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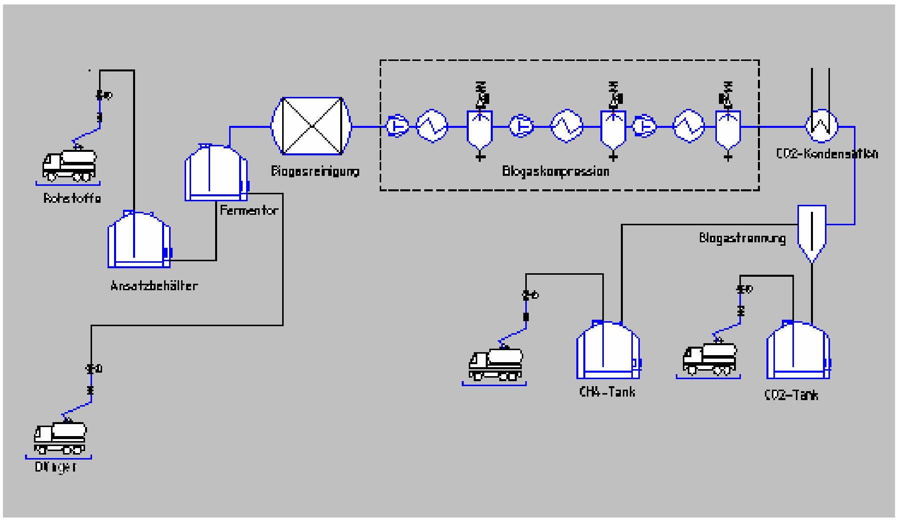
Environmental protection
Process engineering
Plant engineering

DGE
Dr.-Ing. Günther Engineering GmbH

Biogas from waste for the production of current and natural gas

Biogas production plant



BCM method of the company DGE GmbH for biogas processing and recycling in four steps with production of natural gas, carbon dioxide, methanol or other substance treatment

BCM method of natural gas production by firm DGE GmbH

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1. Introduction

The firm DGE GmbH designs and installs complete turnkey plants for biogas production and its utilization from recoverable energy.

Always in accordance with an appropriate application it is possible to realize different designs. These designs include the utilization of different raw materials from agriculture, industry and communal enterprising. During all of the processes it is produced biogas which can be then utilized from the power standpoint. The possibilities of utilization are as follows:

- Electric power production
- Heat for long-distance heating
- Natural gas as a fuel for vehicles
- Natural gas for supplying gas distribution networks
- Carbon dioxide, liquid carbon dioxide or in the form of solid carbon dioxide as dry ice
- Production of methanol
- production of soda solution
- Recycling of fuel cells

The technology of the DGE GmbH for the biogas recycling corresponds to the current amending of the EEG.

The firm DGE GmbH is able to prepare and offer and optimum design for all field of use.

The current knowledge concerning the installation and operation of facilities for the production of biogas forms a basis for any subsequent utilization of components that are contained in biogas. The available biogas resources in Germany have been estimated to amount to 12.4 up to 15.3 bil m^3/a /1/. Despite the fact that, since 1999, the total output power of facilities for the production of biogas has tripled from 45 MW to 150 MW in the year of 2002, the current available capacity is being utilized only at around 4-5 % of the total. If we count just the possibilities for the production of methanol, which result from the difference, we find a very big number. If we go even further take into consideration the fact that 80 % of methanol in the world (the annual consumption of 28,3 million T /2/) is currently being produced from natural gas, we come to a conclusion that there is a possible replacement of this type of production with natural raw-materials.

Our firm is a member of professional association Biogas e.V.

1.1 Fields of use

The biogas production plants are used advantageously in the following sectors:

- agriculture
- food industry
- liquidation of municipal waste

The natural gas production represents the most economical variant the utilization of which from the power standpoint is guaranteed in all cases. When used for electric power production it is necessary to dissipate the waste heat. In summer season, however, heat is unnecessary.

1.2 Use of substance

The first step for the substance use is the production of natural gas quality. With the amending of the EEG in the year 2004, the conditions have been made.

2. Plants for electric power production and waste heat utilization

The following examples prepared in accordance with the professional agency Increase of raw materials e.V. present a survey of possible technically feasible biogas production processes.

It is possible to obtain approximate permanent values of expected economy from the survey presented in the following text.

High-capacity animal husbandry (GVE)	800	1.600	2.500	3.300	6.600
Biogas production (m^3/h)	**50**	**100**	**150**	**200**	**400**
kW fuel	300	600	900	1.200	2.400
Investment €	300.000	590.000	855.000	1.100.000	2.000.000

The production of biogas from natural raw materials and municipal waste materials has been safely in operation for a number of years. The development in the amount of facilities for the production of biogas has been rather unsteady. As a result, thermo-/energy- utilization of biogas is due to its high calorific capacity an obvious move. All this has made it possible to produce electrical power and waste heat in electrical power plants using the biogas. The energy effectiveness of such biogas utilization is within the range of 35% at max. However, together with the utilization of waste heat, it is possible to increase the effectiveness of the conventional use of biogas in the production of electrical power up to 65 or 75 %. This rather simple reasoning indicates that if there is no arrangement for the utilization of waste heat, the cost-effectiveness of the utilization of biogas in the production of electrical power remains somewhere near the edge.

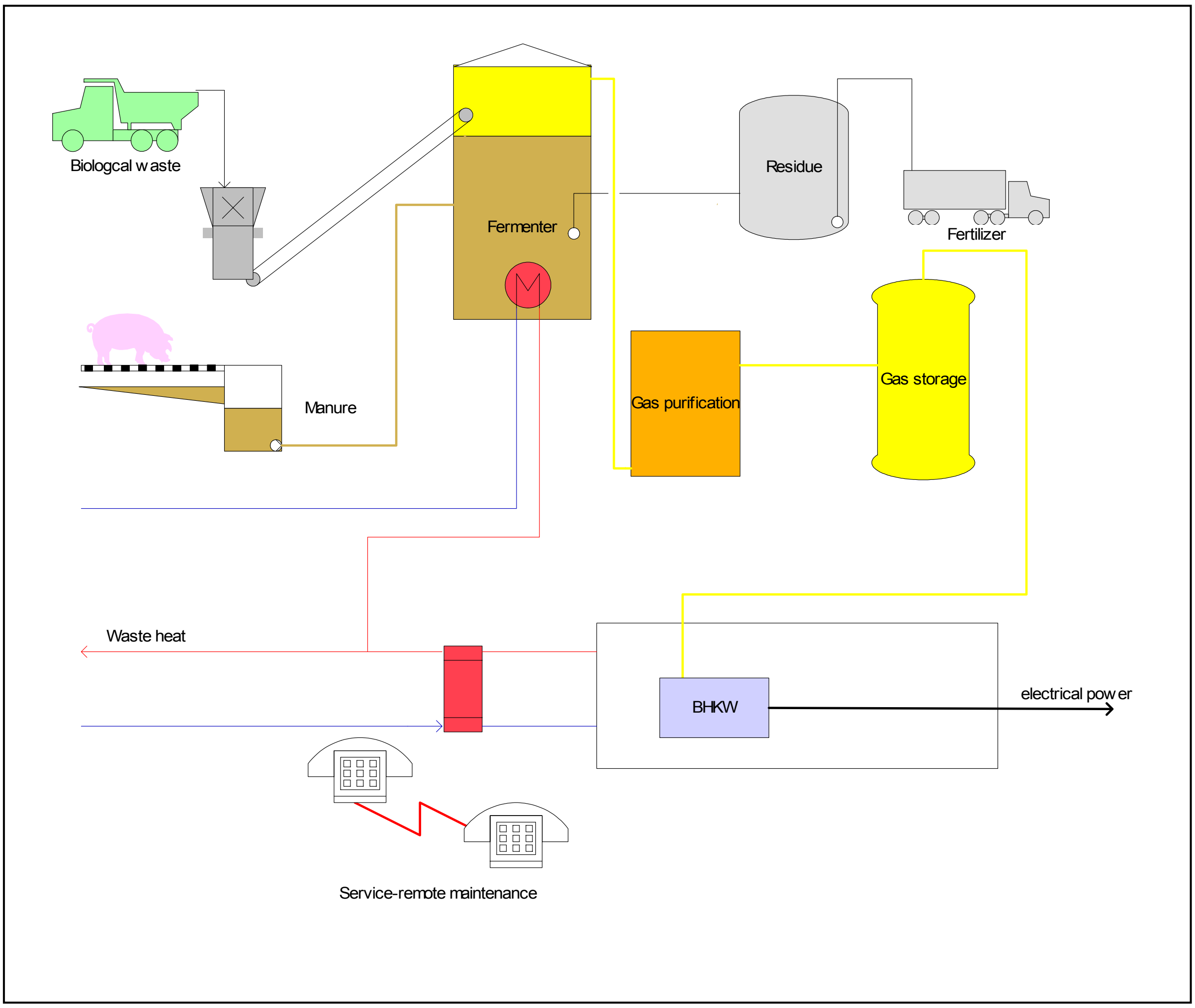
2.1 Biogas production by using a single stage mesophyll method

The single-stage mesophyll wet fermentation method is suitable above all for small agricultural enterprises in which there is at disposal all the time stable manure resulting from cattle breeding or pig breeding.

