REGATRACE
Renewable Gas Trade Centre in Europe

Feasibility analysis for Biomethane production – Czech Republic

Deliverable:	Feasibility analysis of Biomethane production (CZ)
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Version:	Final
Quality review:	Stefano Proietti (ISINNOVA)
Date:	11/10/2022
Dissemination level:	Public
Grant Agreement N°:	857796
Starting Date:	01-06-2019
Duration:	42 months

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This project receives funding from the European Union's Horizon 2020 Framework Programme Research and Innovation under Grant Agreement no. 857796

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Abbreviations

AD	Anaerobic Digestion
CAPEX	Capital Expenditures
CHP	Combined Heat and Power
CNB	Czech National Bank
CNG, bioCNG	Compressed Natural Gas, Compressed Biomethane
CO_2	Carbon Dioxide

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DM	Dry Matter
DS	Distribution System
DSO	Distribution System Operator
ERO	Energy Regulatory Office
EU	European Union
GHG	Green House Gas
GoO	Guarantees of Origin
H_2S	Sulphane
CH_4	Methane
LNG, bioLNG	Liquefied Natural Gas, Liquefied Biomethane
MIT	Ministry of Industry and Trade
NPV	Net Present Value
OP PIK	Operational Programme Enterprise and Innovation
OP TAK	Operational Programme Technologies and Applications for Competitiveness
OPEX	Operating Expense
PoO	Proof of Origin
PoS	Proof of Sustainability
RED II	Renewable Energy Directive (EU) 2018/2001
RHI	Renewable Heat Incentive
SEF	State Environmental Fund
UK	United Kingdom
VOCs	Volatile Organic Compounds
WACC	Weighted Average Cost of Capital

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1 Introduction

The company operates a biogas plant in a city located in the North of the Czech Republic and is interested in entering the market for the production and use of biomethane in the Czech Republic and the EU. For the purpose of this development, it is carrying out a feasibility analysis of the biomethane production technology.

CzBA developed a feasibility analysis under the project REGATRACE following the deliverable D6.4 Guidelines for feasibility analyses.

2 Market feasibility – basic description of the functioning of the biomethane market

2.1 Overview of biomethane use in the Czech Republic and the EU

Biomethane is the technical equivalent of natural gas. The possible applications thus follow the fields of application of natural gas. The only difference, which is also a fundamental pillar for the development of biomethane production and use, is the lower greenhouse gas emission profile compared to natural gas.

Biomethane has been widely used abroad (EU) for about 20 years. The main motive for the expansion of biomethane has been the possibility to use the low emission profile of biogas (agricultural, wastewater, etc.) within any location connected to the gas infrastructure. Thus, currently biomethane is used in transport (bioCNG, bioLNG), heating, electricity generation and as a material feedstock in the chemical industry. Current EU biomethane production is 2.1 bcm, i.e., about 21 TWh per year. Motivations to buy biomethane vary and in principle we can identify the following groups of consumers:

- Households (motivated customer demanding low-emission fuel)
- Corporate industry (for reasons of green image)
- Industry because of the elimination of emissions footprint charges (direct charges e.g., ETS, environmental taxes)
- Industry for financial bonus (e.g., RHI in the UK)
- Subsidy recipient due to compliance with subsidy rules (e.g., subsidies for building heating systems, subsidies for purchase of CNG vehicles, etc.)

In the Czech Republic, biomethane is used almost exclusively in CNG distribution. The use and consumption of biomethane is thus directly linked to the obligations arising from Section 20 of Act 201/2012 Coll. (Air Protection Act). This obliges fuel suppliers to reduce greenhouse gas emissions. According to this law, fuel suppliers can count the greenhouse gas savings from the sale of CNG and any bioCNG/CNG blends against the overall emission reduction requirements. At the same time, the Act allows fuel suppliers to pool their GHG savings for reporting purposes. This effectively allows the creation of reporting entities composed of

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petroleum fuel suppliers and, for example, exclusive CNG suppliers. This creates a real demand for biomethane for the purpose of increasing its share in CNG, thus creating a more advantageous position for joint reporting of GHG savings.

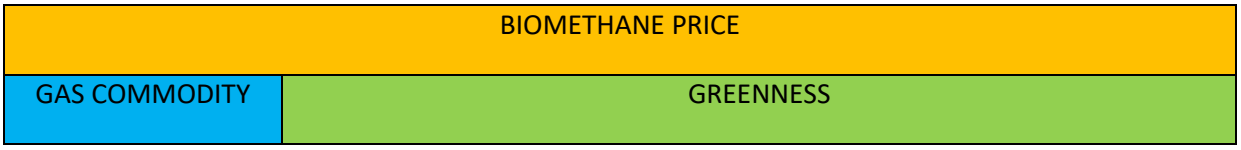
The second area of initial biomethane consumption in the Czech Republic is the MIT subsidies for the purchase of CNG buses. In the new subsidy conditions (2020) there is a requirement for partial use of biomethane or bioCNG during the sustainability period of the projects supported. This subsidy condition creates the initial second part of the domestic demand for biomethane within the Czech Republic.

Local consumption of biomethane by environmentally motivated households and industry is currently marginal.

2.2 Introduction to biomethane pricing, characterization of key parameters

The price of biomethane is composed of two basic components (Figure 1). The first component is the commodity price of gas, which represents the value of the real recoverable heat of combustion. This price reflects the price of natural gas and is thus independent of the use of biomethane as a low-emission energy source. The second component of the biomethane price is the Greenness, which reflects the low carbon nature of the fuel. Given that Greenness is applied in relation to tax, subsidy and other fiscal incentives, its value is independent of the commodity price of natural gas. Thus, the total price of biomethane is the sum of two fundamentally independent prices.

Figure 1: Biomethane price composition



The commodity price of natural gas has always been considered to be relatively constant (EUR 15.276/MWh, October 2020). However, it has risen significantly over the last year, and especially in recent months. As of 21/10/2021, it reached 57 EUR/MWh. This increase dramatically changes the price of biomethane, with the commodity price reaching almost the value of Greening. The reason for the increased gas price is mainly due to the EU's move away from long-term gas supply contracts (Third Energy Package; 2009/73/EC) and the mandatory use of only the short-term (exchange) market analogous to the electricity market. This fundamental change, together with higher prices for all energy in the recovery period after the economic shutdowns of 2020-2021, is very likely to affect the natural gas market for a longer period of time.

Greenness represents the market valuation of the low-emission characteristics of biomethane. Creating and communicating Greenness is the foundation of the biomethane market. There are basically two ways in which this information is processed. The first system is the "Book-and-Claim" method and the second is the "Mass-Balancing" method. These very different approaches are how biomethane trading differs fundamentally from renewable electricity trading.

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The **Book-and-Claim** method is analogous to the green certificate trade in the electricity trade. In principle, it is a simple process whereby a number of green certificates corresponding to the amount of heat of combustion is generated when biomethane is injected into the natural gas network. Green certificates can be traded in a similar way to green certificates for the origin of electricity. The green certificate becomes a financial derivative and is thus independent of the possession of a certain amount of gas (analogous to the functioning of an emission allowance market). The green certificate is an older way of trading the greenness of biomethane. A Green Certificate is usually issued by a private authority (in principle it can be the biomethane producer itself), audited by an independent external auditor. In principle, Green Certificates can only be used for a group of motivated customers who demand a renewable energy source, but not necessarily a low-emission energy source. The green certificate does not contain information on the emission footprint of the biomethane, but only information on the amount of combustion heat of the biomethane injected into the natural gas network. A demonstrative example of the use of this method of tracking and selling Greenness would be the production of biomethane from energy crops and the sale of the gas to residential or corporate customers demanding a green image.

The second way is the **Mass-Balancing system**. A detailed explanation of this scheme is beyond the scope of this techno-economic analysis. The basic principle of this method is that Greenness is at no point in its lifetime detached from the actual commodity gas component. Thus, the Greenness component does not become a financial derivative, and its ownership can only pass under the condition that ownership of a specified quantity of natural gas is transferred simultaneously. The main reason for the creation of this scheme was the demand for the possibility to use biomethane as bioCNG/bioLNG. In the case of the use of biomethane as a biofuel, the biomethane becomes a biocomponent in the blended fuel and must strictly comply with the rules defined for biofuels in general. Here, the contractor has to state the fact that these rules have been developed for liquid biofuels and their implementation in the case of gaseous biofuels proves to be robust, but nevertheless very complicated. One of these rules is Sustainability verification. Sustainability Verification is defined in Regulation COM 2010/C 160/01 "The process by which the link between information and declarations on raw materials or intermediate products and declarations on the final product is established is known as the processing chain."

Due to the fact that this system allows a very **detailed tracking of the origin of the biomethane** from its production materials to the CNG dispenser, it is increasingly being used, even in cases where the biomethane is not primarily used as CNG, e.g., for heating or power generation. This system, together with sustainability verification, is also foreseen by the currently approved amendment to the **Act on Supported Energy Sources No. 382/2021 Coll.**, which was published in the Collection of Laws on 18 October 2021 (effective from 1st January 2022).

The basis of the mass-balancing system is the Guarantees of Origin (GoO). The Guarantee of Origin has two essential components. The first component of the GoO is the Proof of Origin (PoO), which contains a detailed description of the path of the biomethane from production to the consumer. The second component is the Proof of Sustainability (PoS), which contains a relatively detailed description of the raw materials and technology used to produce the

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biomethane. The final part of the PoS is also **the emission footprint of the biomethane in kg CO_2/ 1 MWh**. The PoS is regularly audited by an external auditor.

As a result, the **GoO is an electronic data file** that accompanies the sales of biomethane or its blends with natural gas. The data file is always updated in its PoO section with details of the transfer of ownership.

In the conditions of the amended Energy Act (No. 362/2021 Coll.) and the Act on Supported Energy Sources (No. 382/2021 Coll.), **the system of the national GoO administrator will be implemented by OTE, a.s.** The method of PoS audit will be determined by an implementing decree. Considering the arrangement of supervisory and control functions in the Czech energy sector, the authors speculate that the State Energy Inspectorate will be entrusted with the performance. The importance of the GoO will then be underlined by the \fact that the self-generated GoO will be offered for exchange through OTE, a.s. at a price set by the national regulator (ERO). The transfer of the Greenness to the State, represented by OTE, a.s., will thus be a condition for the payment of State operation support for biomethane production. In the case of interest in exporting biomethane abroad, OTE, a.s. will represent the national registry that will monitor and clear cross-border transfers following cooperation with foreign national registries or with the pan-European Renewable Gas Registry (ERGaR).[1]

2.2.1 Characteristics of key parameters of biomethane production

The key parameters of biomethane production are those that are monitored in the PoS and thus have a real impact on the selling price of biomethane. These parameters are summarized in the table.

The technological parameters, or elements, are determined by the RED II Directive (COM 2018/2001/EU). The substrate parameters are given for guidance only.

[1] The ERGaR system was created by existing national registries to clear cross-border transfers of GoO biomethane and other renewable gases. The system is currently in pilot operation for selected cross-border transactions.

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Table 1: Key parameters of biomethane production

Positive technology	Negative technology	Substrate	Emission profile	Biomethane price
Closed end storage Off-gas processed		solid manure, liquid manure	Best, +++++ even negative values compared to NG	Highest
		Biowaste	Very good, ++++	High
		Energy crops	Good, ++	Middle
Closed end storage	Off-gas into the atmosphere	solid manure, liquid manure	Very good, ++++	High
		Biowaste	Good, ++	Middle
		Energy crops	Sufficient, +	Low
Off-gas processed	Open end storage	solid manure, liquid manure	Good, ++	Middle
		Biowaste	Sufficient, +	Low
		Energy crops	Insufficient, 0	Very low
	Open end storage Off-gas into the atmosphere	All	Insufficient, 0	Lowest

A graphical overview of these parameters is summarized in the figure (Figure 2). It can be seen from the figure that the highest emission savings compared to the corresponding fossil fuel, which in the case of gaseous fuels is natural gas, can only be achieved with a fully specified configuration of the technology and substrates used. Increased demands then apply when biomethane is required to be applied as bioCNG/ bioLNG. In this case, a minimum emission saving of 70 % compared to the corresponding fossil fuel must be achieved. This limit is then represented by the red line in the figure. It is clear from the figure that in the case of bio-waste treatment, an emission saving of 70% compared to natural gas can only be achieved if a closed-end storage technology is chosen and the residual gas after biogas upgrading (off-gas) is treated at the same time.

