scenario is sketched out in the chart below.



Graphic 25: Illustration of sales of SRC – wood (Source: Calculation EEE)

The substitution of lignite requires in total 7.100 ha, of which 1.000 ha for Bogatic and 6.100 for Bijeljina.

5.3.1 Compaction of wood chips from SRC

If wood chips are produced directly during the harvesting process of the coppice, they have a water content of 50 – 55%. At this water content a high biological activity is occurring, causing loss of substance and energy content during the natural drying process. The losses are between 15 and 30%. If heat at a reasonable price level is available, the chips can be dried in a facility, avoiding these huge losses. Sources for heat can be the excess heat of a biogas plant or geothermal heat.

The direct energetic use of wood chips requires special adapted techniques and is normally economically advantageous in combustion units greater than 50 kW. There are also boilers at a thermal power scale from 10 kW upward, but the heat costs in such small units are high because of the higher investment costs of wood chip firings.

The compaction of wood chips to briquettes allows combustion in simple furnaces and allows storage with high energy density.

The following table is giving an overview on the costs of SRC wood chip compaction. The calculation is based on a facility with an annual output of 100.000 tons of briquettes with a total energy content of 500.000 MWh.

Table 15: The costs of SRC wood chip compaction (Source: Calculation EEE)

Output t/a	*100.000*	
Investment		
Constructional	*2.094.000*	*€*
Grinding	*1.596.000*	*€*
Compaction	*2.520.000*	*€*
Technical installations	*3.930.000*	*€*
Total investment	***10.140.000***	***€***
Annual costs		
Acquisition of wood chips	*4.110.000*	*€*
Capital related costs	*293.073*	*€*
Depriciation and impairments	*845.000*	*€*
Maintenance	*304.200*	*€*
Personel expenditures	*284.639*	*€*
Auxiliary energy and materials	*1.557.444*	*€*
Insurance etc.	*101.400*	*€*
Total annual costs	***7.495.756***	***€/a***
Production costs per ton	***74,96***	***€/t***
Production costs per MWh	***14,99***	***€/MWh***

The next table is giving an overview on the performance of the facility. The sales factor is determining the sales price based on the production costs. A factor of 1,1 signifies a sales price which is the production costs plus 10%.

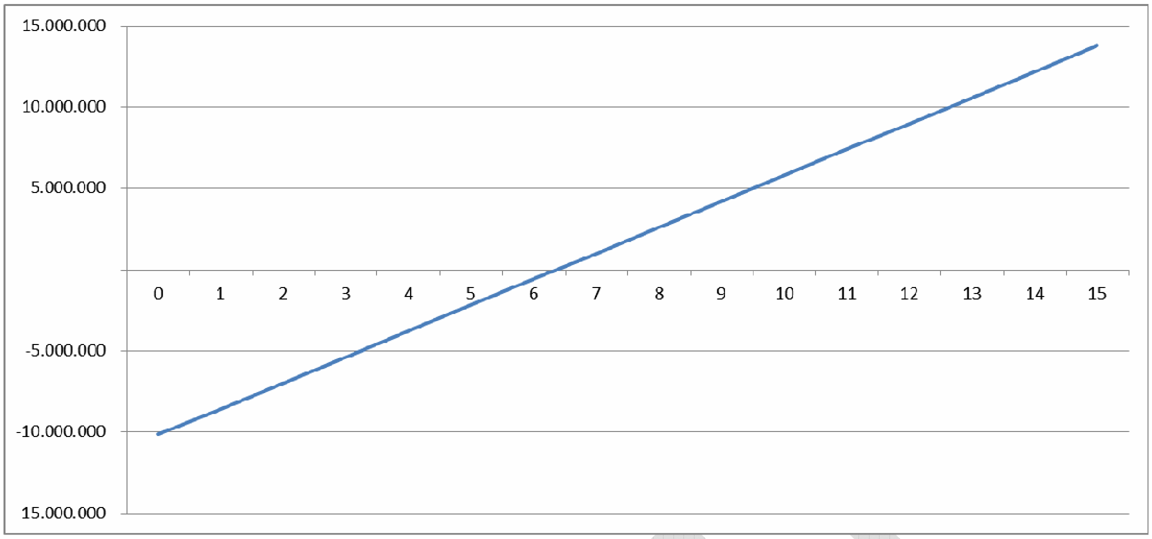
Table 16: The performance of a facility by production of wood chips (Source: Calculation EEE)