At using this method it is possible at the same time to process an insignificant quantity, i.e. an amount of 5-10% of processed substrate to manure or silage. Always according to the equipment size it is possible to install more single-stage fermenters either in series or in parallel.

The produced head is utilized on the fermenter and for heating buildings. The produced electric power is consumed partially for operation of the plant. The surplus electric power is supplied in the mains.

The method can be combined with BCM-method and instead of electric power it is possible to produce natural gas and carbon dioxide.

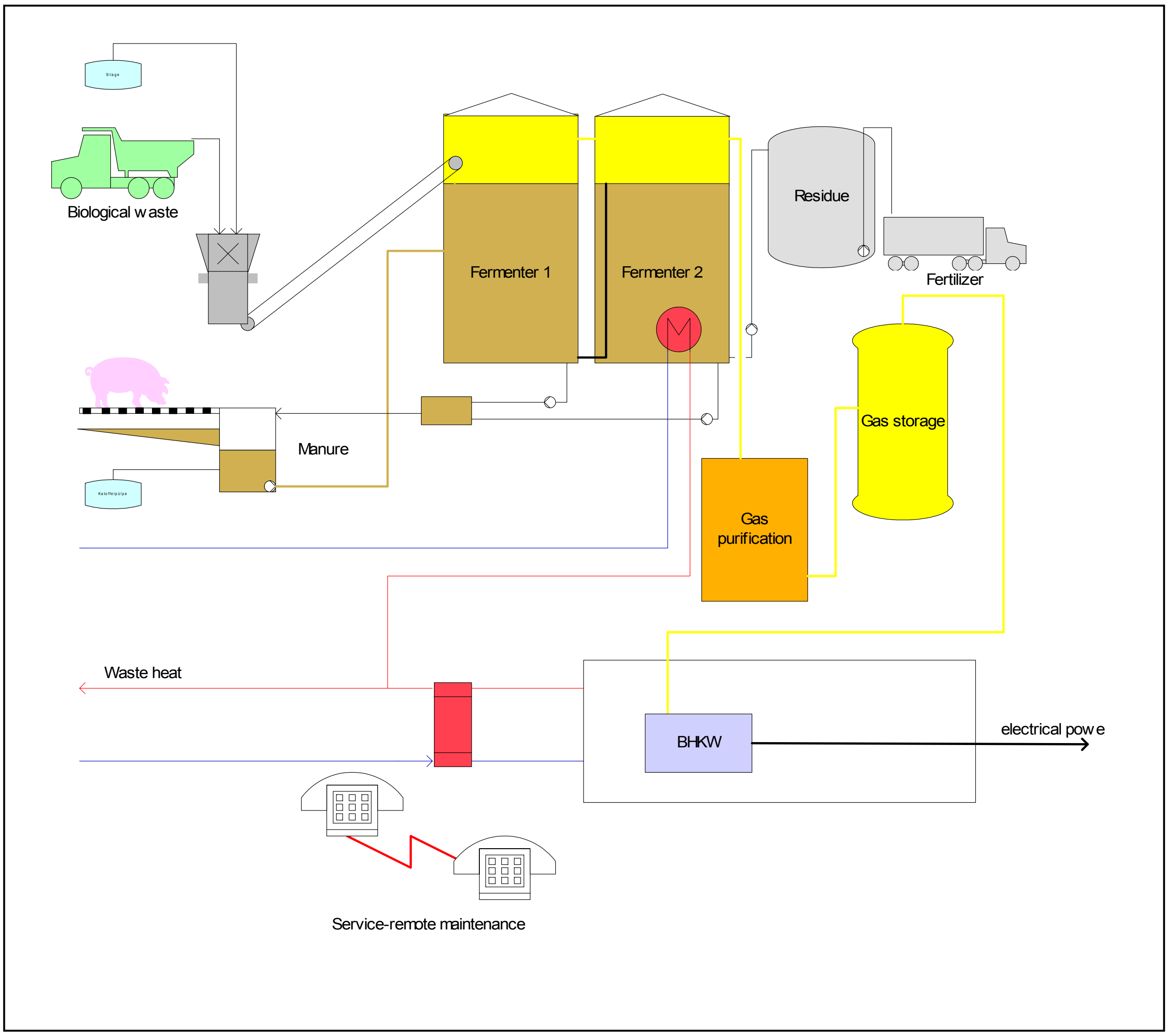


2.2 Biogas production by two-stage mesophill method

The two-stage mesophill method of wet fermentation is suitable particularly for combined treatment of stable manure and natural raw materials. In this method the portion of natural materials may be up to 50 %. Always according to capacity of the equipment it is possible to install in parallel more single-stage fermenters.

The produced heat is utilized in the fermenter and for heating buildings. The produced electric power is partially consumed for operation of the equipment. The surplus electric power is supplied into the mains.

The method can be combined with BCM-method and instead of electric power it is possible to produce natural gas and carbon dioxide.

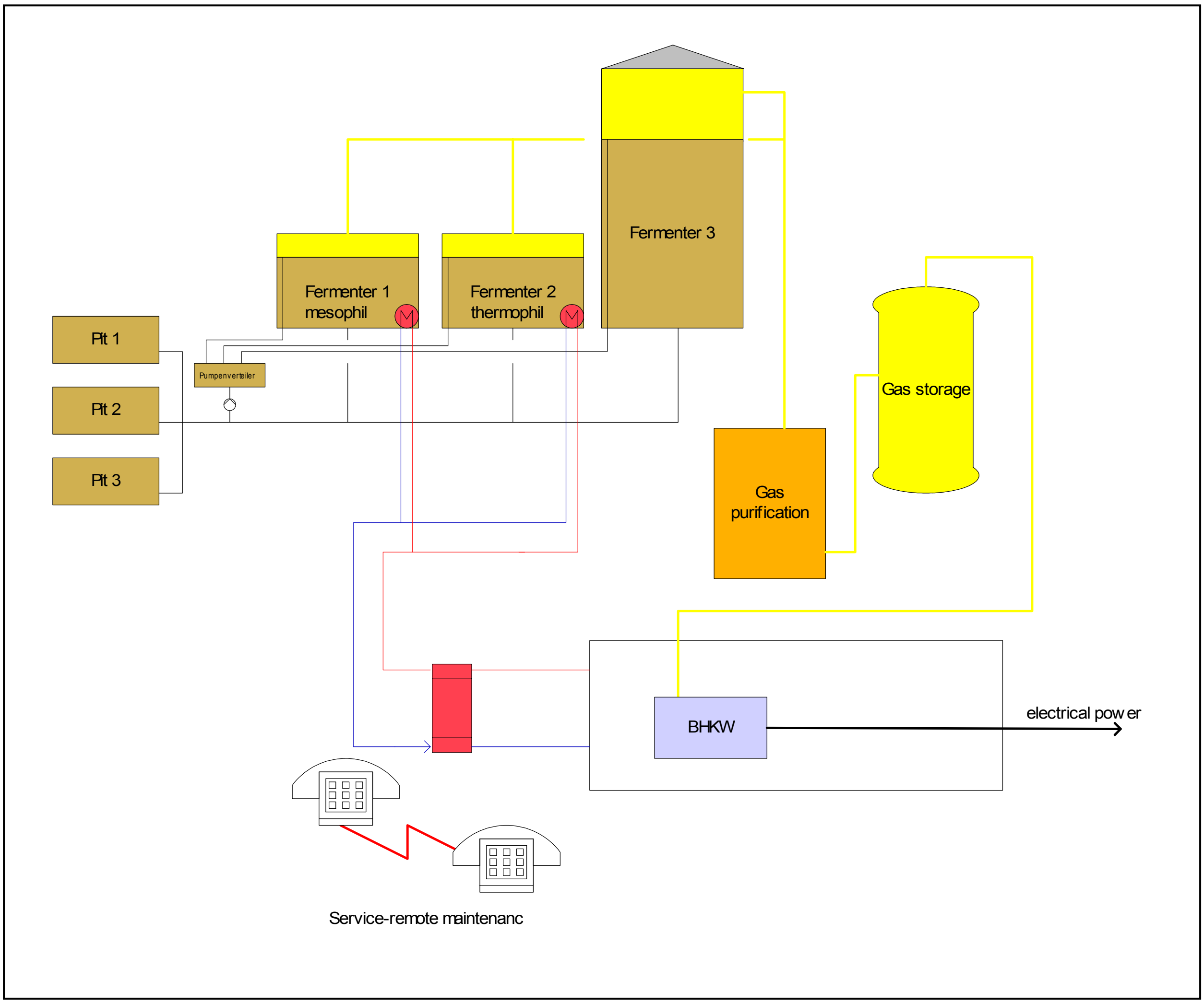


2.3 Biogas production by three-stage mesophill and thermophill method respectively

With the use three-stage method it is possible in combination of mesophill and thermophill wet fermentation process to process markedly higher quantity of natural raw materials. In the framework of this method the portion of natural raw materials and biological waste may be up to 90 to 100 %. Always in accordance with the capacity of the equipment it is possible to connect in parallel more single-stage fermenters.