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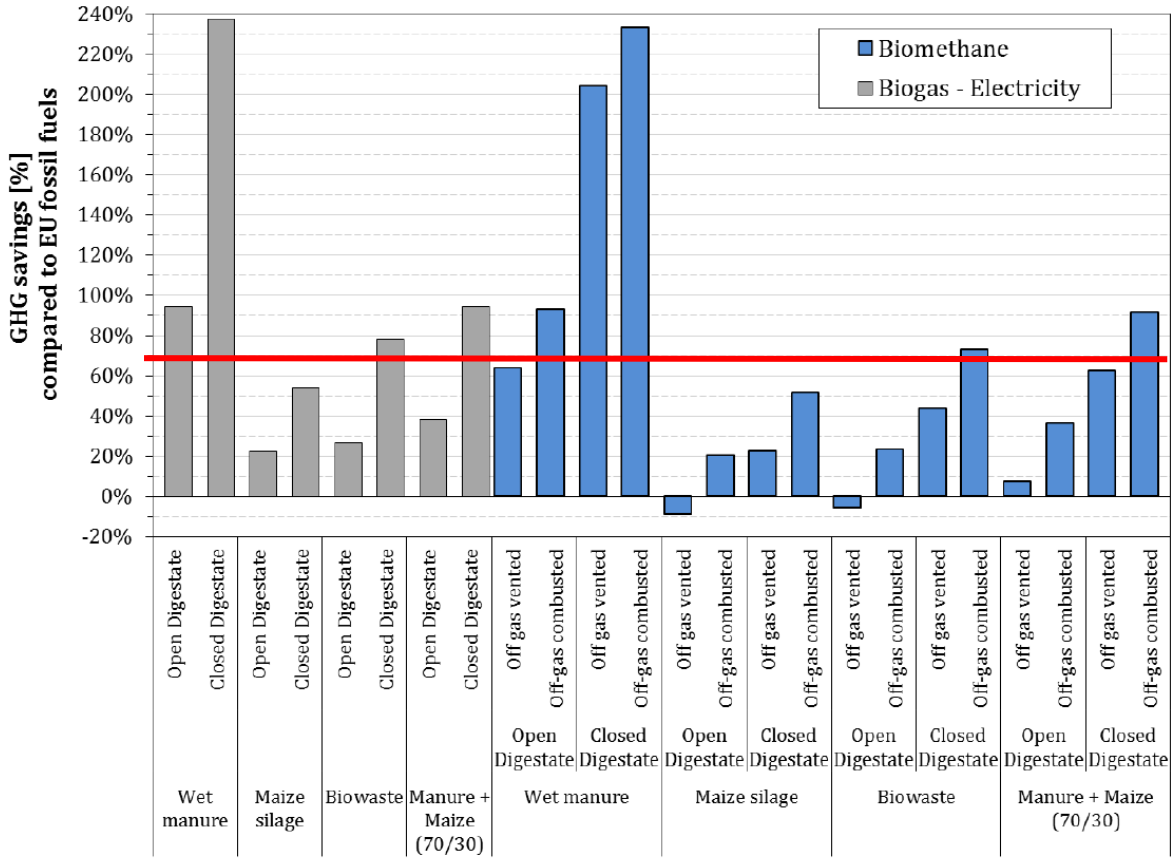
Figure 2: GHG savings [%] compared to EU fossil fuels.



For **the selection of specific values** used in the processing of the PoS, the values listed in the annexes of RED II (default values), which are the basis for the graph in Figure 2, or values measured at the expense of the technology operator and audited by an independent auditor (actual values) are normally used.

2.3 Defining the pricing framework for the cash flow of the project

For the purpose of **creating a cash-flow model**, a starting price frame needs to be determined. Active demand was used to determine the value of Greenness. With active demand, it was assumed that the **biomethane produced meets the sustainability criteria required for transport use**. The current value is 60-72 EUR/MWh. The commodity price value of natural gas is then solved in two alternative models. The conservative model assumes a natural gas value at the historical average. The optimistic model then assumes the value of natural gas at the current price level.

Figure 3: Initial price framework

CONSERVATIVE MODEL; BIOMETHANE PRICE = 85.- EUR/ MWh	
GAS, 20.- EUR/ MWh	GREENNESS, 65.- EUR/ MWh
OPTIMISTIC MODEL; BIOMETHANE PRICE = 120.- EUR/ MWh	
COMODITY GAS, 55.- EUR/ MWh	GREENNESS, 65.- EUR/ MWh

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3 Technical feasibility – Basic description of technical conditions for biomethane production

3.1 Biogas quality requirements

The biogas upgrading technology itself separates methane (CH_4) and carbon dioxide (CO_2). Removal of reactive gases (**ammonia and sulphane**) is the main process of biogas conditioning before the actual upgrading. The biogas quality requirement is thus mainly to ensure low sulphate concentration and moisture reduction.

At the same time, the biogas must be **free of other non-reactive gases**, mainly oxygen and nitrogen, i.e., residues from the addition of air to the biogas for process purposes. This limitation is essential when choosing a biogas desulphurisation technology.

When evaluating the operating data of the AD plant, it is absolutely essential to **determine the sulphate concentration** present in the raw biogas before desulphurisation. Due to the fact that the biogas is produced in continuous desulphurisation technology using air microaeration, it is not possible to determine the sulphate concentration directly by measuring its content in the biogas. In order to calculate the concentration in raw biogas, a model has been developed that determines the sulphate concentration based on the balance of feedstock. The feedstocks used for biogas production have a characteristic elemental composition, and it is thus possible to determine the material balance of each element. The average values of the material balance of sulphur, from the period January 2019 to August 2021, are shown in the following table (Table 2).

Table 2: Average Sulphur balance, AD Plant 2019-2021.

	Sulphur load (kg/month)	H_2S output (kg/month)	H_2S output (g/m^3)	H_2S output (ppm)
Average value	410	436	3,42	**2.250**

This table clearly shows that without the existing micro-aeration, the sulphate concentration would be relatively high at around 2.250 ppm[2]. This concentration is too high for the biogas upgrading input.

There are basically three options to reduce the sulphate concentration sufficiently. An overview of these technologies is given in the table (Table 3). When comparing the different options, we recommend using micro-oxidation by pure oxygen.

[2] Assuming equilibrium between the liquid and gas phases, at a given temperature, pH, and pressure, the proportion of sulphate in the aqueous phase is about 20%, i.e., sulphate dissolved in the aqueous phase that does not pass into the gas phase.

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Table 3: Sulphane removal options

Technology	Advantages	Disadvantages	Usability
Microaeration	Current solution	Oxygen and nitrogen input to biogas	**NO**
Microoxidation by pure oxygen	Low CAPEX, OPEX	Consistent control of residual oxygen concentration	**YES**
Biological desulphurisation	High CAPEX, low OPEX	High investition	**YES**
Activated carbon	Middle CAPEX, high OPEX	High consumption of activated carbon	**YES**

3.2 Quality requirements for biomethane as an output product

The requirements for the quality of the injected biomethane are clearly set by Decree No 108/2011 Coll[3]. The quality parameters are summarised in the following table (Table 4).

Table 4: Composition of gaseous fuels - requirements for biomethane quality parameters.

Parameter	**Unit**	**Value**	
		Transmission system, gas storage and production pipelines	**Distribution system**
Methane content - the specific value is specified in the connection contract	% mol.	≥ 95	≥ 95
Ethane content	% mol.	≤ 3	≤ 3
Propane content	% mol.	≤ 3	≤ 3
Sum of Butane content	% mol.	≤ 1	≤ 1
Sum of Pentane and higher carbohydrates	% mol.	≤ 0.5	≤ 0.5
Water dew point - the temperature at which, at a pressure of 4 MPa, water condenses from the gaseous to the liquid phase	°C	≤ -7°C	≤ -7 °C
Dew point of hydrocarbons - the temperature at which condensation of hydrocarbons from the gas phase to the liquid phase occurs at operating pressure	°C	0°C	0°C
Oxygen content	% mol.	≤ 0,02	≤ 0,5

[3] Decree on Gas Metering and on the Method of Determining Compensation for Unauthorised Taking, Unauthorised Delivery, Unauthorised Storage, Unauthorised Transportation or Unauthorised Distribution of Gas

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Carbon dioxide content	% mol.	≤ 3	≤ 5
Nitrogen content	% mol.	≤ 3	≤ 3
Hydrogen content	% mol.	≤ 0,01	≤ 0,1
Total Sulphur content	$mg.m^{-3}$	≤ 30[1)]	≤ 30[1)]
Sulphane content	$mg.m^{-3}$	≤ 5[1)]	≤ 5[1)]
Ammonia content	$mg.m^{-3}$	≤ 10[1)]	≤ 10[1)]
Halogen content (F, Cl)	$mg.m^{-3}$	≤ 1,5[1)]	≤ 1,5[1)]
Organic silicon content - the specific value is specified in the connection contract	$mg.m^{-3}$	≤ 0,3-1[1)]	≤ 0,3-1[1)]
Particle size / dust, rust	micrometers	≤ 3	≤ 5
Content of harmful living micro-organisms		absent	absent
Temperature	°C	from 0 °C to 40 °C	from 0 °C to 20 °C for < 0,4 MPa and from 0 °C to 40 °C for > 0,4 MPa
Content of selected volatile aromatic hydrocarbons - benzene, toluene, ethylbenzene, xylene	$mg.m^{-3}$	≤ 10[1)]	≤ 10[1)]

[1)]Values at reference conditions

The methods of measurement and the required frequency of individual analyses are defined by Decree No. 459/2012 Coll. (see Annexes 1 and 2).[4] These requirements represent a common standard in gas industry practice. However, it should be noted that the operation and measurement of the above quantities is many times more complex than in the case of electricity transmission measurement. The measuring instruments, led by the gas chromatograph, require skilled operators.

4 Technical and Economic aspects

4.1 Defining production capacity

Considering the submitted values on raw material consumption and electricity production, in relation to the client's forecast, we set the maximum input capacity of biomethane production at 300 m^3/h, with methane concentration in biogas at **65% CH_4**.

4.2 Definition of the range of technologies, identification of possible suppliers

The definition of the technology range is based primarily on the biogas specification (quantity, source). An overview of the main technologies and their applicability is given below.

[4] Decree on requirements for biomethane, method of measuring biomethane and quality of biomethane supplied to the transmission system, distribution system or underground gas storage facilities

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Water scrubber:

- Robust solution, no biogas treatment required, suitable for large installations from approx. 1.200 m^3/h.
- The specific CAPEX increases dramatically with further scaling down

PSA:

- Suitable for smaller installations (approx. 1.000 m^3/h)
- Suitable for landfill gas or for very strict quality of biomethane at the outlet
- High quality pre-treatment required
- Disadvantage is relatively high OPEX

Membrane separation:

- Suitable for smaller installations (approx. 1.000 m^3/h)
- Suitable for pure biogas
- High costs if biogas pre-treatment fails (destruction and replacement of membranes)
- Low CAPEX, relatively low OPEX with clearly defined operation (see previous)

Chemical separation:

- Suitable for smaller installations (approx. 1.200 m^3/h)
- Less requirements for biogas pre-treatment (but some pre-treatment is necessary, unlike water scrubbing)
- Medium CAPEX, relatively low OPEX
- Lowest electricity consumption of all technologies
- Requires relatively high-quality heat (180 °C)

In accordance with the above, we recommend drafting a proposal of biogas upgrading technology at the AD Plant using membrane separation and chemical separation technology. The individual assumptions for use at the AD Plant are presented in the following table (Table 5).

Table 5: Summary of assumptions for the use of selected upgrade technologies.

Membrane separation	**Chemical separation**
Lower CAPEX	Higher CAPEX
A robust biogas desulphurisation solution will be essential	Quality desulphurisation, but not essential
High OPEX when using adsorbent-based desulphurisation	Approx. 240 kW for sorbent regeneration at 180 °C, possibly supplied from local cogeneration (to be checked with CHP supplier). If not, major problem (heat source).

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Dramatic cost of desulphurisation failure
(complete membrane replacement)

Technology supplier A was selected as the model supplier of membrane separation technology. **Technology supplier B** (Germany) was selected as the model supplier of chemical separation technology.