Sales factor: 1,1		
Sales price	*82,45*	*€/t*
	16,49	*€/MWh*
Revenue	*8.245.332*	*€/a*
Result	***749.576***	***€/a***

In this case, the sales price is approximately € 16,50 / MWh, which is about € 5,00 above the current customer´s price for hardwood (€ 11,50/ MWh) and € 8,50.- above the price for softwood. Because of compaction the water content is at least the half of naturally dried fire wood and thus the heating value much higher, at approximately 4,8 MWh/t (well dried firewood has 3,6 – 3,8 MWh/t). In this case the heating value equals the average heating value of cheaper types lignite.

The compacted chips, thus, could be competitive with lignite.

The cashflow performance of the facility is sketched out in the following chart. The expected reinvestment regarding machines and technical equipment occurring in year 10 of about € 4.000.000.-, can be covered from the performance, if all frame conditions remain correlated.



Graphic 26: Illustration of the cashflow of a facility of production wood chips (Source: Calculation EEE)

5.3.2 Compaction of a mix of SRC wood-chips and agricultural residues

The compaction of a composite of wood chips and maize straw is a possibility to use the straw as a cheaper component for feedstock input. Another effect of using this kind of composite is, that the disadvantages of sole maize straw (variable content of chlorine and sulphur, lower melting point of ash than in case of wood, higher amount of ash output…) can be balanced by the wood chip component. Adding small amounts of fine grinded limestone is also enhancing the combustive characteristics.

The production costs per ton are reduced by 12% if a mix of 30% of maize straw and 70% of wood-chips from SRC are used. The need for SRC area is reduced from 7.100 to 4.300 and thus leaving more space for non-energy agricultural production.

The investment is the same as for the compaction of sole maize straw or sole wood-chips. The following table is giving an overview on investments, annual costs and production costs per ton of briquette.

Table 17: Costs of production of 1 to of briquette (Source: Calculation EEE)

Output t/a	***100.000***	
Investment		
Constructional	*2.094.000*	*€*
Grinding	*1.596.000*	*€*
Compaction	*2.520.000*	*€*

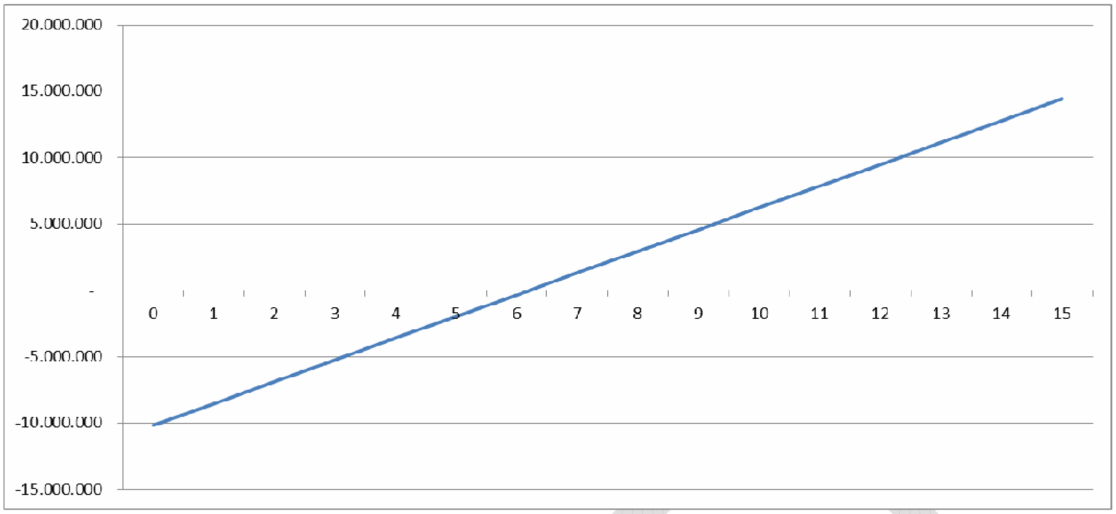
Technical installations	*3.930.000*	*€*
Total investment	***10.140.000***	***€***
Annual costs		
Acquisition of feedstock	*3.222.000*	*€*
Capital related costs	*293.073*	*€*
Depriciation and impairments	*845.000*	*€*
Maintenance	*304.200*	*€*
Personel expenditures	*284.639*	*€*
Auxiliary energy and materials	*1.557.444*	*€*
Insurance etc.	*101.400*	*€*
Total annual costs	***6.607.756***	***€/a***
Production costs per ton	***66,08***	***€/t***
Production costs per MWh	***14,68***	***€/MWh***