The produced heat is utilized in the fermenter and for heating buildings. The produced electric power is partially consumed for operation of the equipment. The surplus electric power is supplied into the mains.

The method can be combined with BCM-method and instead of electric power it is possible to produce natural gas and carbon dioxide.



3. Biogas production according to BCM method®

The biogas production has been introduced successfully from the beginning of 1970 after the oil crisis. Legislative in 1990 and 2000 for “recoverable energy” has been a cause in the last years of a marked increase of the rate of growth of the number of biogas production plants. The number of the biogas production plants in Germany in 2003 was more than ten times higher when compared to that number of biogas production plants in 1990.

The produced biogas is utilized above all for electric power production and for revaluation of waste heat. As a higher degree of utilization of biogas consists in feeding natural gas distribution networks or using the biogas as a fuel of vehicles and eventually its use as a synthesis gas. It was realized successfully and several plants of this type were put into operation in Scandinavia.

In several countries as for example in England or United States quota system does exist for sale of electric power produced from biogas. If a sufficient quota is attained, then consumption is taken in consideration and the biogas production plant must be put out of operation to be in standstill condition. From /3/ it is possible to estimate attained biogas flow-rates for m³ or t.

Cow stable manure	200 m³ Methane/ t oTS	20 m³ of biogas/m³
Pig stable manure	300 m³ Methane/ t oTS	30 m³ of biogas/m³
Poultry manure	250 m³ Methane/ t oTS	40 m³ of biogas/m³
Sludge	300 m³ Methane/ t oTS	5 m³ of biogas/m³
Biowaste	250 m³ Methane/ t oTS	100 m³ of biogas/m³
Fat	720 m³ Methane/ t oTS	650 m³ of biogas/m³
Gas	480 m³ Methane/ t oTS	125 m³ of biogas/m³

High capacity fermentation plants with a gas storage tank

Biogas composition

Components	formula	vol.%
Methane	CH_4	40-75
Carbon dioxide	CO_2	25-55
Water vapour	H_2O	0-10
Nitrogen	N_2	0-5
Oxygen	O_2	0-2
Hydrogen	H_2	0-1
Ammonia	NH_3	0-1
Hydrogen sulphide	H_2S	0-1

In accordance with these data it is possible using a biogas production plant with a middle capacity at treating cow stable manure in an amount of 10 m³/h to produce an amount of 200 m³/h of biogas. Modern equipments have been designed in such a way that in the fermentation part it is possible at the same time to increase the value of different kinds of biomass. It is possible then utilize the fermented substrate as a manure.

As the most usual method of increasing the value of biogas is considered to be in the present time the use of biogas for electric power production. In this case, however, it is attained a lower power efficiency for the reason of a relatively high CO_2 portion in biogas. When utilizing biogas very often also other components of the biogas are as disturbing components as for example ammonia and hydrogen sulphide.

Therefore, the technological development carried out by the firm DGE GmbH is aimed at a marked increase of economy and flexibility when increasing the value of biogas. At the same time it must be enabled above all the industrial increase of the value of biogas products.

In summer season the heat consumption is negligible or that heat consumption is zero. This fact represents often an insufficiency when utilizing biogas for electric power production.

Investigations /4/ carried out have shown that the existing methods of production and treatment of biogas are too expensive:

High-capacity animal husbandry (GVE)	800	1.600	2.500	3.300	6.600
Biogas production (m^3/h)	**50**	**100**	**150**	**200**	**400**
kW fuel	300	600	900	1.200	2.400
Investment €	300.000	590.000	855.000	1.100.000	2.000.000
Capital costs	30.889	60.748	88.033	113.259	205.926
Personnel	17.000	30.000	43.000	53.000	70.000
W+R+various	10.500	20.650	29.925	38.500	70.000
Costs per year	58.389	111.398	160.958	204.759	345.926
Annual production (MWh)	2.400	4.800	7.200	9.600	19.200
Gas purchase costs (Biogas) (€/MWh)	**24**	**23**	**22**	**21**	**18**
Production costs (ct/kWh)	**2,4**	**2,3**	**2,2**	**2,1**	**1,8**
Bioplant proper heat consumption (kW)	96	182	259	326	576
(MWh)	480	912	1.296	1.632	2.880

Costs and proper heat consumption of agricultural high-capacity animal husbandry

Biogas production (m^3/h)	50	100	150	200	400
Production (ct/kWh)	2,4	2,3	2,2	2,1	1,8
Conversion to natural gas quality (ct/kWh) from	1,6	1,4		0,9	0,7
to	3,5	2,7		2,5	2,2
probably	2,6	1,8	1,3	1,2	0,8
Necessary output (ct/kWh)	5,0	4,1	3,5	3,3	2,6

Purchase cost of biogas produced in a comparable quality with that of natural gas

With the use BCM method® by the firm DGE GmbH we are presenting now an economic technology by means of which the biogas is produced in such a way that it can be utilized as synthesis gas. The separated carbon dioxide reaches in this case even food quality. In this time it is in course necessary technological development.

3.1 Technological description of BCM-methods®

Biogas contains valuable raw-components. This invites the option of substance-utilization of these raw-components, since these can be processed independently of the utilization process of waste heat. The cleaning of biogas in order to remove NH_3, H_2S and exsiccation is a tried-and-true method and has already been in use. Its implementation is a prerequisite for substance-utilization of main components CH_4 and CO_2 which are contained in biogas. The DGE GmbH Company has developed four different cleaning and modification techniques for different available options of substance-utilization of biogas – ref. to the following shortened versions of descriptions.

3.1.1 Means of biogas utilization BCM-0
Natural gas production

The basic method for the production of natural gas is the split-up of biogas into natural gas and carbon dioxide. As a result of a newly enacted Law of Renewable Energy Resources (EEG), the utilization of this method itself brings considerable advantages to everyone who operates a facility based on biogas, where this biogas is used to produce electrical power.

3.1.2 Means of biogas utilization BCM-1
Soda and natural gas production

Biogas that comes out of a container is always cleaned first, using one washer; forming NH_3 and H_2S, and having been modified in this way, the biogas is further taken into the waste-gas washer, in which CO_2 and NaOH are removed for the purpose of producing Na_2CO_3.

Subsequently, with the use of a compressor, the cleaned-up biogas is compressed like a natural gas to reach the desired pressure. Following the first compression phase, gas dehydration is prescribed, along with the so-called “police filter”.

The achieved quality of the natural gas is somewhere in the neighborhood of 98 vol. % CH_4 and 2 vol. % CO_2.

3.1.3 Means of biogas utilization BCM-2
Compressive condensation in the production of split mixtures CO_2/CH_4

Biogas that comes out of a container is always cleaned first, using one washer; forming NH_3 and H_2S, and having been modified in this way, the biogas is further taken into a compression device. The following condensation phase gives rise to the forming of a gas rich on methane, which is of the same quality as natural gas, and carbon dioxide saturated with methane is being obtained, as well.

Following the first compression phase, gas dehydration is prescribed, along with the so-called “police filter”.
The cleaned-up gas, just like natural gas (high-caloric gas), may be supplied into the (distribution) system or be used as fuel. The carbon dioxide (classified as low-caloric gas), which is obtained in

a liquid-state, may be used after its expansion in an electrical power plant in the production of electric power. The temperature of – 50°C is a condensation temperature at which methanol and carbon dioxide become disintegrated to form 1 kmol/h of biogas:

	Gaseous phase rich gas	gas in liquid state poor gas	Total
Methane	0,385	0,275	0,66
Carbon dioxide	0,06	0,27	0,33

In addition, both parts are separately used to produce products such as methanol, hydrogen, or other hydrocarbons, using the "Fischer Tropsch Synthese". It is possible to produce up to 70 1/h of methanol from 100 m³/h of biogas.