4.3 Communication of the current price level of supplied technologies

4.3.1 Chemical separation

The offer of chemical separation of biomethane includes all the necessary technological parts, from the intake of raw biogas to the injection into the distribution system. The offer includes the following additional parts:

- Delivery time 10-12 months
- Instalment payment upon signing of the binding order 20% (followed by 25% upon finalisation of the project, 25% before shipment, 25% before commissioning, 5% for handover of the work)
- 12 months warranty
- 21 days for construction included
- Training 2 days theory, 4 days practice included
- Complete documentation in English

A description of the individual components and an indicative quotation from the manufacturer is given below:

Main chemical separation system: €1.445.000

- Biogas cooling, condensate removal (frame for external installation, tubular heat exchanger, biogas blower, local control)
- Residual desulphurisation (3.0 m^3 stainless steel desulphurisation column with operating holes, ladder and working platform, including thermal insulation)
- VOC (volatile organic compound) separation: 3.0 m^3 stainless steel column with operating holes, ladder and working platform, including thermal insulation
- Thermal management (without heat extraction from existing CHP)
- Basic chemical analysis of biogas and biomethane
- Chemical separation unit: 2 × 40 ft ISO container including all internal equipment, scraping column including all equipment, stripping column including all equipment, piping connections
- Adsorption drying of biomethane
- Biomethane cooling

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Injection unit	€249.900

- Main compressor stage (24 bar)
- Main compressor stage (38 bar)

Control and measurement according to DSO requirement	€257.900

- Container transfer station unit, including measurement and regulation

Catalytic oxidation	€78.000

- Catalytic oxidation system for residual methane in the CO_2 waste stream

Total	€2.032.800

4.3.2 Membrane separation

The offer of membrane separation of biomethane includes basic technological parts, from raw biogas reception to primary compression. The actual transfer station, catalytic oxidation and secondary compressions of the biomethane were not provided by the supplier. For the actual economic analysis, these components will be counted in the price sent by the chemical separation supplier. This approximation is applicable for the purpose of this assessment, given that these are auxiliary process components behind the actual biogas separation technology. The tender includes the following additional parts:

- Delivery time 10 months (38 weeks)
- Instalment on signing of the binding order 20 % (followed by 20 % on finalisation of the project, 50 % before shipment, 5 % before commissioning, 5 % for handover)
- 12 months warranty
- Construction days are not specified in the price
- Training, length not specified
- Complete documentation in English

A description of the individual components and an indicative quotation from the manufacturer is given below:

Main membrane module	€1.060.410

- 3× membrane module
- Biogas cooling, condensate removal (frame for external installation, tubular heat exchanger, biogas blower, local control)
- Residual desulphurisation (2× 2.0 m^3 stainless steel desulphurisation column with operating holes, ladder and working platform, including thermal insulation)
- Basic chemical analysis of biogas and biomethane
- Adsorption drying of biomethane
- Cooling of biomethane

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Injection unit	€290.000

- Main compressor stage (24 bar)
- Main compressor stage (38 bar)

Control and measurement according to DSO requirement	€257.900

- Container transfer station unit, including metering and regulation

Catalytic oxidation	€78.000

- Catalytic oxidation system for residual methane in the CO_2 waste stream

Total	€1.686.310

4.4 Construction and description of alternative solutions, technical analysis

The integration of biogas upgrading technology into the existing AD Plant assumes the preservation of the existing cogeneration of electricity and heat. This production will suitably provide for the self-consumption of energy on the entire site, including the reception and treatment of bio-waste, biogas production and also the production and injection of biomethane into the natural gas distribution system.

4.4.1 Requirements for the existing operation of the biogas plant

The current biogas production and its possible expansion will require minor operational modifications. This is mainly due to the high concentration of sulphate (H_2S) that is produced during the decomposition of bio-waste.

In the design of the process layout, we propose to use **pure oxygen desulphurisation**, which is the most investment and operationally efficient method of sulphate removal. Thus, in the technological design, we use both the existing desulphurisation with ferric hydroxide and supplement it with micro-oxidation with pure oxygen. Market research has shown that it is most advantageous to receive and store the required amount of pure oxygen in liquid form, which is approximately 5 times cheaper than supplying compressed oxygen in the gaseous phase. The liquid oxygen storage tank and the evaporator in which the liquid oxygen is converted to the gaseous phase then require certain installation conditions. These conditions include, in particular, a concrete foundation and a containment sump. It is expressly stated that liquid oxygen storage technology cannot be installed indoors or on an asphalt surface (only concrete is permissible).

4.4.2 Chemical separation

A simplified process flow diagram for the chemical separation of biomethane is shown in the schematic (Diagram 1). The biodegradable waste is treated in a biogas plant, with simultaneous addition of ferric hydroxide to the fermentate and pure oxygen to the gas space. The resulting biogas is channelled to existing CHP units and simultaneously to the chemical separation technology for biomethane.

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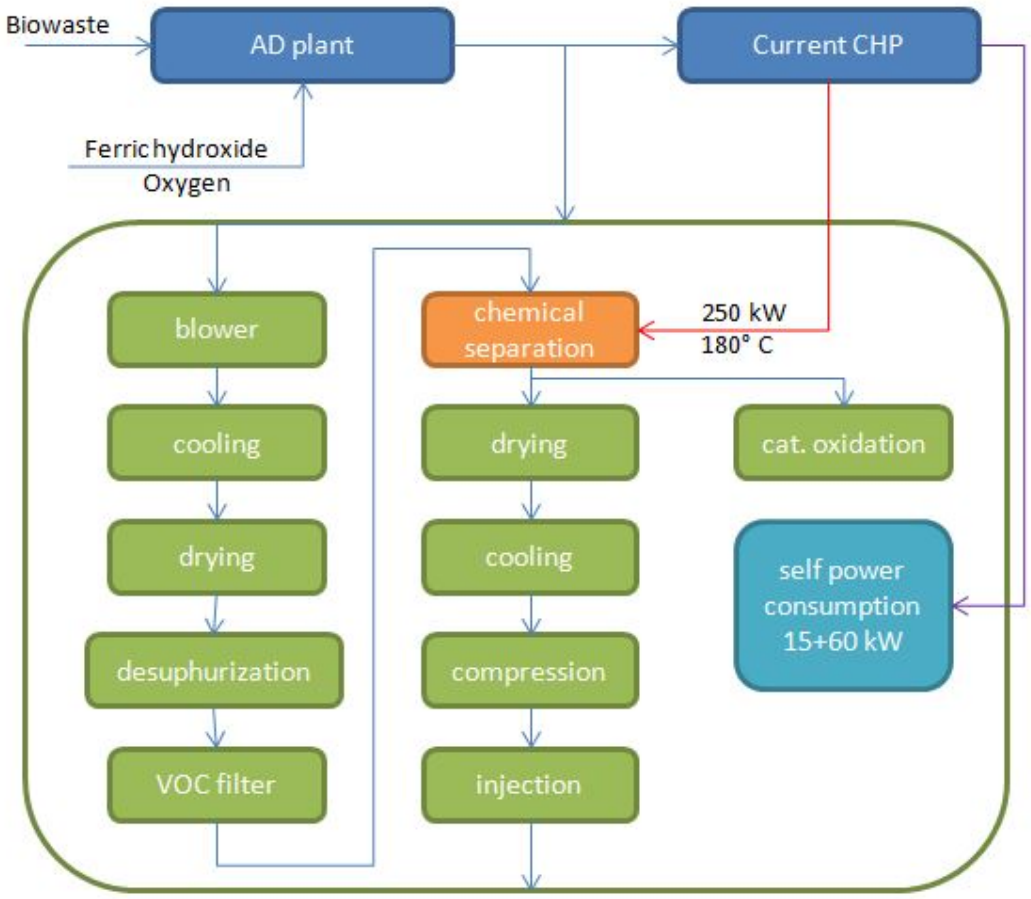
The first step is to increase the pressure required for **biogas pre-treatment**. This is followed by cooling and drying of the biogas, removal of residual sulphate and volatile organic compounds (VOCs). The removal of these substances is particularly important when treating wastes that may contain VOC components (a typical example is citrus waste, which contains terpenic substances that inappropriately odorise the biomethane produced).

The next step is the **actual chemical separation** of the biomethane and carbon dioxide. The actual separation is based on the chemical reaction of carbon dioxide and tertiary amines, which takes place in a sorption column. The inert biomethane is transferred for further processing. The resulting complex of carbon dioxide and tertiary amine is split by heat in a regeneration column. **The regeneration temperature is about 150-160 °C**. The heat input of the amine regeneration is quoted by the technology supplier as **241 kW**. If a certain heat loss and temperature gradient are taken into account, it is then possible to assume a **heat input from the cogeneration at a temperature level of approx. 180 °C and a power input of 250 kW**. The potential for heat extraction from existing CHP units has not been addressed in this analysis and needs to be communicated directly with the manufacturer of the CHP unit.

Diagram 1: Simplified technological scheme of chemical separation.



The outgoing carbon dioxide contains a very small amount of biomethane. This amount is about 0.1% of the total input, i.e., 0.2 m^3/hr. Due to the required low emission footprint of

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biomethane, we recommend that this amount is further reduced by **catalytic oxidation** technology, which reduces the amount of methane by 95-98 %. The final amount of methane escaping into the atmosphere will therefore be 0,01 m^3/hr, i.e., **0,005 % of the original amount**.

The biomethane produced is then dried and cooled according to the requirements of the distribution network operator (DSO). This is followed by compression to a relatively high transfer pressure of 38 bar and injection into the DS.

The **total energy costs** of the chemical separation technology are 250 kW thermal, 15 kW electrical for the technology itself and then about 60 kW for compressing the gas to the required transfer pressure in the distribution system.

4.4.3 Membrane separation

A simplified technological scheme of membrane separation of biomethane is shown in the schematic (Diagram 2). Biodegradable waste is treated in a biogas plant, with simultaneous addition of ferric hydroxide to the fermentate and pure oxygen to the gas space. The resulting biogas is transferred to existing CHP units and simultaneously to the chemical separation technology for biomethane.

The first step is to increase the pressure required for **biogas pre-treatment**. This is followed by cooling and drying of the biogas, removing residual sulphate. The removal of VOCs is not foreseen in this technology, which we consider to be a shortcoming that we model by increasing the investment cost by this unit so that the technologies are fully comparable.

In the next step, biogas is compressed to a pressure of about 8-10 bar, which is then cooled, dried and fed to **the actual membrane separation** of biomethane and carbon dioxide. The membrane separation takes place in three parallel modules. The biogas is fed into the first module where partial separation takes place. The concentrated biomethane is fed into the second module where it is further purified to the quality required by the DSO. Residual CO_2 from the second module and biomethane from the third module are fed to the compressor inlet for recycling.