The minimum sales factor for achieving a positive performance and for having the capital for the necessary re-investment in year 10 is 1,12.

Table 18: The sales performace of briquette (Source: Calculation EEE)

Sales factor: 1,12		
Sales price	74,01	€/t
	16,45	€/MWh
Revenue	7.136.377	€/a
Result	528.620	€/a

The cashflow performance of the facility is sketched out in the following chart.



Graphic 27: Illustration of cashflow of briquetts sale (Source: Calculation EEE)

5.4 Energy production of biomass

5.4.1 Electricity production by biomass combustion

Besides compaction for the use in single furnaces or central heating systems, agricultural residues can also be used for direct firing, without being processed before. There is also the possibility to generate electricity, but the conversion efficiency in electricity generation is, more or less, at the level of 20% of the primary energy content. In order to have a sustainable use of the resource, also a use for the excess heat of the process needs to be found. Furthermore it is required, that all the heat is used sold all over the year or the operating hours of the CHP facility. Differently from a biogas plant, where only approximately 40-45% of the primary energy is converted into heat, in combustion plants the share of heat is 60-80%.

The conversion can take place by use of a steam turbine or by a ORC unit. In case of agricultural biomass the use of the ORC process should be preferred because it is also applicable for smaller capacities, whereas a steam turbine, from the economical point of view, will be applicable from an electric power capacity of at least 2 MWel .

A power plant based on solid biomass, no matter if an ORC unit or a steam turbine is used results in a 4-fold thermal capacity and a 5-fold input capacity.

All tested variants have a negative performance and do not break even within the period of 12 years at heat sale prices (additionally to incentive electricity feed in) below € 80.- /MWh and a heat sales rate of 100%. After the incentive period the heat sales price would be needing to increase by 20% in order to maintain a positive performance.

These needed minimum heat sales prices are far beyond the current prices for heat supply, except heating oil, which is even more expensive.

5.4.2 District heat from solid biomass

Biomass can be used as a sole or additional fuel for district heat supply. Costs can be estimated for the heat central, but total heat supply costs are depending on the total length of the amount of heat transported per meter.

The following table is giving an overview on average investments for various sizes of heat centrals, comparing biomass fired and fossil fired facilities:

Table 19: Avarage investments for various sizes of heating facilities (Source: Calculation EEE)

Power	Investments in biomass based facilities	Investments in fossil based facilities
	Average investment in 1.000 of €	
500 kW	125 - 250	90 - 110
1 MW	250 - 400	100 - 150
5 MW	1 250 - 1 500	550 - 750
10 MW	5 500 - 7 000	1 500 - 2 000

The costs for the distribution grid depend on the grid length and the dimension of the used pipes according to the needed heat transport capacities. They can vary between € 160.- and € 300.- per trass meter.