3.1.4 Means of biogas utilization BCM-3
Compressive washing for the production of carbon dioxide and natural gas

Biogas that comes out of a container is always cleaned first, using one washer; forming NH_3 and H_2S, and having been modified in this way, the biogas is further taken into a compressor. The compressed gas must be washed either after the first or the second compression stage, depending on the type of the washing medium used. The washing procedure of the compressed gas is when the biogas gets rid of CO_2 up to less than 1 vol. %, and in this condition, it may be supplied into the natural gas distribution system. The required compression phase, as well as exsiccation that might be possibly needed, must be adjusted to the current conditions.

Carbon dioxide, which has been removed from the washing solution, is of high cleanness and may be liquefied after it is submitted to another compression phase. The achieved quality of the natural gas is higher than 99 vol. % CH_4 and less than 1 vol. % CO_2. It is technically possible to reduce the amount of CO_2 below 10 ppm.

The thus produced carbon dioxide can be easily modified to achieve the quality commonly used in the food industry. There are, however, many ways of how the technically-clean carbon dioxide can be used, ranging from dry ice, through its applicability in fire extinguishers, to material tests or its use in coolants.

3.1.5 Means of biogas utilization BCM-4
Absorption caused by a change in pressure for the production of carbon dioxide and natural gas

Using a compressor, the previously cleaned biogas is compressed to the desired pressure of the natural gas from 12 to 20 bars and subsequently is brought to absorption by a change in pressure. The absorption, which is caused by the change in pressure, is preceded by desiccation using silica gel. The absorption, brought about by a pressure change, is composed of four absorbers, two of which are always absorption-active, one of the remaining absorbers is activated for the release and regressive conveyance of biogas, and the last of the absorbers serves for the separation of CO_2. This ensures that the absorption, along with a pressure change, yields the production of the same product CH_4 a CO_2 over time. Special molecular sieves are used for the absorption.

3.2 Economic evaluation of BCM-methods®

3.2.1 Method BCM-0

With the use of this basic method, biogas may be easily modified and divided into natural gas and CO_2. Here, there is no substance-utilization of CO_2. The thus produced natural gas is effectively used to produce electrical power. This method is cost-effective for devices/equipment at 100 Nm^3/h or smaller amounts of biogas.

3.2.2 Method BCM-1

Biogas cleaning is carried out with good reliability, even up to the quality of natural gas. The method of production of brine from concentrated waste gas CO_2 is one of commonly tried, verified, and used methods, and an example of a company using this method is Bayer Co.

This method is cost-effective starting at an amount of 300 Nm^3/h of biogas.

The cost-effectiveness is highly dependent on the selling price of soda. There are many ways of utilization of the produced soda, e.g. in glass industry. Due to the fact that this method calls for additional personnel, two new employees have been hired per shift, i.e. a total of 6 employees per day. Wage expenses must be adjusted to the current situation. Shall there be a long-lasting demand for the produced soda to be sold at good prices; this would surely be an interesting alternative. For the purpose of utilization in the production of electrical power, the evaluation included a bonus or premium of 0.02 €/KWh of natural gas.

3.2.3 Method BCM-2

There is a need to consider restrictions concerning the relatively high amount of CO_2 after condensation, when looking at the biogas cleaning process and the quality of natural gas. In case a bonus or premium of 0,02 €/KWh is also obtained for biogas cleaning, then this method could also be very interesting.

Shall the acquired high-caloric gas be used for the production of methanol instead of electricity, this method will yield a quick return on investment for even small devices and appliances.
With the use of compressive condensation, it is possible for the purpose of further substance-utilization in Fischer Tropsch Synthese to produce fractions of desired configuration.

3.2.4 Method BCM-3

Biogas cleaning with the use of compressive washing and retrogressive acquisition of carbon dioxide is cost-effective for appliances or facilities starting at amounts of 200 Nm^3/h of biogas.

Shall the produced natural gas be used for the production of methanol instead of electricity; the cost-effectiveness is given for amounts starting at 200 Nm^3/h of biogas. If we take into account expenses incurred to purchase the desired equipment/facility for methanol, the return on investment shall be more than five years from now. Since there is a big market for methanol, the long-term sales are secured.

3.2.5 Method BCM-4

The biogas cleaning process that employs absorption and change in pressure is economically feasible even for small devices with the amount of biogas equal to 100 m³/h.

Natural gas and carbon dioxide are of high quality. The advantage of this process is that it is not necessary to use any chemical additives as opposed to compressive washing machines.

3.2.5 Summary

The four different biogas-cleaning methods described above may be implemented, depending on the given utilization. Nowadays, it is without a doubt that the technically easiest option is method BCM 0. The highest possible effectiveness can be achieved only together with some equipment for retrogressive acquisition of carbon dioxide or equipment for the production of soda according to methods BCM-1 and BCM-3. The BCM-4 process is advantageous especially when there is a need for the direct distribution of natural gas, since the natural gas is of sufficient overpressure to be fed into the distribution system. The production of methanol should be worthy of consideration in a few years, after the rise of prices of natural gas.

Sources:

/1/ Biogasgewinnung und –nutzung
Institut für Energetik und Umwelt GmbH
Torgauer Straß3 116
04347 Leipzig

/2/ Schweizer Zentrum für Ökoinventare
20.Diskussionsforum Ökobilanzen
19. September 2003 ETH Zürich

/3/ FH Bochum Solar Netz, December 2001

/4/ Bremer Energie Institut
Untersuchung zur Aufbereitung von Biogas zur Erweiterung von Nutzungsmöglichkeiten
June 2003

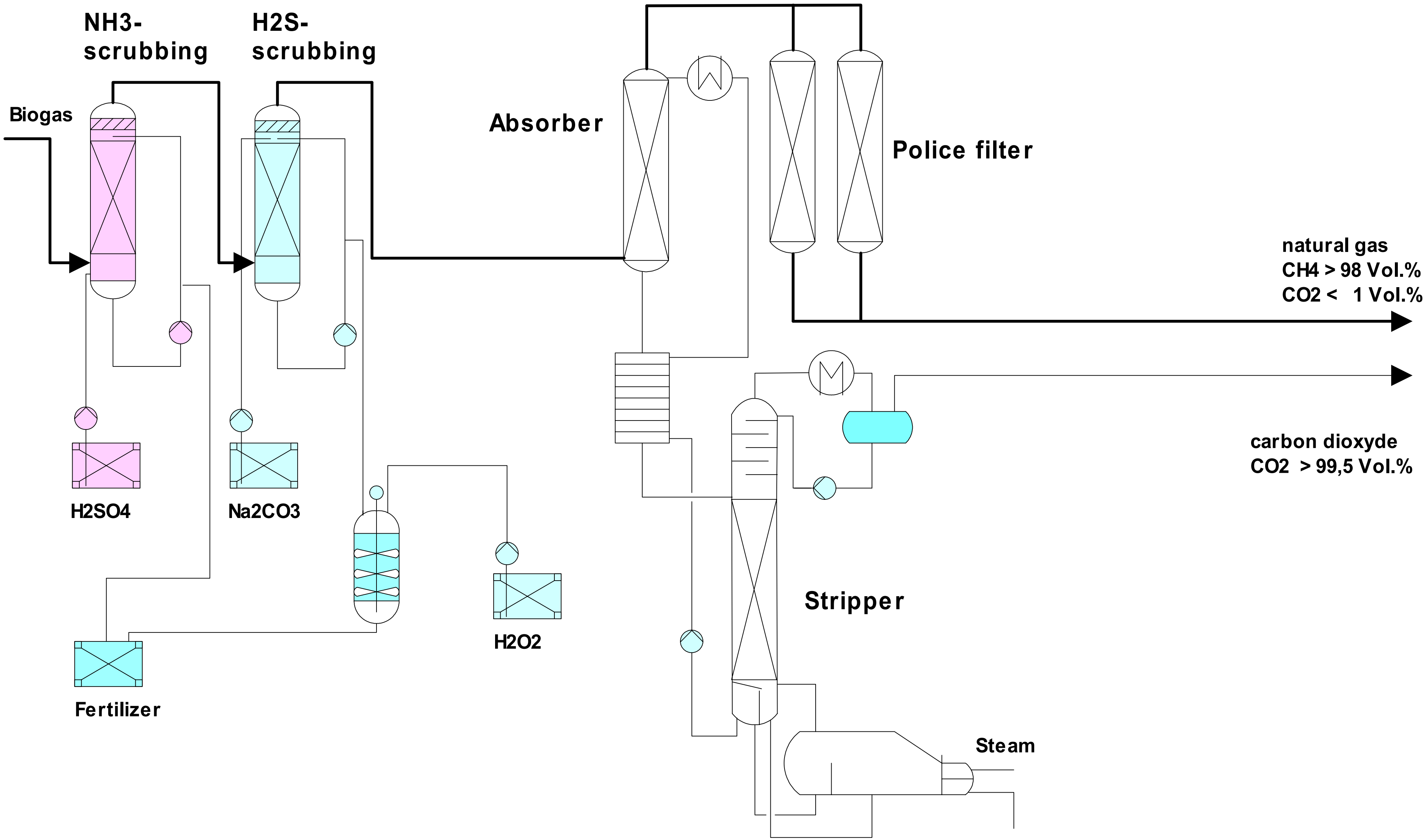
Enclosures

1-1 Drawing of method BCM 0
1-2 Drawing of method BCM 1
1-3 Drawing of method BCM 2
1-4 Drawing of method BCM 3
1-5 Drawing of method BCM 4