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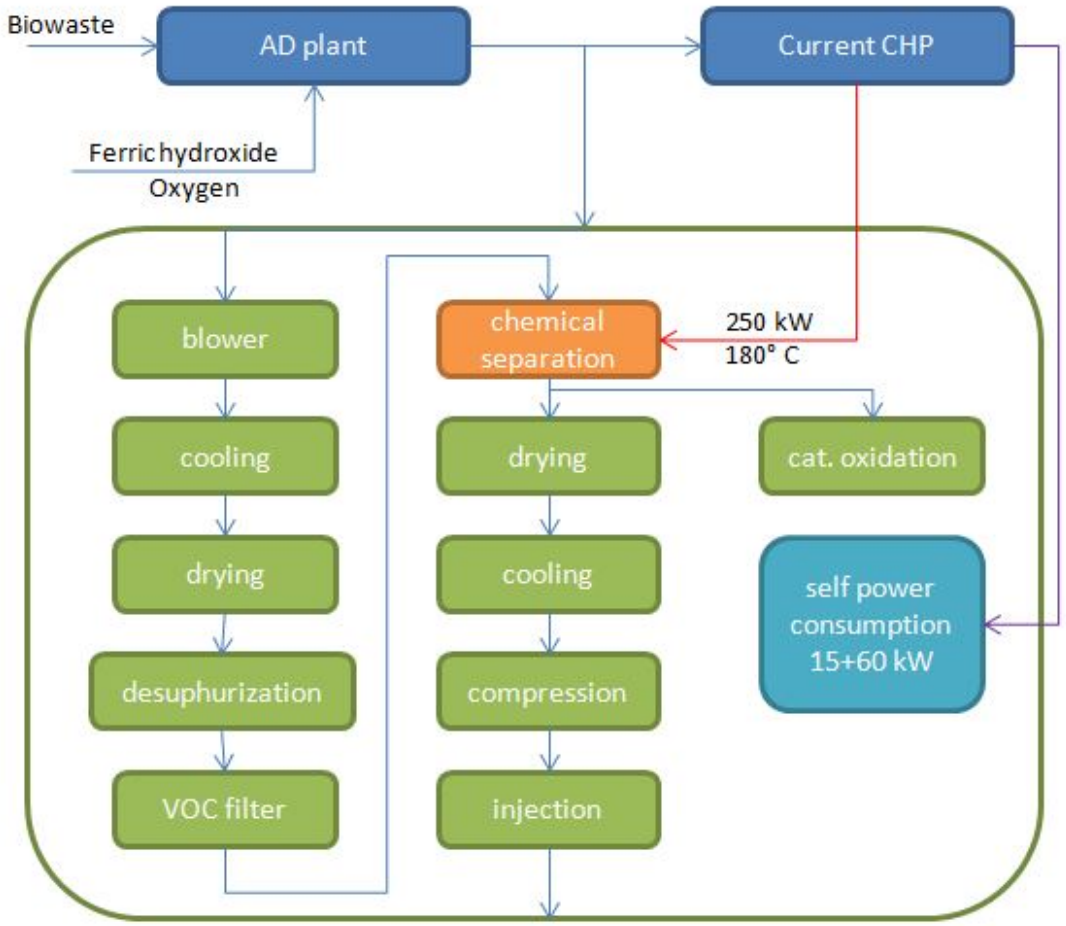
Diagram 2: Simplified technological scheme of membrane separation.



The concentrated carbon dioxide stream from the first module is directed to the third module where the carbon dioxide is concentrated and discharged. The residual methane content of this stream is typically 0,5-1 % of the total methane input in the biogas, i.e., 1-2 m^3/h. It is highly recommended to further reduce this amount by catalytic oxidation (efficiency 95-98 %), when the amount of methane discharged is reduced to 0,05-0,1 m^3/h, i.e., 0,025-0,05 % of the original amount (about 10-20 times more than in the case of chemical separation).

The following table summarises the comparison of the main technical parameters (Table 6):

Table 6: Comparison of the main technical parameters of chemical and membrane separation

Monitored parameter	Chemical separation	Membrane separation
Max. biogas capacity (m^3/h)	500	365
Projected biogas capacity (m^3/h)	300 (@65 % CH_4)	300 (@65 % CH_4)
Biomethane production (m^3/h)	194,8	193

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Methane emissions to the atmosphere (m^3/h)	0,01	0,1
Heat input (kW)	250	0
Electricity input for technology (kW)	15	45
Electricity input for injection (kW)	60	55
Total electricity input	75	100

4.5 Economic analysis, model cash-flow of alternative solutions

Based on the above values, an economic analysis of the biomethane production project using chemical and membrane separation technology was performed for two defined price levels of biomethane at 85 and 120 EUR / 1 MWh. The Euro exchange rate on the foreign exchange market was set for all calculations of this analysis at 25.496 CZK / EUR, which represents the average value in the period 3Q 2021 set by the CNB.[5]

4.5.1 Summary of input values for the economic analysis of chemical separation

The input values are given in the summary table (Table 7). The initial investments include the main chemical separation unit as offered by the supplier, plus an estimate of the investment of the heat output from the CHP units of EUR 100.000. In addition, the cost of the catalytic oxidation of the residual methane in the carbon dioxide waste stream is added according to the supplier's offer. The last part of the process costs are the items for the compression of the biomethane to transfer pressure and the dragging unit containing the necessary measuring instruments and control of the injection into the DS (both according to the supplier's offer). The technological investments are supplemented by an estimate of the construction costs, which will mainly consist of paved areas for the installation of technological containers and other equipment. The construction costs are estimated at 15 % of the total cost of the process equipment.

Another item is the financing of the investment. Equity is assumed at 10 % of the total investment. The investment subsidy is assumed at the maximum level that could be achieved in the OP PIK programme in 2020, i.e., at EUR 35 million. The maximum amount of the investment is CZK 100 million. The remaining value is then covered by a commercial loan. The cost of obtaining the loan is assumed to be 1% of the total loan.

The following are the production cost items, which are broken down by accounting group. In the group of purchases consumed, we identify the cost of biomass feedstock. Due to the fact that it will be exclusively biodegradable waste, we assume a zero cost for the material itself. At the same time, however, we assume some transport costs, which may be of a

[5] https://www.cnb.cz/cs/financni-trhy/devizovy-trh/kurzy-devizoveho-trhu/kurzy-devizoveho-trhu/prumerne_mena.html?mena=EUR

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considerable value given by current fuel prices. The price for the input biomass is thus understood only as a handling cost of CZK 250 per tonne.

The following is the electricity consumption item, which is based on the technological consumption declared by the technology producer and the electricity price. Although the electricity will be supplied from the cogeneration plant itself, we have to value this accordingly, as it will be a lost sale in relation to the operation of the cogeneration unit.

The following items are the proportional cost of handling the feedstock for the operation of the biogas plant (CZK 25/tonne) and the proportional cost of handling the digestate (CZK 50/tonne).

Another cost item is the oxygen consumption for micro-oxidation of sulphate in biogas in order to maintain the relatively high efficiency of the current raw biogas desulphurisation. The actual liquid oxygen tank with evaporator is not a capital cost, but it is possible to rent it from a liquid oxygen producer as a service. The consumption of own oxygen is then calculated for the operation of the whole biogas plant (desulphurisation of all biogas, including the share for the CHP units). The total consumption is about 2,0 kg/h.

The other cost items are other services, which we normally estimate as a percentage of the total investment. Specifically, repair and maintenance values of 3%, insurance of 0.7% and other services of 0,1% of the total investment.

This is followed by personnel costs, where we assume only one person in a technical position and one operations manager.

The list of items is rounded off by property tax rates, depreciation and one-off costs associated with the start-up of the process in the first year of operation.

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Table 7: Input values for the economic analysis of chemical separation

Description	Popis	Variables / Proměnné			Results / Výsledky (za rok)		
Investment Costs	**Investiční náklady**						
Capital investment	**Počáteční investice**						
Chmical separation	Chemická separace	25.496	Kč/EUR		1,445,000 €		36,841,720 Kč
Roads & Fundaments	Obslužné komunikace & stavby	15% z celkových technol.			319,620 €		8,149,032 Kč
CHP heat extraction	Tepelné hospodářství	odhad - viz. dodavatel KGJ			100,000 €		2,549,600 Kč
Catalytic oxidation	Katalytická oxidace	kapacita 200 m3/hod			78,000 €		1,988,688 Kč
Final compresion	Komprese na tlak 38 bar				249,900 €		6,371,450 Kč
Injection unit	Vtláčecí jednotka				257,900 €		6,575,418 Kč
Total Investment	Investice celkem				2,450,420 €		62,475,908 Kč
Financial Issues	**Financování investice**						
Own Capital	Vlastní kapitál		10.0%				6,247,591 Kč
Subsidies	Poskytnutá dotace		56.0%				35,000,000 Kč
Commercial Loan	Úvěr		34.0%				21,228,317 Kč
Loan Costs	Náklady na úvěr		1.0%				212,283 Kč
Subsidies Costs	Náklady na dotaci						0 Kč
Production Costs	**Výrobní nákladové položky**						
	úč. sk. 50 Spotřebované nákupy						
Biomass input	**Vstupy biomasy**						
Biomass Costs	Náklady na biomasu		250	Kč/t	12,000	t/r	3,000,000 Kč
Energy	**Energie**						
Electricity	Elektrická energie		5	Kč/kWh	75	kW	3,285,000 Kč
	úč. sk. 51 Služby						
Biomass Loading	**Nakládka biomasy**						
Loader utilization	Manipulace biomasou		25	Kč/t	12,000	t/r	300,000 Kč
Fuel	Nafta - teleskop. nakladač		n.a.				0 Kč
Process Chemistry	**Procesní chemie**						
Laboratory analyses	Laboratorní analýzy						0 Kč
Digestate handling	**Manipulace s digestátem**						
Digestate handling	Manipulace s digestátem		50	Kč/t	9,600	t/r	480,000 Kč
Oxygen	**Kyslík**						
Storage rental	Pronájem zásobníku		5,500	Kč/měs.			66,000 Kč
Oxygen consumption	Spotřeba kyslíku		5.3	Kč/kg	2.0	kg/h	92,856 Kč
Other Services	**Ostatní služby**						
Repair & Maintenance	Opravy a údržba	3.0%	z investice				1,874,277 Kč
Other Services	Ostatní služby	0.1%	z investice				62,476 Kč
Insurance	Pojištění	0.7%	z investice				437,331 Kč
	úč. sk. 52 Osobní náklady						
Personal costs, technician	Osobní náklady, nakladač	ve službách (nakladač)					0 Kč
Personal costs, technician	Osobní náklady, technik						300,000 Kč
Personal costs, manager	Osobní náklady, vedoucí						420,000 Kč
Personal costs, total	Osobní náklady celkem						720,000 Kč
Social-Health Insurance	Platby zdravotní a soc. pojištění		35%				252,000 Kč
	úč. sk. 53 Daně a poplatky						
Property Tax	Daň z nemovitosti		9	Kč/m2	10,000	m2	90,000 Kč
	úč. sk. 54 Jiné provozní náklady						
Process Start-up	Spuštění procesu						500,000 Kč
	úč. sk. 55 Odpisy						
	Odpisy technologie		8	roků			6,790,860 Kč
	Odpisy staveb		20	roků			407,452 Kč

4.5.2 Cash-flow analysis, chemical separation, 85 EUR/1 MWh

The above values are processed in a cash-flow analysis, which is shown in the following table (Table 8).

In this variant, a positive profit is achieved in all years of operation of the technology, as well as a stable cash flow. A positive NPV (net present value of the project) is achieved in the fifth full year of operation of the technology, or in the sixth year of operation.

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The analysis shows that the specific realisation price of biomethane is about 1.7 times the total specific cost of its production. By analysing the above table, it is also possible to calculate the **break-even point** of the chemical separation technology, i.e., the minimum selling price of biomethane at which the equality of specific costs and unit sales of biomethane will be achieved. This minimum selling price of biomethane is, under all the above-mentioned boundary conditions, **49,4 EUR/1 MWh, i.e. about 0,494 EUR/1 Nm^3**.