Because of no currently definable project, only these specific values for the components are given.

The economic viability is dependent on the specific heat production costs, which are composed of the investment, the type and quality of biomass and the number of operating hours.

Straw combustion facilities are more expensive in investments (special technology) but relatively cheaper in operation, whereas wood combustion facilities are cheaper in investments and relatively costly in operation. These differences are important to be observed in the power scale below 1 MW and are vanishing in the power scale from 2,5 MW and beyond.

5.5 Evaluation of variants regarding the use of solid biomass

Solid biomass is considered to be a valuable substitute for lignite in private households as well as in public buildings or industry.

The two possibilities for solid biomass use in the project regions are on one hand the use of agricultural residues, especially maize straw, and on the other hand the cultivation of short rotation coppices (SRC) on poor or frequently flooded farmland.

The economic viability of the substitution is depending on the production costs and the minimum needed sales margin in order to be competitive with forestall biomass and lignite.

The production of split logs and stock wood as well as wood chips is an extensive way of farming and the production costs are lower, compared to other energy crops. The average production costs have been calculated at approximately € 6.- /MWh and the minimum sales price for economic viability is approximately € 7,80 /MWh and are thus competitive with firewood.

The disadvantage of focussing on SRC wood is, that it is binding about 7.100 ha of farmland for decades, if the total demand for lignite shall be covered by SRCs.

The cheaper feedstock is the abundant amount of maize straw, but it needs to be processed and compacted for being used in smaller scale furnaces. The production costs are about € 10,90 /MWh in case of a facility with an annual output of 100.000 t (this capacity can cover the comparable demand for lignite) and the minimum sales price is € 12,50 /MWh.

As can be seen, the costs for compacted maize straw are higher than the ones for SRC wood, but this variant is characterized by not binding any farmland for long term and the feedstock can be obtained from regular agricultural production. The higher costs are caused by the necessary processing of the straw.

The compaction of wood chips from SRC, which are already produced in the course of mechanical harvest is more costly than the compacting of maize straw, but provides an energy carrier with high energy density, comparable to lignite and, compared with lignite, a very low ash output. The production costs for chip briquettes are € 15.- / MWh and the minimum sales price is € 16,50 /MWh. Also this variant could be competitive with lignite.

The compaction of a mix of 70 SRC wood chips and 30% maize straw has almost the same cost structure. This variant is only requiring less farmland than the full SRC variant.

Electricity production from biomass combustion turned out to be not profitable because of the high investments, low conversion efficiency regarding electricity generation and the absolute need to sell all co-generated heat at a minimum sales price of at least € 80.-/MWh in order to be viable. This heat price is not competitive with other energy sources.

The combustion of agricultural residues in a district heating plant could be an economically effective way of energy supply, but the parameter of grid dimensioning as well as the combustion technology can vary widely and therefore the feasibility of such a heating plant is depending on a defined dimension of the facility and the grid.

The examination of all discussed variants showed that agricultural biomass is competitive with lignite and fuel wood, but it is not convenient for electricity production in the combustive way.

6. Effects of biomass utilization on land use

Since the project regions are not very rich in forests and thus the use of forestal biomass for energy supply is very limited, biomass needs to be provided from other sources.

These sources are mainly located in agriculture and energy production has an impact on the land use. Depending on the type of biomass and the used conversion technology this impact can create conflicts with other forms of land use.

The aspect of energy supply is subordinated to the aspect of nutrition if farmland is used. Thus, it has to be checked, if and how much farmland can be used for energy supply.

The total area of farmland in the regions is about 75.500 hectares. If calculating with an area demand of 0,25 ha per capita for nutrition, for the total population an area of 34.700 hectares needs to be reserved.

For other purposes, as for example energy production, 40.700 ha can be accessed.

Electricity production from biogas requires about 500 ha under the current growth conditions for maize in the regions. If a grass-clover mix is used, the double area (1.000 ha) is required. The use of processed maize straw as a co-substrate can reduce the area demand for silo maize, depending on the share of it, up to 20%.