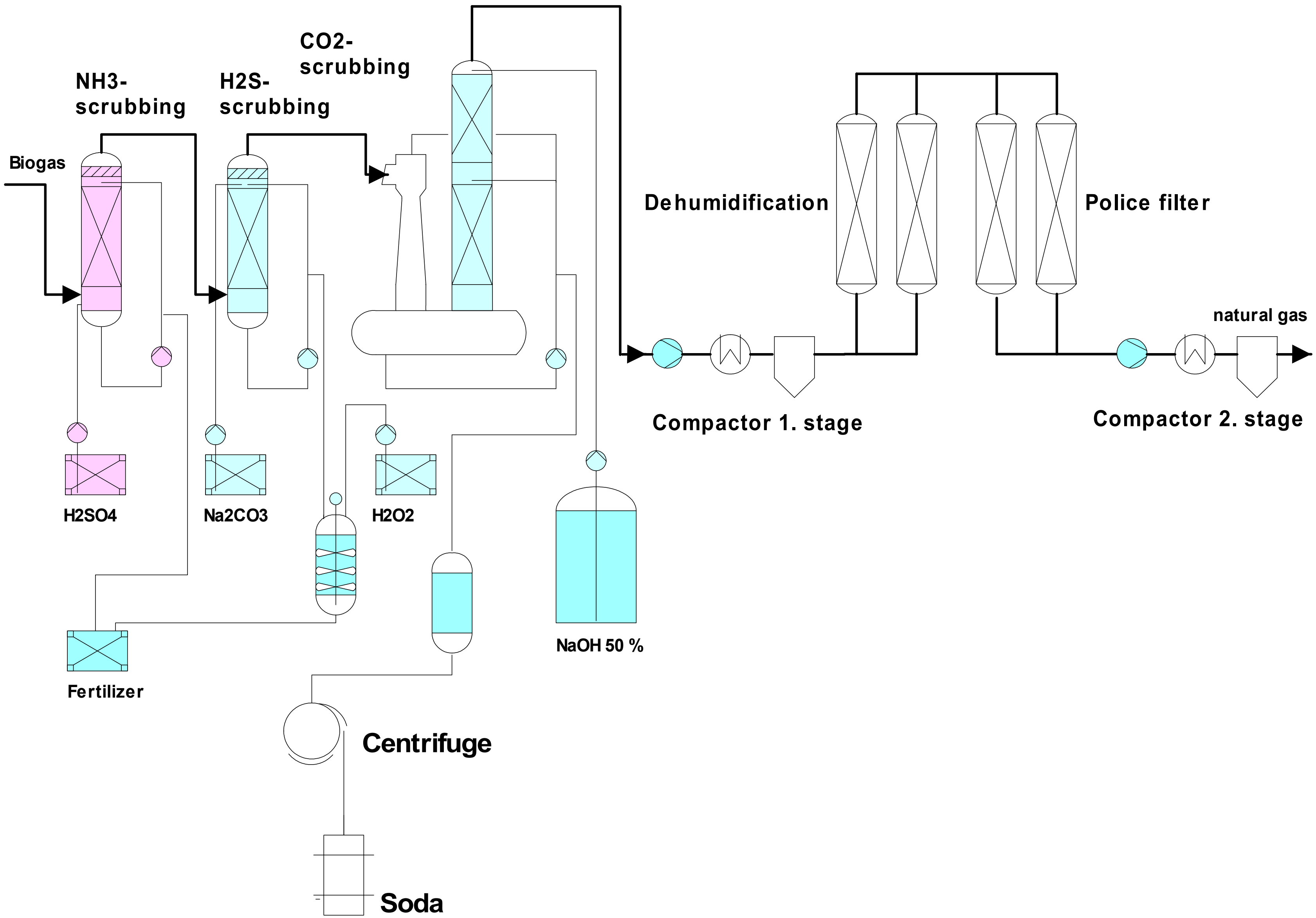
2-1 Diagram process of biogas treatment – natural gas with substance use
2-2 Diagram process of biogas treatment – profitability calculation of methods
2-3 Diagram process of biogas treatment – calculated amortisation of methods