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Table 8: Cash-flow analysis, chemical separation, 85 EUR/1 MWh

Techno-economic data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**85**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

Time period	2022		2023		2024		2025		2026		2027	
	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3
Total production MWh	4 938	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.
Total production Nm^3	523 311	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.
Production costs												
Biomass consumption	1 000 000	1,911	3 075 000	1,959	3 151 875	2,008	3 230 672	2,058	3 311 439	2,109	3 394 225	2,162
Process Chemistry and Analysis	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Electricity	1 007 400	1,925	3 097 755	1,973	3 175 199	2,023	3 254 579	2,073	3 335 943	2,125	3 419 342	2,178
Biomass loading	100 000	0,191	307 500	0,196	315 188	0,201	323 067	0,206	331 144	0,211	339 422	0,216
Digestate handling	160 000	0,306	492 000	0,313	504 300	0,321	516 908	0,329	529 830	0,337	543 076	0,346
Oxygen consumption	52 952	0,101	162 827	0,104	166 898	0,106	171 071	0,109	175 347	0,112	179 731	0,114
Repair and maintenance	624 759	1,194	1 921 134	1,224	1 969 163	1,254	2 018 392	1,286	2 068 851	1,318	2 120 573	1,351
Other (1 year with startup)	520 825	0,995	64 038	0,041	65 639	0,042	67 280	0,043	68 962	0,044	70 686	0,045
Insurance	145 777	0,279	448 265	0,286	459 471	0,293	470 958	0,300	482 732	0,307	494 800	0,315
Personnel costs, loader	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Personnel costs, technician	100 000	0,191	307 500	0,196	315 188	0,201	323 067	0,206	331 144	0,211	339 422	0,216
Personnel costs, manager	140 000	0,268	430 500	0,274	441 263	0,281	452 294	0,288	463 601	0,295	475 191	0,303
Total personnel costs	240 000	0,459	738 000	0,470	756 450	0,482	775 361	0,494	794 745	0,506	814 614	0,519
Health and social insurance payments	84 000	0,161	258 300	0,165	264 758	0,169	271 376	0,173	278 161	0,177	285 115	0,182
Property tax	30 000	0,057	92 250	0,059	0	0,000	0	0,000	0	0,000	0	0,000
Depreciation of technology	2 263 620	4,326	6 960 631	4,434	7 134 647	4,545	7 313 013	4,658	7 495 838	4,775	7 683 234	4,894
Depreciation of buildings	135 817	0,260	417 638	0,266	428 079	0,273	438 781	0,279	449 750	0,286	460 994	0,294
Financial costs												
Interests	-350 378	0,670	-995 142	0,634	-907 820	0,578	-816 031	0,520	-719 546	0,458	-618 124	0,394
Financing costs	212 283	0,406	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total costs	6 927 812	13,238	19 030 480	12,122	19 299 485	12,293	19 667 488	12,528	20 042 289	12,766	20 423 936	13,009
	-6 927 812		-19 030 480		-19 299 485		-19 667 488		-20 042 289		-20 423 936	
Biomethane revenues	10 702 321	20,451	32 749 102	20,860	33 404 084	21,277	34 072 166	21,703	34 753 609	22,137	35 448 681	22,580
Revenue heat	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total revenue	10 702 321	20,451	32 749 102	20,860	33 404 084	21,277	34 072 166	21,703	34 753 609	22,137	35 448 681	22,580
Result before tax		3 774 509		13 718 622		14 104 599		14 404 678		14 711 320		15 024 745
Income tax		717 157		2 606 538		2 679 874		2 736 889		2 795 151		2 854 702
Result after tax		3 057 352		11 112 084		11 424 725		11 667 789		11 916 169		12 170 043
Loan repayment		-550 259		-1 706 769		-1 794 091		-1 885 880		-1 982 365		-2 083 786
Annual profit		2 507 093		9 405 315		9 630 634		9 781 909		9 933 804		10 086 257
Operating Cash Flow		4 906 531		16 783 584		17 193 360		17 533 703		17 879 393		18 230 485
Net present value		-58 015 426		-44 144 696		-31 227 070		-19 251 315		-8 149 618		2 141 015

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Techno-economic data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		3%	
Revenue escalation		2%	
Discount rate		10%	
Income tax for legal entities		19%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**85**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

2028		2029		2030		2031		2032		2033		2034	
total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3
14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.
1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.
3 479 080	2,216	3 566 057	2,271	3 655 209	2,328	3 746 589	2,386	3 840 254	2,446	3 936 260	2,507	4 034 666	2,570
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
3 504 825	2,232	3 592 446	2,288	3 682 257	2,345	3 774 314	2,404	3 868 672	2,464	3 965 388	2,526	4 064 523	2,589
347 908	0,222	356 606	0,227	365 521	0,233	374 659	0,239	384 025	0,245	393 626	0,251	403 467	0,257
556 653	0,355	570 569	0,363	584 833	0,373	599 454	0,382	614 441	0,391	629 802	0,401	645 547	0,411
184 224	0,117	188 830	0,120	193 551	0,123	198 389	0,126	203 349	0,130	208 433	0,133	213 644	0,136
2 173 587	1,385	2 227 927	1,419	2 283 625	1,455	2 340 715	1,491	2 399 233	1,528	2 459 214	1,566	2 520 695	1,606
72 453	0,046	74 264	0,047	76 121	0,048	78 024	0,050	79 974	0,051	81 974	0,052	84 023	0,054
507 170	0,323	519 850	0,331	532 846	0,339	546 167	0,348	559 821	0,357	573 817	0,366	588 162	0,375
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
347 908	0,222	356 606	0,227	365 521	0,233	374 659	0,239	384 025	0,245	393 626	0,251	403 467	0,257
487 071	0,310	499 248	0,318	511 729	0,326	524 522	0,334	537 636	0,342	551 076	0,351	564 853	0,360
834 979	0,532	855 854	0,545	877 250	0,559	899 181	0,573	921 661	0,587	944 702	0,602	968 320	0,617
292 243	0,186	299 549	0,191	307 038	0,196	314 713	0,200	322 581	0,205	330 646	0,211	338 912	0,216
90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057
7 875 315	5,016	8 072 198	5,142	8 274 003	5,270	8 480 853	5,402	8 692 874	5,537	8 910 196	5,676	9 132 951	5,817
472 519	0,301	484 332	0,309	496 440	0,316	508 851	0,324	521 572	0,332	534 612	0,341	547 977	0,349
-511 514	0,326	-399 449	0,254	-281 651	0,179	-157 826	0,101	-33 310	0,021	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
20 902 471	13,314	21 297 930	13,566	21 700 344	13,822	22 109 736	14,083	22 531 768	14,352	23 058 670	14,688	23 632 886	15,053
-20 902 471		-21 297 930		-21 700 344		-22 109 736		-22 531 768		-23 058 670		-23 632 886	
36 157 655	23,031	36 880 808	23,492	37 618 424	23,962	38 370 793	24,441	39 138 208	24,930	39 920 973	25,428	40 719 392	25,937
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
36 157 655	23,031	36 880 808	23,492	37 618 424	23,962	38 370 793	24,441	39 138 208	24,930	39 920 973	25,428	40 719 392	25,937
	15 255 184		15 582 878		15 918 080		16 261 056		16 606 440		16 862 303		17 086 506
	2 898 485		2 960 747		3 024 435		3 089 601		3 155 224		3 203 838		3 246 436
	12 356 699		12 622 131		12 893 645		13 171 456		13 451 217		13 658 465		13 840 070
	-2 190 397		-2 302 462		-2 420 260		-2 544 085		-1 767 964		0		0
	10 166 302		10 319 669		10 473 385		10 627 371		11 683 253		13 658 465		13 840 070
	18 514 136		18 876 199		19 243 828		19 617 075		20 897 700		23 103 273		23 520 998
	11 641 694		20 447 581		28 608 842		36 172 074		43 496 590		50 858 005		57 671 200

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Techno-economic data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		85	EUR/MWh
Realization price of heat		0	EUR/GJ

2035		2036		2037		2038		2039		2040		2041		2042	
total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3
14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.
1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.
4 135 533	2,634	4 238 921	2,700	4 344 894	2,768	4 453 517	2,837	4 564 855	2,908	4 678 976	2,980	4 795 951	3,055	4 915 849	3,131
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
4 166 136	2,654	4 270 289	2,720	4 377 047	2,788	4 486 473	2,858	4 598 635	2,929	4 713 601	3,002	4 831 441	3,077	4 952 227	3,154
413 553	0,263	423 892	0,270	434 489	0,277	445 352	0,284	456 485	0,291	467 898	0,298	479 595	0,305	491 585	0,313
661 685	0,421	678 227	0,432	695 183	0,443	712 563	0,454	730 377	0,465	748 636	0,477	767 352	0,489	786 536	0,501
218 985	0,139	224 459	0,143	230 071	0,147	235 823	0,150	241 718	0,154	247 761	0,158	253 955	0,162	260 304	0,166
2 583 712	1,646	2 648 305	1,687	2 714 512	1,729	2 782 375	1,772	2 851 934	1,817	2 923 233	1,862	2 996 314	1,909	3 071 222	1,956
86 124	0,055	88 277	0,056	90 484	0,058	92 746	0,059	95 064	0,061	97 441	0,062	99 877	0,064	102 374	0,065
602 866	0,384	617 938	0,394	633 386	0,403	649 221	0,414	665 451	0,424	682 088	0,434	699 140	0,445	716 618	0,456
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
413 553	0,263	423 892	0,270	434 489	0,277	445 352	0,284	456 485	0,291	467 898	0,298	479 595	0,305	491 585	0,313
578 975	0,369	593 449	0,378	608 285	0,387	623 492	0,397	639 080	0,407	655 057	0,417	671 433	0,428	688 219	0,438
992 528	0,632	1 017 341	0,648	1 042 775	0,664	1 068 844	0,681	1 095 565	0,698	1 122 954	0,715	1 151 028	0,733	1 179 804	0,751
347 385	0,221	356 069	0,227	364 971	0,232	374 095	0,238	383 448	0,244	393 034	0,250	402 860	0,257	412 931	0,263
90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057
9 361 275	5,963	9 595 307	6,112	9 835 190	6,265	10 081 069	6,421	10 333 096	6,582	10 591 423	6,746	10 856 209	6,915	11 127 614	7,088
561 676	0,358	575 718	0,367	590 111	0,376	604 864	0,385	619 986	0,395	635 485	0,405	651 373	0,415	667 657	0,425
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
24 221 459	15,428	24 824 745	15,813	25 443 114	16,207	26 076 941	16,610	26 726 615	17,024	27 392 530	17,448	28 075 094	17,883	28 774 721	18,329
24 221 459		24 824 745		25 443 114		26 076 941		26 726 615		27 392 530		28 075 094		28 774 721	
41 533 780	26,456	42 364 455	26,985	43 211 745	27,525	44 075 979	28,075	44 957 499	28,637	45 856 649	29,209	46 773 782	29,794	47 709 258	30,389
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
41 533 780	26,456	42 364 455	26,985	43 211 745	27,525	44 075 979	28,075	44 957 499	28,637	45 856 649	29,209	46 773 782	29,794	47 709 258	30,389
	17 312 321		17 539 711		17 768 631		17 999 038		18 230 884		18 464 119		18 698 688		18 934 537
	3 289 341		3 332 545		3 376 040		3 419 817		3 463 868		3 508 183		3 552 751		3 597 562
	14 022 980		14 207 166		14 392 591		14 579 221		14 767 016		14 955 936		15 145 938		15 336 975
	0		0		0		0		0		0		0		0
	14 022 980		14 207 166		14 392 591		14 579 221		14 767 016		14 955 936		15 145 938		15 336 975
	23 945 932		24 378 191		24 817 892		25 265 154		25 720 098		26 182 845		26 653 519		27 132 246
	63 976 912		69 812 857		75 213 954		80 212 530		84 838 516		89 119 620		93 081 496		96 747 892

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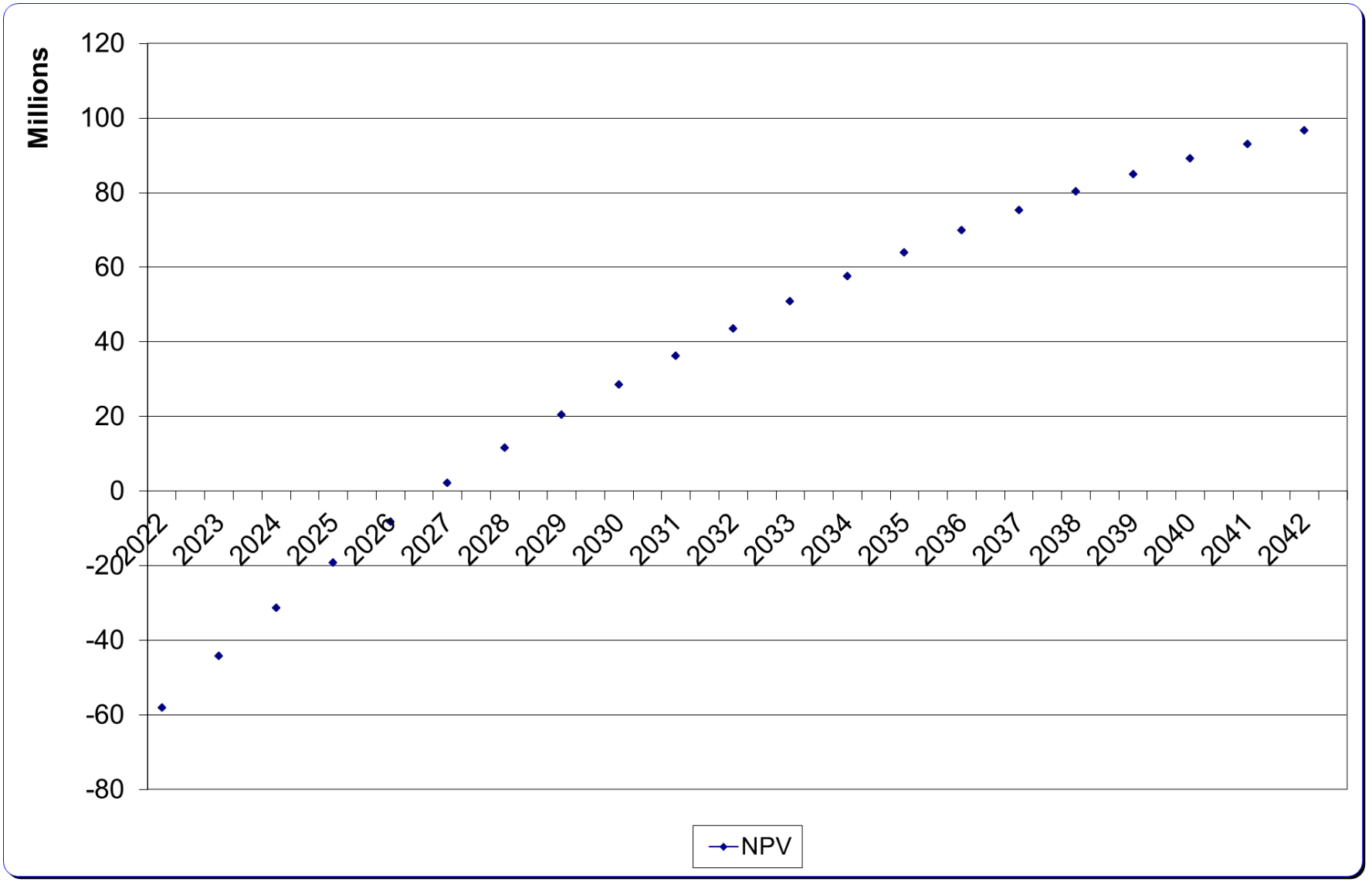
Figure 4: NPV, chemical separation, 85 EUR/1 MWh