Since there is a large amount of farmland at disposition for not strictly nutritional purposes, biogas production does not have a strong impact on land use. The digestate is even serving as a fertilizer.

The sole use of agricultural residues does not require additional farmland but can possibly lead to a higher demand of mineral fertilizers if all the biomass is carried away.

Short rotation coppices do have the biggest impact because of their long term life cycle of 25 to 30 years. For the production of compacted briquettes from wood chips for lignite substitution an area of 7.100 to 9.100 ha would be bound for the long run. Co-compaction of agricultural residues up to a share of 30% could contribute to a less intensive change in land use. Short rotation coppices should be established on less productive or frequently flooded soils for not stressing valuable farmland.

7. Recapitulation

The study is covering variants of the use of geothermy and biomass for heat and electricity production.

7.1 Geothermy

The potential of geothermy and its exploitation is treated for each project region, whereas the variants for the use of biogas and solid biomass are not so bound to already given conditions. The latter variants have been examined by modelling cases and checking them for economic viability under the given circumstances like feed in tariffs or costs for other energy carriers already used.

In Bogatic there are existing already developed geothermal wells. The two possibilities of use, power production and district heat, have been examined with respect to their economic feasibility and viability.

The variant of geothermal power generation turned out to be not feasible if credit capital is used, because the investments will not pay back within the period of the incentive feed in tariff payment. A combination with biomass is only rising investments and annual costs and the payback is even reduced.

The variants of district heating by geothermal water turned out to be a possible and even economically viable solution, yet depending on the share of credit capital in the investments.

The situation in Bijeljina is different from the one in Bogatic, because only smaller wells are developed, which are not suitable for energy supply on a larger scale or for electricity production.

Of all examined model-variants the one regarding the power range between 2,5 and 5 MW is the most promising one. Also the dumping of the heat loads by a district heating system seems to be manageable, because the loads are not too high and the amount of heat which needs to be sold for economic viability can be managed easier.

7.2 Biogas

Among the examined variants only the ones including electricity production are performing in a positive way – at least in the first 12 years of the facility´s life span (which is commonly between 25-30 years). After these 12 years the performance turns into negative, if no subsequent use for the biogas produced in the facility can be found. This is requiring investments in the years 10-12, not for the silos and fermenters, but for the energy supply technology. From the present point of view the switch from electricity generation to direct gas applications seems to be a viable alternative.

After the period of incentives, the performance of all variants turns into negative, although the facility is still operable. Therefore a scenario has been developed which might enable a further operation of the power plant by switching from electricity production to sole gas production with the possibility of biogas upgrading to natural gas quality or the sale of roughly purified biogas via a biogas grid for heat purposes.

7.3 Solid biomass

The two possibilities for solid biomass use in the project regions are on one hand the use of agricultural residues, especially maize straw, and on the other hand the cultivation of short rotation coppices (SRC) on poor or frequently flooded farmland.

The production of split logs and and loose stock wood as well as wood chips from SRC is an extensive way of farmig and the production costs are lower, compared to other energy crops. The produced wood is competitive with forestal firewood.

The disadvantage of focussing on SRC wood is, that it is binding about 7.000 to 9.000 ha of farmland for decades, if the total demand for lignite shall be covered by SRCs.

A cheaper feedstock is the abundant amount of maize straw in the regions, but it needs to be processed and compacted for being used in smaller scale furnaces. The costs for compacted maize straw are higher than the ones for SRC wood, but this variant is characterized by not binding any farmland for the long term and the feedstock can be obtained from regular agricultural production.

Electricity production from biomass combustion turned out to be not profitable because of the high investments, low conversion efficiency regarding electricity generation and the absolute need to sell all co-generated heat at a minimum sales price which is not competitive with other energy sources.

The examination of all discussed variants showed that agricultural biomass is competitive with lignite and fuel wood, but it is not convenient for electricity production in the combustive way.

Content of graphics

Content of tables