3 Why biogas?

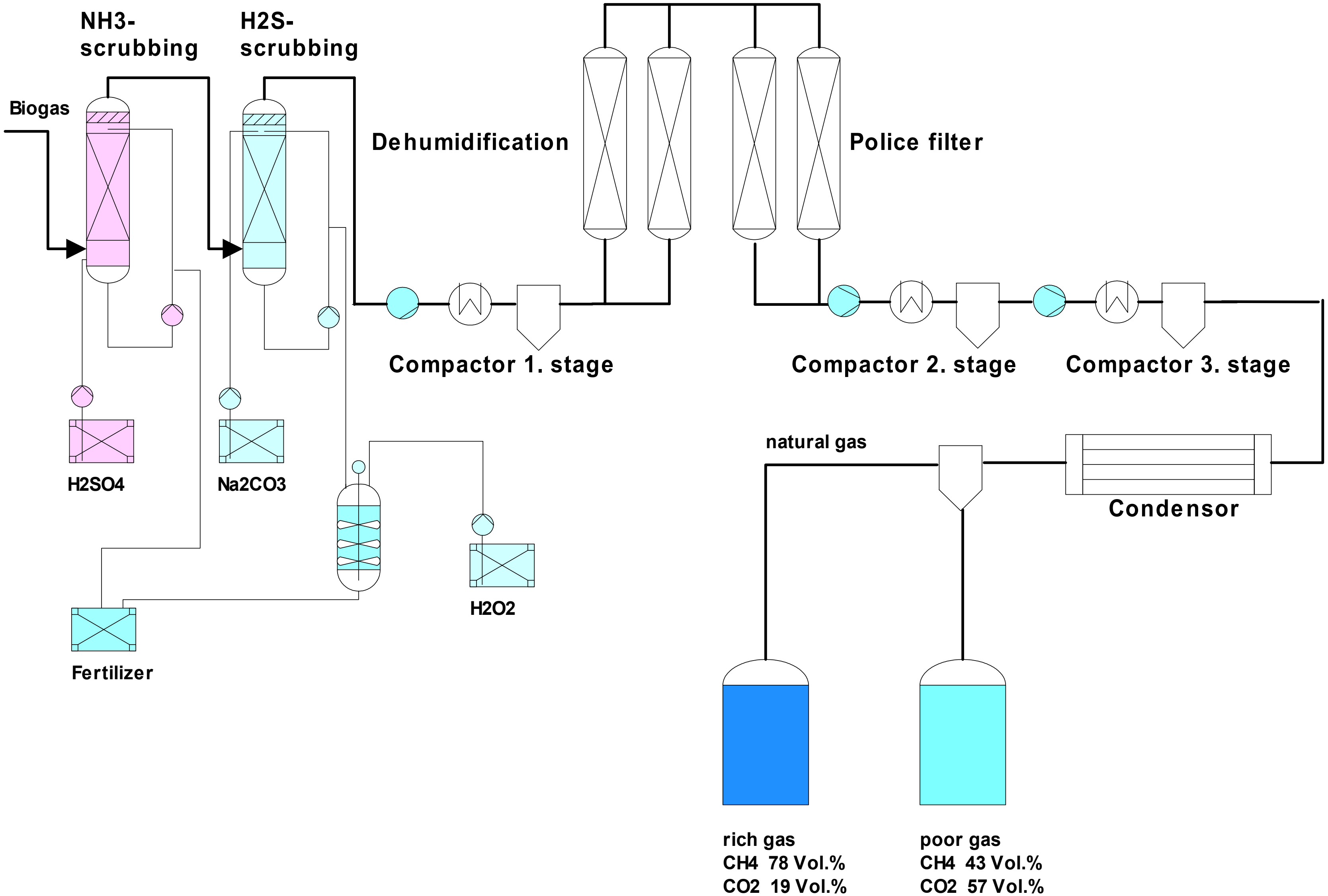
4 Questionnaire



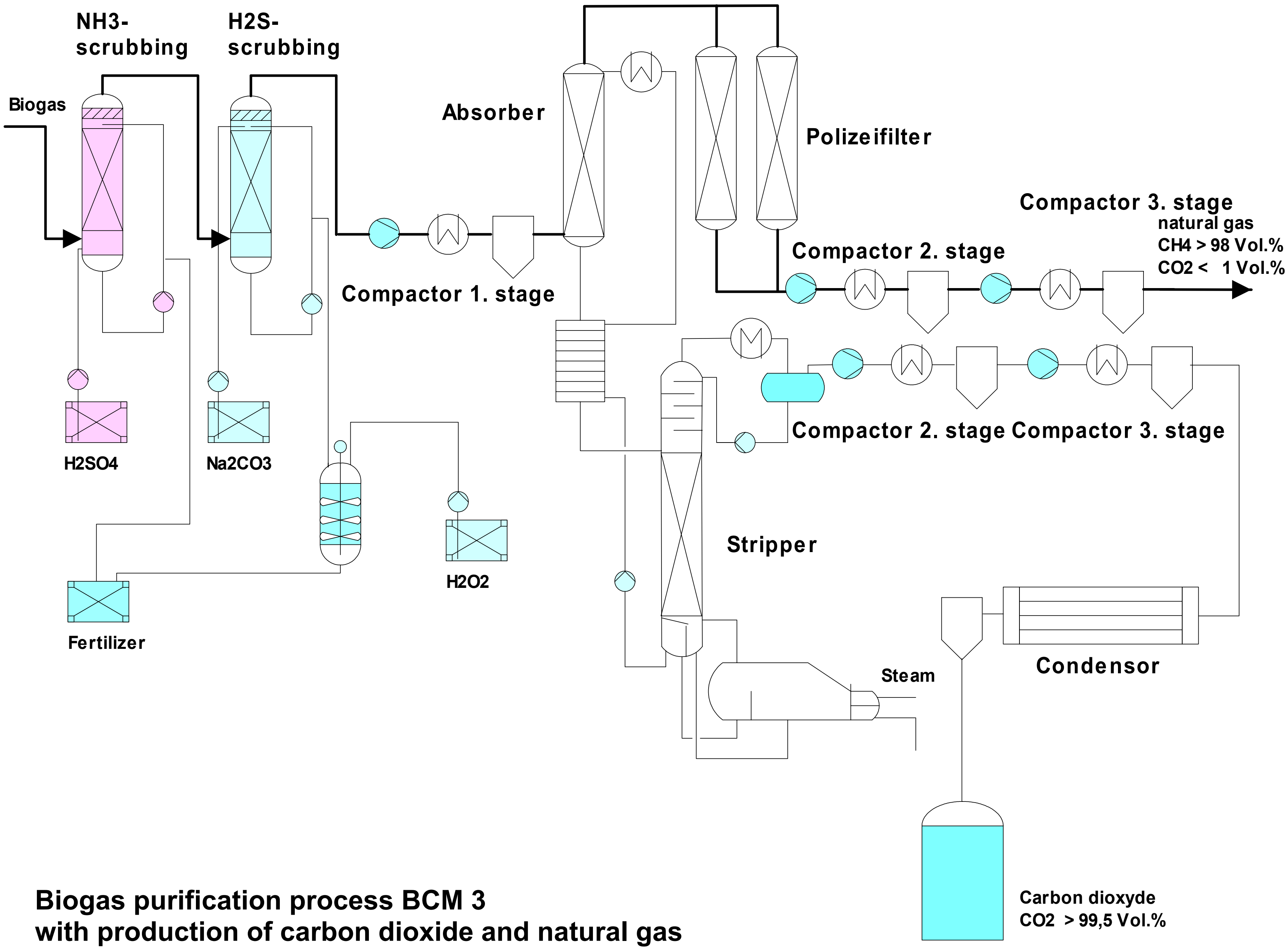
Biogas purification process BCM 0
Basic variant for natural gas quality



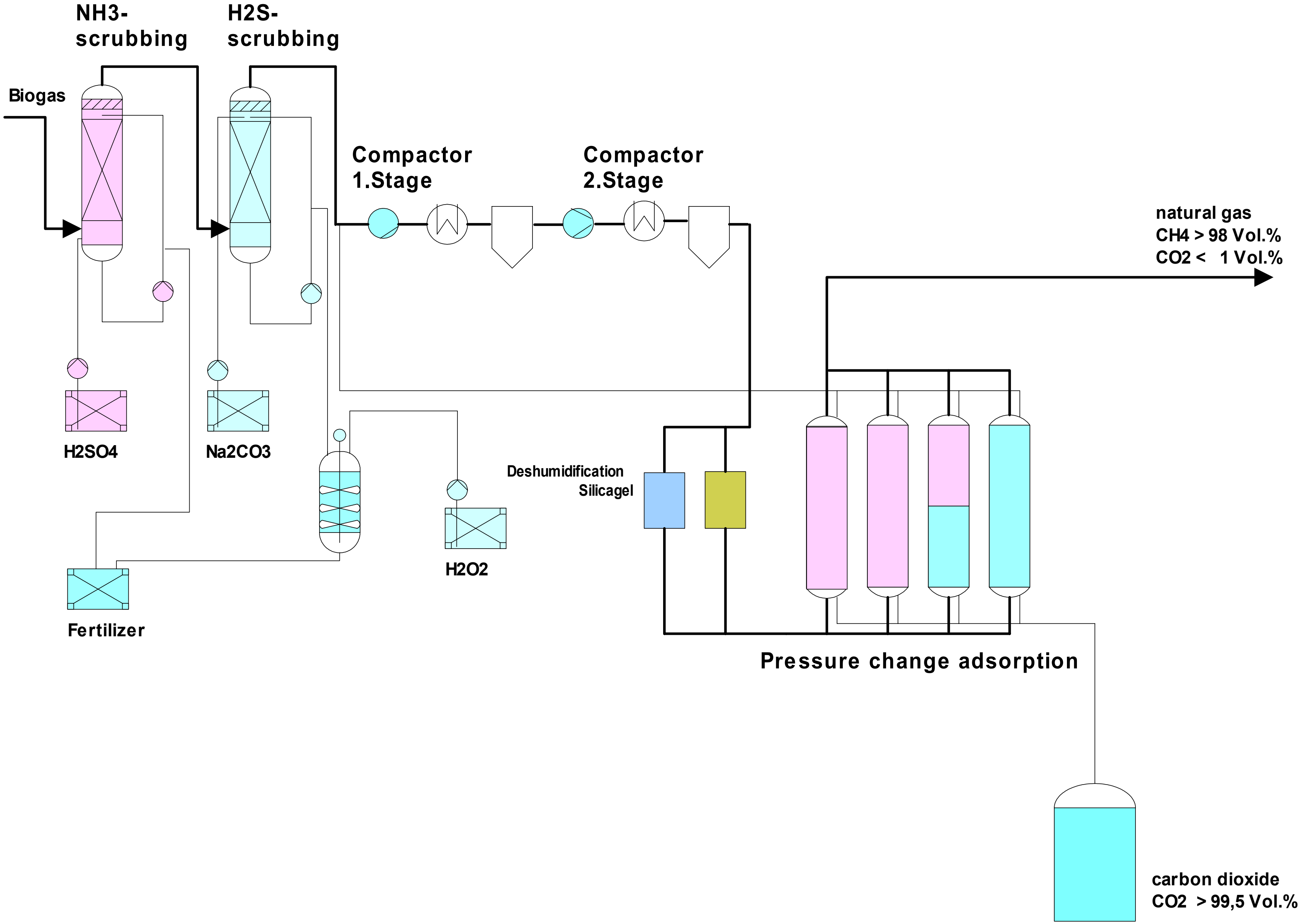
Biogas purification process BCM 1 with production of soda