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4.5.3 Cash-flow analysis, chemical separation, 120 EUR/ 1 MWh

This analysis is the same analysis, with the only difference that the realisation price of biomethane is set at 120 EUR/ 1 MWh.

In this variant, a positive profit is achieved in all years of operation of the technology, as well as a stable cash-flow. **A positive NPV** (net present value of the project) is achieved in the third full year of operation of the technology, or in the fourth year of operation.

The analysis shows that **the specific realisation price of biomethane is about 2,4 times the total specific cost of its production**.

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Table 9: Cash-flow analysis, chemical separation, 120 EUR/ 1 MWh

Techno-economic data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**120**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

Time period	2022		2023		2024		2025		2026		2027	
	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3
Total production MWh	4 938	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.
Total production Nm^3	523 311	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.
Production costs												
Biomass consumption	1 000 000	1,911	3 075 000	1,959	3 151 875	2,008	3 230 672	2,058	3 311 439	2,109	3 394 225	2,162
Process Chemistry and Analysis	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Electricity	1 007 400	1,925	3 097 755	1,973	3 175 199	2,023	3 254 579	2,073	3 335 943	2,125	3 419 342	2,178
Biomass loading	100 000	0,191	307 500	0,196	315 188	0,201	323 067	0,206	331 144	0,211	339 422	0,216
Digestate handling	160 000	0,306	492 000	0,313	504 300	0,321	516 908	0,329	529 830	0,337	543 076	0,346
Oxygen consumption	52 952	0,101	162 827	0,104	166 898	0,106	171 071	0,109	175 347	0,112	179 731	0,114
Repair and maintenance	624 759	1,194	1 921 134	1,224	1 969 163	1,254	2 018 392	1,286	2 068 851	1,318	2 120 573	1,351
Other (1 year with startup)	520 825	0,995	64 038	0,041	65 639	0,042	67 280	0,043	68 962	0,044	70 686	0,045
Insurance	145 777	0,279	448 265	0,286	459 471	0,293	470 958	0,300	482 732	0,307	494 800	0,315
Personnel costs, loader	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Personnel costs, technician	100 000	0,191	307 500	0,196	315 188	0,201	323 067	0,206	331 144	0,211	339 422	0,216
Personnel costs, manager	140 000	0,268	430 500	0,274	441 263	0,281	452 294	0,288	463 601	0,295	475 191	0,303
Total personnel costs	240 000	0,459	738 000	0,470	756 450	0,482	775 361	0,494	794 745	0,506	814 614	0,519
Health and social insurance payments	84 000	0,161	258 300	0,165	264 758	0,169	271 376	0,173	278 161	0,177	285 115	0,182
Property tax	30 000	0,057	92 250	0,059	0	0,000	0	0,000	0	0,000	0	0,000
Depreciation of technology	2 263 620	4,326	6 960 631	4,434	7 134 647	4,545	7 313 013	4,658	7 495 838	4,775	7 683 234	4,894
Depreciation of buildings	135 817	0,260	417 638	0,266	428 079	0,273	438 781	0,279	449 750	0,286	460 994	0,294
Financial costs												
Interests	-350 378	0,670	-995 142	0,634	-907 820	0,578	-816 031	0,520	-719 546	0,458	-618 124	0,394
Financing costs	212 283	0,406	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total costs	6 927 812	13,238	19 030 480	12,122	19 299 485	12,293	19 667 488	12,528	20 042 289	12,766	20 423 936	13,009
	-6 927 812		-19 030 480		-19 299 485		-19 667 488		-20 042 289		-20 423 936	
Biomethane revenues	15 109 159	28,872	46 234 026	29,450	47 158 707	30,039	48 101 881	30,639	49 063 919	31,252	50 045 197	31,877
Revenue heat	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total revenue	15 109 159	28,872	46 234 026	29,450	47 158 707	30,039	48 101 881	30,639	49 063 919	31,252	50 045 197	31,877
Result before tax		8 181 347		27 203 547		27 859 221		28 434 393		29 021 629		29 621 261
Income tax		1 554 456		5 168 674		5 293 252		5 402 535		5 514 110		5 628 040
Result after tax		6 626 891		22 034 873		22 565 969		23 031 858		23 507 520		23 993 221
Loan repayment		-550 259		-1 706 769		-1 794 091		-1 885 880		-1 982 365		-2 083 786
Annual profit		6 076 632		20 328 104		20 771 879		21 145 979		21 525 155		21 909 435
Operating Cash Flow		8 476 069		27 706 373		28 334 604		28 897 772		29 470 744		30 053 663
Net present value		-54 770 391		-31 872 562		-10 584 355		9 153 213		27 452 226		44 416 735

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Techno-economic data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		3%	
Revenue escalation		2%	
Discount rate		10%	
Income tax for legal entities		19%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**120**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

2028		2029		2030		2031		2032		2033		2034	
total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3
14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.
1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.
3 479 080	2,216	3 566 057	2,271	3 655 209	2,328	3 746 589	2,386	3 840 254	2,446	3 936 260	2,507	4 034 666	2,570
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
3 504 825	2,232	3 592 446	2,288	3 682 257	2,345	3 774 314	2,404	3 868 672	2,464	3 965 388	2,526	4 064 523	2,589
347 908	0,222	356 606	0,227	365 521	0,233	374 659	0,239	384 025	0,245	393 626	0,251	403 467	0,257
556 653	0,355	570 569	0,363	584 833	0,373	599 454	0,382	614 441	0,391	629 802	0,401	645 547	0,411
184 224	0,117	188 830	0,120	193 551	0,123	198 389	0,126	203 349	0,130	208 433	0,133	213 644	0,136
2 173 587	1,385	2 227 927	1,419	2 283 625	1,455	2 340 715	1,491	2 399 233	1,528	2 459 214	1,566	2 520 695	1,606
72 453	0,046	74 264	0,047	76 121	0,048	78 024	0,050	79 974	0,051	81 974	0,052	84 023	0,054
507 170	0,323	519 850	0,331	532 846	0,339	546 167	0,348	559 821	0,357	573 817	0,366	588 162	0,375
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
347 908	0,222	356 606	0,227	365 521	0,233	374 659	0,239	384 025	0,245	393 626	0,251	403 467	0,257
487 071	0,310	499 248	0,318	511 729	0,326	524 522	0,334	537 636	0,342	551 076	0,351	564 853	0,360
834 979	0,532	855 854	0,545	877 250	0,559	899 181	0,573	921 661	0,587	944 702	0,602	968 320	0,617
292 243	0,186	299 549	0,191	307 038	0,196	314 713	0,200	322 581	0,205	330 646	0,211	338 912	0,216
90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057
7 875 315	5,016	8 072 198	5,142	8 274 003	5,270	8 480 853	5,402	8 692 874	5,537	8 910 196	5,676	9 132 951	5,817
472 519	0,301	484 332	0,309	496 440	0,316	508 851	0,324	521 572	0,332	534 612	0,341	547 977	0,349
-511 514	0,326	-399 449	0,254	-281 651	0,179	-157 826	0,101	-33 310	0,021	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
20 902 471	13,314	21 297 930	13,566	21 700 344	13,822	22 109 736	14,083	22 531 768	14,352	23 058 670	14,688	23 632 886	15,053
-20 902 471		-21 297 930		-21 700 344		-22 109 736		-22 531 768		-23 058 670		-23 632 886	
51 046 101	32,515	52 067 023	33,165	53 108 363	33,828	54 170 531	34,505	55 253 941	35,195	56 359 020	35,899	57 486 201	36,617
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
51 046 101	32,515	52 067 023	33,165	53 108 363	33,828	54 170 531	34,505	55 253 941	35,195	56 359 020	35,899	57 486 201	36,617
30 143 630		30 769 093		31 408 020		32 060 795		32 722 173		33 300 351		33 853 314	
5 727 290		5 846 128		5 967 524		6 091 551		6 217 213		6 327 067		6 432 130	
24 416 340		24 922 965		25 440 496		25 969 244		26 504 960		26 973 284		27 421 184	
-2 190 397		-2 302 462		-2 420 260		-2 544 085		-1 767 964		0		0	
22 225 943		22 620 503		23 020 236		23 425 158		24 736 996		26 973 284		27 421 184	
30 573 777		31 177 033		31 790 679		32 414 863		33 951 443		36 418 092		37 102 113	
60 105 917		74 650 233		88 132 585		100 629 917		112 529 691		124 133 618		134 880 778	

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Techno-economic data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		120	EUR/MWh
Realization price of heat		0	EUR/GJ

2035		2036		2037		2038		2039		2040		2041		2042	
total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3	total	per 1 Nm^3
14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.	14 815	n.a.
1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.	1 569 932	n.a.
4 135 533	2,634	4 238 921	2,700	4 344 894	2,768	4 453 517	2,837	4 564 855	2,908	4 678 976	2,980	4 795 951	3,055	4 915 849	3,131
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
4 166 136	2,654	4 270 289	2,720	4 377 047	2,788	4 486 473	2,858	4 598 635	2,929	4 713 601	3,002	4 831 441	3,077	4 952 227	3,154
413 553	0,263	423 892	0,270	434 489	0,277	445 352	0,284	456 485	0,291	467 898	0,298	479 595	0,305	491 585	0,313
661 685	0,421	678 227	0,432	695 183	0,443	712 563	0,454	730 377	0,465	748 636	0,477	767 352	0,489	786 536	0,501
218 985	0,139	224 459	0,143	230 071	0,147	235 823	0,150	241 718	0,154	247 761	0,158	253 955	0,162	260 304	0,166
2 583 712	1,646	2 648 305	1,687	2 714 512	1,729	2 782 375	1,772	2 851 934	1,817	2 923 233	1,862	2 996 314	1,909	3 071 222	1,956
86 124	0,055	88 277	0,056	90 484	0,058	92 746	0,059	95 064	0,061	97 441	0,062	99 877	0,064	102 374	0,065
602 866	0,384	617 938	0,394	633 386	0,403	649 221	0,414	665 451	0,424	682 088	0,434	699 140	0,445	716 618	0,456
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
413 553	0,263	423 892	0,270	434 489	0,277	445 352	0,284	456 485	0,291	467 898	0,298	479 595	0,305	491 585	0,313
578 975	0,369	593 449	0,378	608 285	0,387	623 492	0,397	639 080	0,407	655 057	0,417	671 433	0,428	688 219	0,438
992 528	0,632	1 017 341	0,648	1 042 775	0,664	1 068 844	0,681	1 095 565	0,698	1 122 954	0,715	1 151 028	0,733	1 179 804	0,751
347 385	0,221	356 069	0,227	364 971	0,232	374 095	0,238	383 448	0,244	393 034	0,250	402 860	0,257	412 931	0,263
90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057	90 000	0,057
9 361 275	5,963	9 595 307	6,112	9 835 190	6,265	10 081 069	6,421	10 333 096	6,582	10 591 423	6,746	10 856 209	6,915	11 127 614	7,088
561 676	0,358	575 718	0,367	590 111	0,376	604 864	0,385	619 986	0,395	635 485	0,405	651 373	0,415	667 657	0,425
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
24 221 459	15,428	24 824 745	15,813	25 443 114	16,207	26 076 941	16,610	26 726 615	17,024	27 392 530	17,448	28 075 094	17,883	28 774 721	18,329
24 221 459		24 824 745		25 443 114		26 076 941		26 726 615		27 392 530		28 075 094		28 774 721	
58 635 925	37,349	59 808 643	38,096	61 004 816	38,858	62 224 912	39,635	63 469 410	40,428	64 738 799	41,237	66 033 575	42,061	67 354 246	42,903
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
58 635 925	37,349	59 808 643	38,096	61 004 816	38,858	62 224 912	39,635	63 469 410	40,428	64 738 799	41,237	66 033 575	42,061	67 354 246	42,903
	34 414 466		34 983 898		35 561 702		36 147 971		36 742 795		37 346 268		37 958 481		38 579 525
	6 538 749		6 646 941		6 756 723		6 868 114		6 981 131		7 095 791		7 212 111		7 330 110
	27 875 717		28 336 957		28 804 979		29 279 856		29 761 664		30 250 477		30 746 370		31 249 415
	0		0		0		0		0		0		0		0
	27 875 717		28 336 957		28 804 979		29 279 856		29 761 664		30 250 477		30 746 370		31 249 415
	37 798 669		38 507 983		39 230 280		39 965 790		40 714 746		41 477 386		42 253 951		43 044 686
	144 834 349		154 052 854		162 590 506		170 497 524		177 820 429		184 602 313		190 883 094		196 699 747