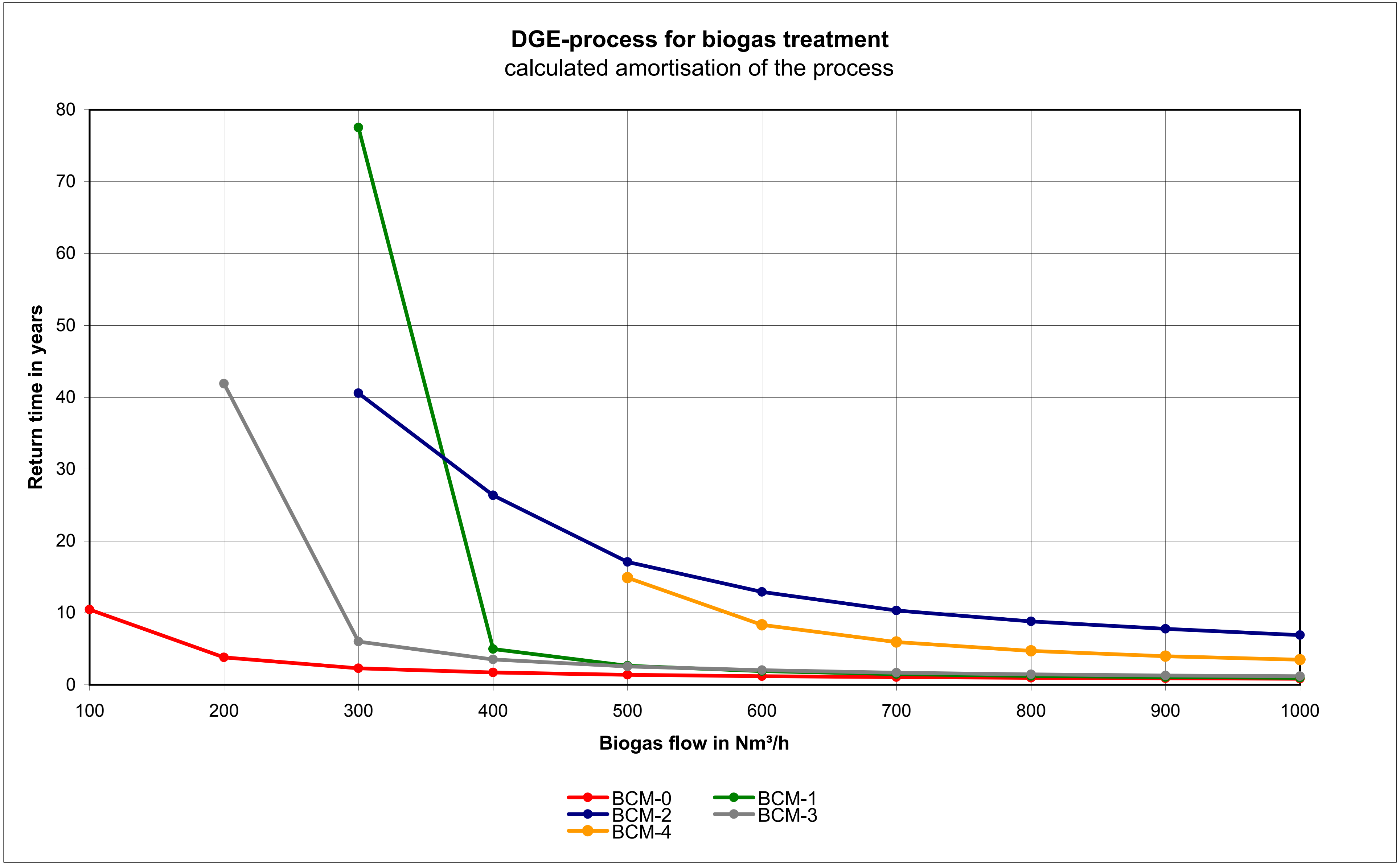
Biogas purification process BCM 2 with pressure condensation