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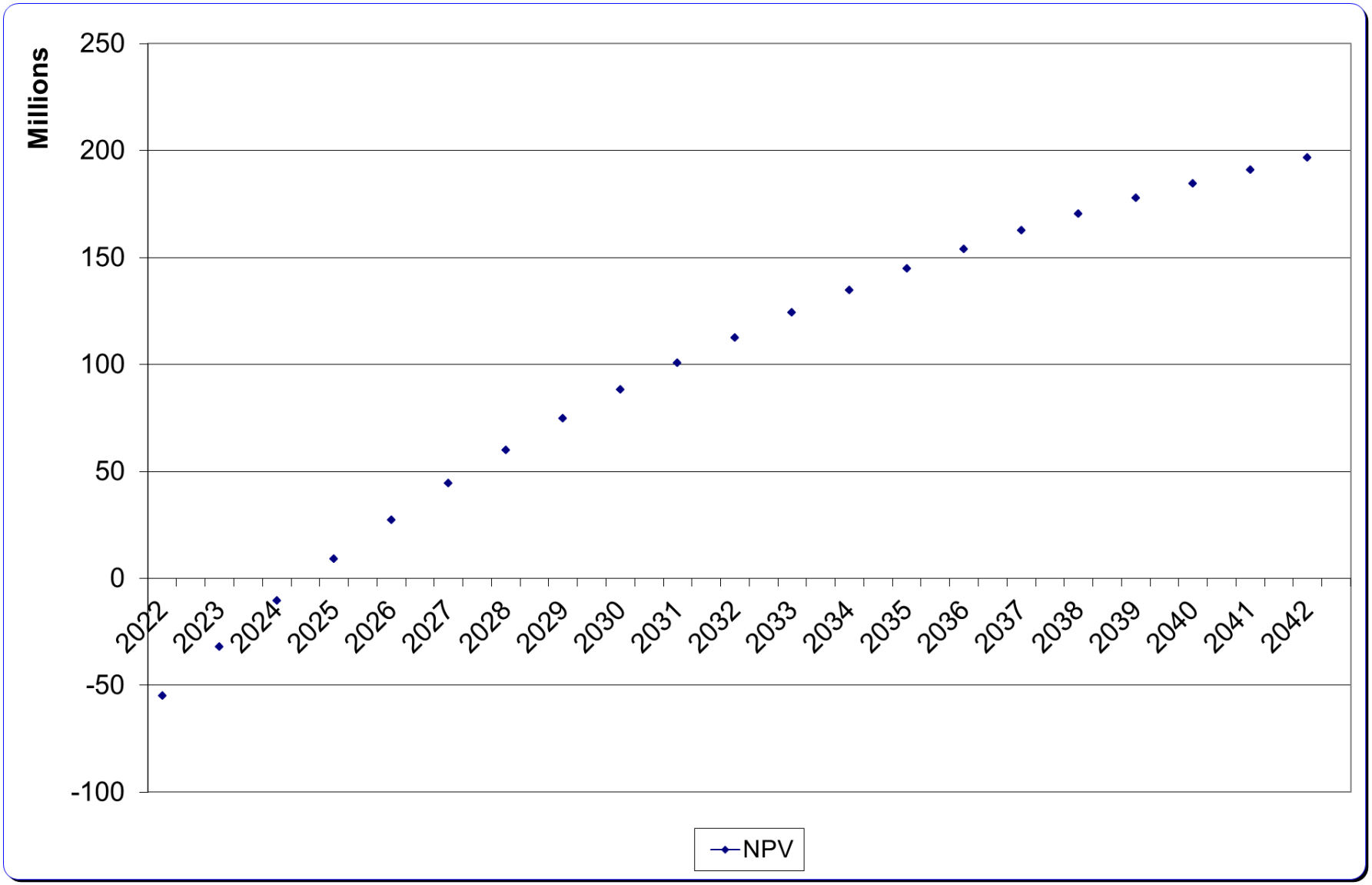
Figure 5: NPV, chemical separation, 120 EUR/1 MWh



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4.5.4 Summary of input values for the economic analysis of membrane separation

The input values are given in the summary table (Table 10). Initial investments include the main membrane separation unit as offered by the supplier. In addition, the cost of the catalytic oxidation of the residual methane in the carbon dioxide waste stream is added according to the supplier's offer. The last part of the process costs are the items for the compression of the biomethane to the feed pressure and the injection unit containing the necessary measuring instruments and control of the injection into the DS (both according to the supplier's offer). The technological investments are supplemented by an estimate of the construction costs, which will mainly consist of paved areas for the installation of technological containers and other equipment. The construction costs are estimated at 15 % of the total cost of the process equipment.

Another item is the financing of the investment. Equity is assumed at 10 % of the total investment. The investment subsidy is assumed at the maximum level that could be achieved in the OP PIK programme in 2020, i.e., at EUR 35 million. The remaining value is then covered by a commercial loan. The cost of obtaining the loan is assumed to be 1 % of the total loan.

The other cost items are the same as in the previous economic analysis of chemical separation. The differences are in the following items:

- Electricity consumption: the reason is the higher electricity consumption in membrane separation technology (33%)
- Depreciation of the technology: in this analysis, the depreciation of the technology is divided into two parts in order to perceive the risk of damage to the membrane unit due to high concentrations of sulphate or other volatile substances generated in the treatment of biodegradable waste. For this reason, a depreciation period of 4 years is conservatively assumed for the separate membrane unit. The remaining parts of the technology are then depreciated over a standard period of 8 years.

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Table 10: Summary of input values for the economic analysis of membrane separation.

Description	Popis	Variables / Proměnné			Results / Výsledky (za rok)		
Investment Costs	**Investiční náklady**						
Capital investment	**Počáteční investice**						
Membrane separation	Membránová separace	25.496	Kč/EUR		1,060,410 €		27,036,213 Kč
Roads & Fundaments	Obslužné komunikace & stavby	15% z celkových technol.			252,947 €		6,449,124 Kč
CHP heat extraction	Tepelné hospodářství	odhad - viz. dodavatel KGJ			0 €		0 Kč
Catalytic oxidation	Katalytická oxidace	kapacita 200 m3/hod			78,000 €		1,988,688 Kč
Final compresion	Komprese na tlak 38 bar				290,000 €		7,393,840 Kč
Injection unit	Vtláčecí jednotka				257,900 €		6,575,418 Kč
Total Investment	Investice celkem				1,939,257 €		49,443,284 Kč
Financial Issues	**Financování investice**						
Own Capital	Vlastní kapitál		10.0%				4,944,328 Kč
Subsidies	Poskytnutá dotace		70.8%				35,000,000 Kč
Commercial Loan	Úvěr		19.2%				9,498,955 Kč
Loan Costs	Náklady na úvěr		1.0%				94,990 Kč
Subsidies Costs	Náklady na dotaci						0 Kč
Production Costs	**Výrobní nákladové položky**						
	úč. sk. 50 Spotřebované nákupy						
Biomass input	**Vstupy biomasy**						
Biomass Costs	Náklady na biomasu		250	Kč/t	12,000	t/r	3,000,000 Kč
Energy	**Energie**						
Electricity	Elektrická energie		5	Kč/kWh	100	kW	4,380,000 Kč
	úč. sk. 51 Služby						
Biomass Loading	**Nakládka biomasy**						
Loader utilization	Manipulace biomasou		25	Kč/t	12,000	t/r	300,000 Kč
Fuel	Nafta - teleskop. nakladač		n.a.				0 Kč
Process Chemistry	**Procesní chemie**						
Laboratory analyses	Laboratorní analýzy						0 Kč
Digestate handling	**Manipulace s digestátem**						
Digestate handling	Manipulace s digestátem		50	Kč/t	9,600	t/r	480,000 Kč
Oxygen	**Kyslík**						
Storage rental	Pronájem zásobníku		5,500	Kč/měs.			66,000 Kč
Oxygen consumption	Spotřeba kyslíku		5.3	Kč/kg	2.0	kg/h	92,856 Kč
Other Services	**Ostatní služby**						
Repair & Maintenance	Opravy a údržba	3.0%	z investice				1,483,299 Kč
Other Services	Ostatní služby	0.1%	z investice				49,443 Kč
Insurance	Pojištění	0.7%	z investice				346,103 Kč
	úč. sk. 52 Osobní náklady						
Personal costs, technician	Osobní náklady, nakladač	ve službách (nakladač)					0 Kč
Personal costs, technician	Osobní náklady, technik						300,000 Kč
Personal costs, manager	Osobní náklady, vedoucí						420,000 Kč
Personal costs, total	Osobní náklady celkem						720,000 Kč
Social-Health Insurance	Platby zdravotní a soc. pojištění		35%				252,000 Kč
	úč. sk. 53 Daně a poplatky						
Property Tax	Daň z nemovitosti		9	Kč/m2	10,000	m2	90,000 Kč
	úč. sk. 54 Jiné provozní náklady						
Process Start-up	Spuštění procesu						500,000 Kč
	úč. sk. 55 Odpisy						
	Odpisy membrán		4	roků			6,759,053 Kč
	Odpisy technologie		8	roků			1,994,743 Kč
	Odpisy staveb		20	roků			322,456 Kč

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4.5.5 Cash-Flow analysis, membrane separation, 85 EUR/ 1 MWh

The above values are processed in the Cash-Flow analysis, which is shown in the following table (Table 11).

In this variant, a positive profit is achieved in all years of operation of the technology, as well as a stable cash flow. A positive NPV (net present value of the project) is achieved in the fourth full year of operation of the technology, or in the fifth year of operation.

The analysis shows that the specific realisation price of biomethane is about 1,5 times the total specific cost of its production. See the comparison with the value of 1.7 times in the case of chemical separation. From this value it is clear that the specific operating costs of membrane separation (OPEX) are slightly higher than in the case of chemical separation (about 11%).

By analysing the above table, it is also possible to calculate the break-even point of the chemical separation technology, i.e., the minimum selling price of biomethane at which the equality of the specific costs and unit sales of biomethane will be achieved. This minimum selling price of biomethane is, under all the above-mentioned boundary conditions, 54,8 EUR/1 MWh, i.e., about 0,548 EUR/1 Nm^3.