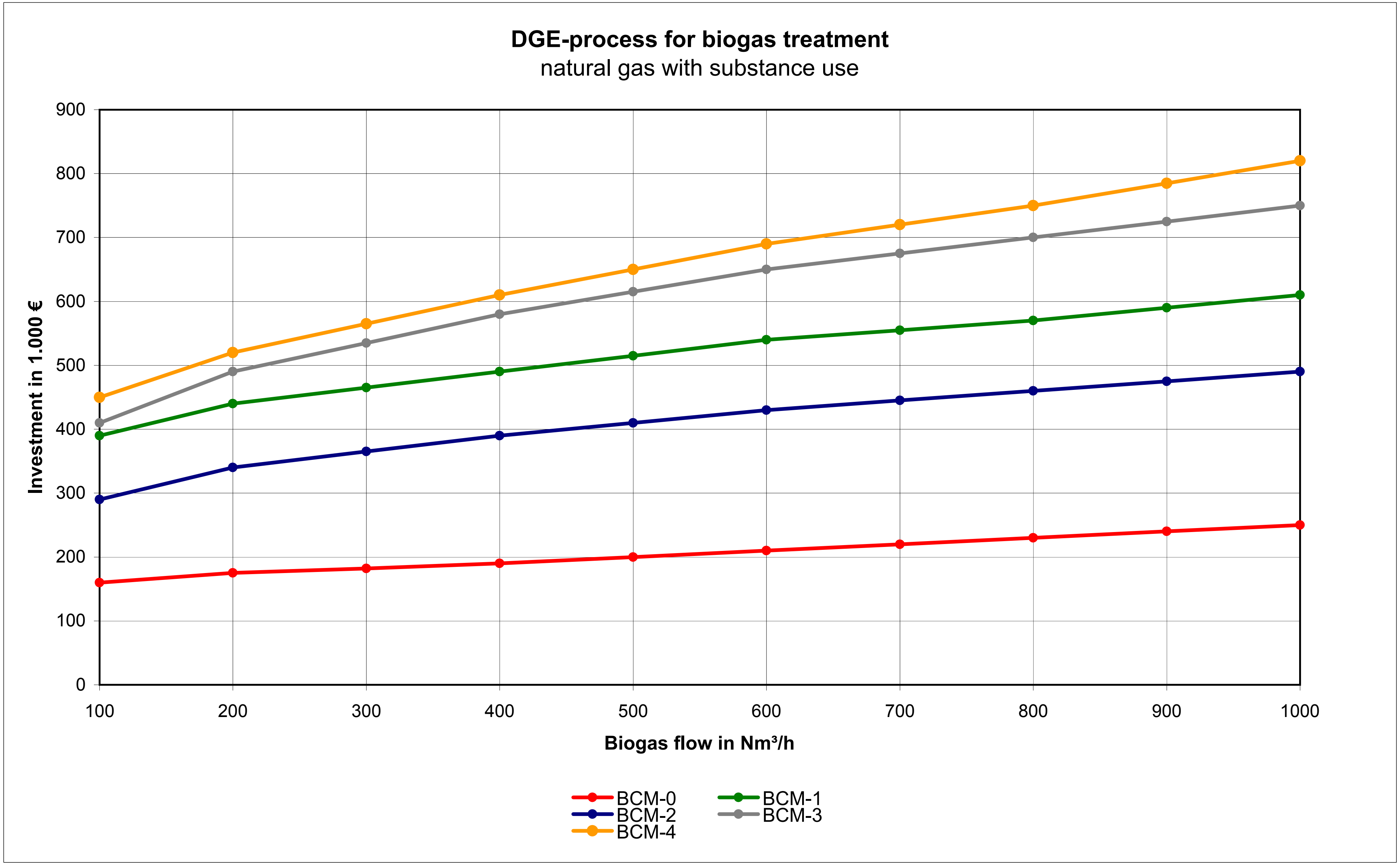


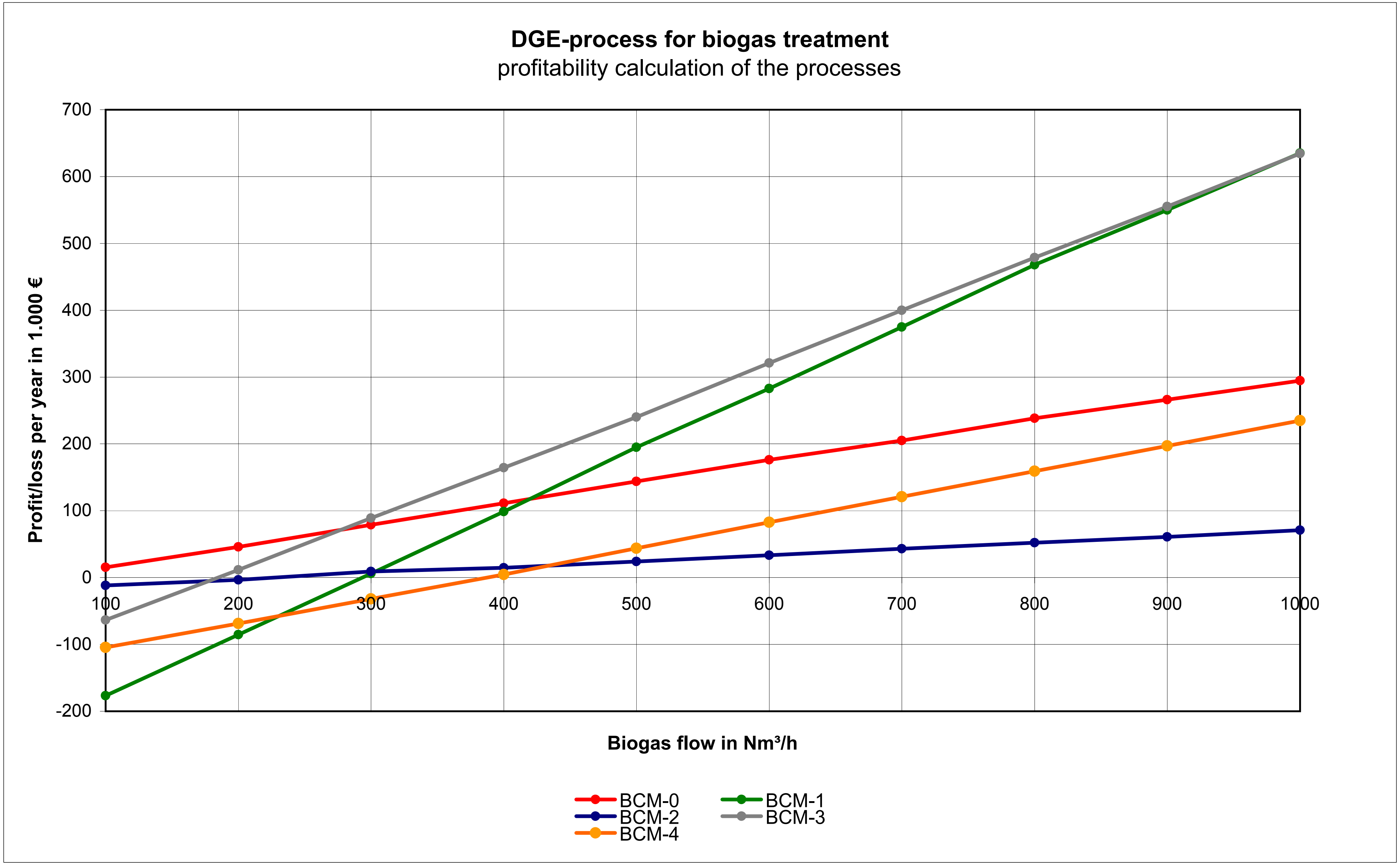
Biogas purification process BCM 3
with production of carbon dioxide and natural gas



Biogas purification process BCM 4 with production of carbon dioxide and natural gas


DGE-process for biogas treatment
calculated amortisation of the process
Return time in years
Biogas flow in Nm³/h
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
700
800
900
1000
BCM-0
BCM-1
BCM-2
BCM-3
BCM-4


DGE-process for biogas treatment
natural gas with substance use
Investment in 1.000 €
Biogas flow in Nm³/h
900
800
700
600
500
400
300
200
100
0
100
200
300
400
500
600
700
800
900
1000
BCM-0
BCM-1
BCM-2
BCM-3
BCM-4

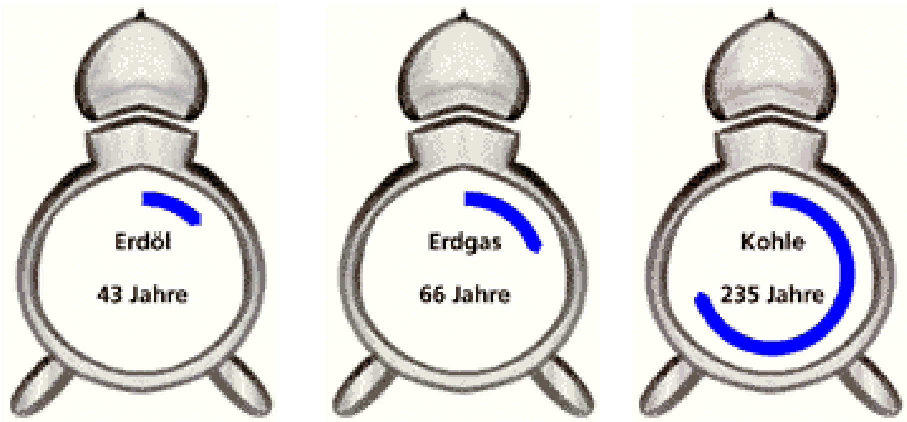

DGE-process for biogas treatment
profitability calculation of the processes
700
600
500
400
300
200
100
0
-100
-200
Profit/loss per year in 1.000 €
100
200
300
400
500
600
700
800
900
1000
Biogas flow in Nm³/h
BCM-0
BCM-1
BCM-2
BCM-3
BCM-4

Why biogas?

Nobody can tell exactly how large are the reserves that fossil energy bearers hold in store, and nobody can predict how these reserves will be consumed over time in the future. After all, it is entirely up to us, whether we consume a lot of energy or a little. The prospects, however, are such that the world consumption will be rising rather than falling. Enhanced industrialization is under way particularly in Asia and South America.

It is possible to easily predict the statistical outlook for the reserves, well known to us. At the current rate of consumption, we must count on running out of petroleum and natural gas within the course of the next 40 to 50 years. Although there are reserves available for another extra 10 years, the problem remains the same. Shall the rate of consumption keep on rising, the reserves could be depleted earlier than expected. The supplies of petroleum are being reduced long before they are expected to be used up. The process of extracting petroleum will be getting more difficult and more expensive as well. That, in turn, will lead to a substantial increase in prices, and under certain circumstances, even to fights over how the reserves will be divided.

Since there is still a lot of time available for the implementation of a change in the energy-supply structure, it is the right time to consider the possible alternatives.



The graphical representation of the statistical outlook for petroleum, gas and coal. (1994)

Source: www.hyweb.de

Questionnaire for clients in agriculture and industry
For biogas equipment conception

Dr.-Ing. Günther Engineering GmbH

Send please the completed questionnaire back to the following address:

DGE GmbH
Hufelandstr. 33
06886 Wittenberg

Fax: 03491-661842

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1. Address

Firm: ____________________
Contact person: ____________________
Street: ____________________
Organization number
Postcode, place ____________________
Telephone, Fax: ____________________

2. Power situation

2.1 Electric power consumption

Proper electric power consumption	kW / year	
Cost of electric current	EUR /year	
Mode of statement of cost (electric supply meter, 96 hours electricity meter, high/low rate)		
Name of power supplier		
Existing power supply (middle, low voltage etc.)		
Distance to the nearest transformer and transformer power	m	kW

2.2 Heat consumption

Has to be connected the proper buildings to biogas heat?

□ Yes
Number of residential houses □ 1 □ 2 □ 3 □ stable/cowshed □ operating building

The present fuel kind	Heat consumption in summer (April – September)	Heat consumption in winter (October - March)	Approximate yearly cost
			EUR
			EUR

You can state your consumption above all in kWh or also in liters (heating oil) or eventually in cubic meters (natural gas).

□ Not

Are there in your neighbourhood eventual heat consumers?
For example garden centres, drying equipments, schools, hospitals, an existing network of long-distance heat supply etc.

Type of heat consumer	Heat consumption in summer (April – September)	Heat consumption in winter (October - March)	Distance
			m
			m

2.3 Natural gas consumption

Natural gas proper consumption	kW /year
Cost of natural gas	EUR/year
Mode of statement of cost	
Name of power supplier	

Are there in your neighbourhood eventual natural gas consumers?
For example industrial plants etc.

Type of heat consumer	Heat consumption in summer (April – September)	Heat consumption in winter (October - March)	Distance
			m
			m

2.4 Consumption of natural gas for vehicles

Natural gas proper consumption	KW /year
Cost of natural gas	EUR /year

2.5 Carbon dioxide consumption

Carbon dioxide consumption	kW /year
Cost of carbon dioxide	EUR /year

3. Amount of cattle

Kind of animals (precisely if possible please) Heifers	Number of heads of cattle / places	Cattle unit	Mode of location	Liquid manure quantity

In case of free breeding specify please number of days, mode of location.

Straw litter: □ Yes _______ hectare/year
_______ quintal/year

□ Not

4. Cofermentation

Does exist a prospect of cofermentation of additional waste:
For example: scraps, vegetables waste, slaughterhouse waste or dairy waste, meal waste, oils, fats, etc.?

□ Yes (complete please the following table) □ Not

Kind of waste	Period	Quantity a year	Origin	Price/t from farmstead

5. Further completing data

- Connection to canalization ☐ exists ☐ is planned ☐ none of the two variants
- Existing capacity for storing liquid manure ___________________ m³
- Area utilized for agriculture in total ___________________hectare
  hired ___________________ hectare
- Which amount of area taken away is at disposal
  at the present time? ___________________ hectare
- How many hectares would be at disposal
  for growing of growing up raw materials
  (voluntary taking away) ___________________ hectare
- I am interesting in full financing the equipment ☐ yes ☐ not