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Table 11: Cash-Flow analysis, membrane separation, 85 EUR/ 1 MWh

Technicko-ekonomická data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**85**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

Time period	2022		2023		2024		2025		2026		2027	
	total	per 1 Nm³	total	per 1 Nm³	total	per 1 Nm³	total	per 1 Nm³	total	per 1 Nm³	total	per 1 Nm³
Total production MWh	4 893	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.
Total production Nm³	518 475	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.
Production costs												
Biomass consumption	1 000 000	1,929	3 075 000	1,977	3 151 875	2,026	3 230 672	2,077	3 311 439	2,129	3 394 225	2,182
Process Chemistry and Analysis	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Electricity	1 343 200	2,591	4 130 340	2,655	4 233 599	2,722	4 339 438	2,790	4 447 924	2,860	4 559 123	2,931
Biomass loading	100 000	0,193	307 500	0,198	315 188	0,203	323 067	0,208	331 144	0,213	339 422	0,218
Digestate handling	160 000	0,309	492 000	0,316	504 300	0,324	516 908	0,332	529 830	0,341	543 076	0,349
Oxygen consumption	52 952	0,102	162 827	0,105	166 898	0,107	171 071	0,110	175 347	0,113	179 731	0,116
Repair and maintenance	494 433	0,954	1 520 381	0,977	1 558 390	1,002	1 597 350	1,027	1 637 284	1,053	1 678 216	1,079
Other (1 year with startup)	516 481	0,996	50 679	0,033	51 946	0,033	53 245	0,034	54 576	0,035	55 941	0,036
Insurance	115 368	0,223	354 756	0,228	363 624	0,234	372 715	0,240	382 033	0,246	391 584	0,252
Personnel costs, loader	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Personnel costs, technician	100 000	0,193	307 500	0,198	315 188	0,203	323 067	0,208	331 144	0,213	339 422	0,218
Personnel costs, manager	140 000	0,270	430 500	0,277	441 263	0,284	452 294	0,291	463 601	0,298	475 191	0,306
Total personnel costs	240 000	0,463	738 000	0,474	756 450	0,486	775 361	0,498	794 745	0,511	814 614	0,524
Health and social insurance payments	84 000	0,162	258 300	0,166	264 758	0,170	271 376	0,174	278 161	0,179	285 115	0,183
Property tax	30 000	0,058	92 250	0,059	0	0,000	0	0,000	0	0,000	0	0,000
Depreciation of technology	2 917 932	5,628	8 972 642	5,769	9 196 958	5,913	9 426 882	6,061	9 662 554	6,212	9 904 117	6,367
Depreciation of buildings	107 485	0,207	330 518	0,212	338 781	0,218	347 250	0,223	355 931	0,229	364 830	0,235
Financial costs												
Interests	-156 782	0,302	-445 292	0,286	-406 219	0,261	-365 146	0,235	-321 973	0,207	-276 590	0,178
Financing costs	94 990	0,183	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total costs	7 413 623	14,299	20 930 485	13,456	21 308 985	13,700	21 790 482	14,009	22 282 941	14,326	22 786 583	14,650
	-7 413 623		-20 930 485		-21 308 985		-21 790 482		-22 282 941		-22 786 583	
Biomethane revenues	10 603 429	20,451	32 446 492	20,860	33 095 422	21,277	33 757 331	21,703	34 432 477	22,137	35 121 127	22,580
Revenue heat	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total revenue	10 603 429	20,451	32 446 492	20,860	33 095 422	21,277	33 757 331	21,703	34 432 477	22,137	35 121 127	22,580
Result before tax		3 189 806		11 516 007		11 786 437		11 966 849		12 149 536		12 334 544
Income tax		606 063		2 188 041		2 239 423		2 273 701		2 308 412		2 343 563
Result after tax		2 583 743		9 327 966		9 547 014		9 693 148		9 841 124		9 990 981
Loan repayment		-246 222		-763 722		-802 795		-843 867		-887 041		-932 424
Annual profit		2 337 520		8 564 244		8 744 219		8 849 280		8 954 083		9 058 557
Operating Cash Flow		5 362 938		17 867 404		18 279 957		18 623 412		18 972 568		19 327 504
Net present value		-44 567 886		-29 801 436		-16 067 434		-3 347 393		8 433 079		19 342 951

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Technicko-ekonomická data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		3%	
Revenue escalation		2%	
Discount rate		10%	
Income tax for legal entities		19%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**85**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

0

2028		2029		2030		2031		2032		2033		2034	
total	per 1 Nm[9]	total	per 1 Nm[10]	total	per 1 Nm[11]	total	per 1 Nm[12]	total	per 1 Nm[13]	total	per 1 Nm[14]	total	per 1 Nm[15]
14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.
1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.
3 479 080	2,237	3 566 057	2,293	3 655 209	2,350	3 746 589	2,409	3 840 254	2,469	3 936 260	2,531	4 034 666	2,594
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
4 673 101	3,004	4 789 928	3,079	4 909 676	3,156	5 032 418	3,235	5 158 229	3,316	5 287 184	3,399	5 419 364	3,484
347 908	0,224	356 606	0,229	365 521	0,235	374 659	0,241	384 025	0,247	393 626	0,253	403 467	0,259
556 653	0,358	570 569	0,367	584 833	0,376	599 454	0,385	614 441	0,395	629 802	0,405	645 547	0,415
184 224	0,118	188 830	0,121	193 551	0,124	198 389	0,128	203 349	0,131	208 433	0,134	213 644	0,137
1 720 172	1,106	1 763 176	1,134	1 807 255	1,162	1 852 437	1,191	1 898 747	1,221	1 946 216	1,251	1 994 872	1,283
57 339	0,037	58 773	0,038	60 242	0,039	61 748	0,040	63 292	0,041	64 874	0,042	66 496	0,043
401 373	0,258	411 408	0,264	421 693	0,271	432 235	0,278	443 041	0,285	454 117	0,292	465 470	0,299
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
347 908	0,224	356 606	0,229	365 521	0,235	374 659	0,241	384 025	0,247	393 626	0,253	403 467	0,259
487 071	0,313	499 248	0,321	511 729	0,329	524 522	0,337	537 636	0,346	551 076	0,354	564 853	0,363
834 979	0,537	855 854	0,550	877 250	0,564	899 181	0,578	921 661	0,593	944 702	0,607	968 320	0,623
292 243	0,188	299 549	0,193	307 038	0,197	314 713	0,202	322 581	0,207	330 646	0,213	338 912	0,218
90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058
10 151 720	6,527	10 405 513	6,690	10 665 651	6,857	10 932 292	7,028	11 205 600	7,204	11 485 740	7,384	11 772 883	7,569
373 950	0,240	383 299	0,246	392 882	0,253	402 704	0,259	412 771	0,265	423 090	0,272	433 668	0,279
-228 885	0,147	-178 740	0,115	-126 029	0,081	-70 622	0,045	-14 905	0,010	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
23 391 628	15,039	23 918 301	15,377	24 456 829	15,724	25 007 442	16,078	25 572 896	16,441	26 194 690	16,841	26 847 308	17,260
-23 391 628		-23 918 301		-24 456 829		-25 007 442		-25 572 896		-26 194 690		-26 847 308	
35 823 549	23,031	36 540 020	23,492	37 270 821	23,962	38 016 237	24,441	38 776 562	24,930	39 552 093	25,428	40 343 135	25,937
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
35 823 549	23,031	36 540 020	23,492	37 270 821	23,962	38 016 237	24,441	38 776 562	24,930	39 552 093	25,428	40 343 135	25,937
12 431 921		12 621 719		12 813 991		13 008 795		13 203 666		13 357 403		13 495 827	
2 362 065		2 398 127		2 434 658		2 471 671		2 508 697		2 537 906		2 564 207	
10 069 856		10 223 592		10 379 333		10 537 124		10 694 969		10 819 496		10 931 620	
-980 129		-1 030 274		-1 082 985		-1 138 392		-791 104		0		0	
9 089 728		9 193 318		9 296 348		9 398 732		9 903 865		10 819 496		10 931 620	
19 615 398		19 982 131		20 354 881		20 733 728		21 522 236		22 728 326		23 138 171	
29 408 752		38 730 563		47 363 020		55 356 769		62 900 182		70 142 127		76 844 431	

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Technicko-ekonomická data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		85	EUR/MWh
Realization price of heat		0	EUR/GJ

0

2035		2036		2037		2038		2039		2040		2041		2042	
total	per 1 Nm[16]	total	per 1 Nm[17]	total	per 1 Nm[18]	total	per 1 Nm[19]	total	per 1 Nm[20]	total	per 1 Nm[21]	total	per 1 Nm[22]	total	per 1 Nm[23]
14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.
1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.
4 135 533	2,659	4 238 921	2,725	4 344 894	2,793	4 453 517	2,863	4 564 855	2,935	4 678 976	3,008	4 795 951	3,083	4 915 849	3,160
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
5 554 848	3,571	5 693 719	3,661	5 836 062	3,752	5 981 964	3,846	6 131 513	3,942	6 284 801	4,041	6 441 921	4,142	6 602 969	4,245
413 553	0,266	423 892	0,273	434 489	0,279	445 352	0,286	456 485	0,293	467 898	0,301	479 595	0,308	491 585	0,316
661 685	0,425	678 227	0,436	695 183	0,447	712 563	0,458	730 377	0,470	748 636	0,481	767 352	0,493	786 536	0,506
218 985	0,141	224 459	0,144	230 071	0,148	235 823	0,152	241 718	0,155	247 761	0,159	253 955	0,163	260 304	0,167
2 044 743	1,315	2 095 862	1,347	2 148 259	1,381	2 201 965	1,416	2 257 014	1,451	2 313 439	1,487	2 371 275	1,525	2 430 557	1,563
68 158	0,044	69 862	0,045	71 609	0,046	73 399	0,047	75 234	0,048	77 115	0,050	79 043	0,051	81 019	0,052
477 107	0,307	489 034	0,314	501 260	0,322	513 792	0,330	526 637	0,339	539 803	0,347	553 298	0,356	567 130	0,365
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
413 553	0,266	423 892	0,273	434 489	0,279	445 352	0,286	456 485	0,293	467 898	0,301	479 595	0,308	491 585	0,316
578 975	0,372	593 449	0,382	608 285	0,391	623 492	0,401	639 080	0,411	655 057	0,421	671 433	0,432	688 219	0,442
992 528	0,638	1 017 341	0,654	1 042 775	0,670	1 068 844	0,687	1 095 565	0,704	1 122 954	0,722	1 151 028	0,740	1 179 804	0,759
347 385	0,223	356 069	0,229	364 971	0,235	374 095	0,241	383 448	0,247	393 034	0,253	402 860	0,259	412 931	0,265
90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058
12 067 205	7,758	12 368 885	7,952	12 678 108	8,151	12 995 060	8,355	13 319 937	8,564	13 652 935	8,778	13 994 259	8,997	14 344 115	9,222
444 509	0,286	455 622	0,293	467 013	0,300	478 688	0,308	490 655	0,315	502 922	0,323	515 495	0,331	528 382	0,340
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
27 516 240	17,690	28 201 896	18,131	28 904 694	18,583	29 625 061	19,046	30 363 438	19,521	31 120 274	20,008	31 896 030	20,506	32 691 181	21,018
-27 516 240		-28 201 896		-28 904 694		-29 625 061		-30 363 438		-31 120 274		-31 896 030		-32 691 181	
41 149 998	26,456	41 972 997	26,985	42 812 457	27,525	43 668 707	28,075	44 542 081	28,637	45 432 922	29,209	46 341 581	29,794	47 268 412	30,389
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
41 149 998	26,456	41 972 997	26,985	42 812 457	27,525	43 668 707	28,075	44 542 081	28,637	45 432 922	29,209	46 341 581	29,794	47 268 412	30,389
	13 633 757		13 771 101		13 907 764		14 043 645		14 178 643		14 312 649		14 445 550		14 577 231
	2 590 414		2 616 509		2 642 475		2 668 293		2 693 942		2 719 403		2 744 655		2 769 674
	11 043 343		11 154 592		11 265 289		11 375 353		11 484 701		11 593 245		11 700 896		11 807 557
	0		0		0		0		0		0		0		0
	11 043 343		11 154 592		11 265 289		11 375 353		11 484 701		11 593 245		11 700 896		11 807 557
	23 555 058		23 979 100		24 410 409		24 849 101		25 295 293		25 749 102		26 210 649		26 680 054
	83 047 214		88 787 620		94 100 036		99 016 298		103 565 879		107 776 063		111 672 109		115 277 400

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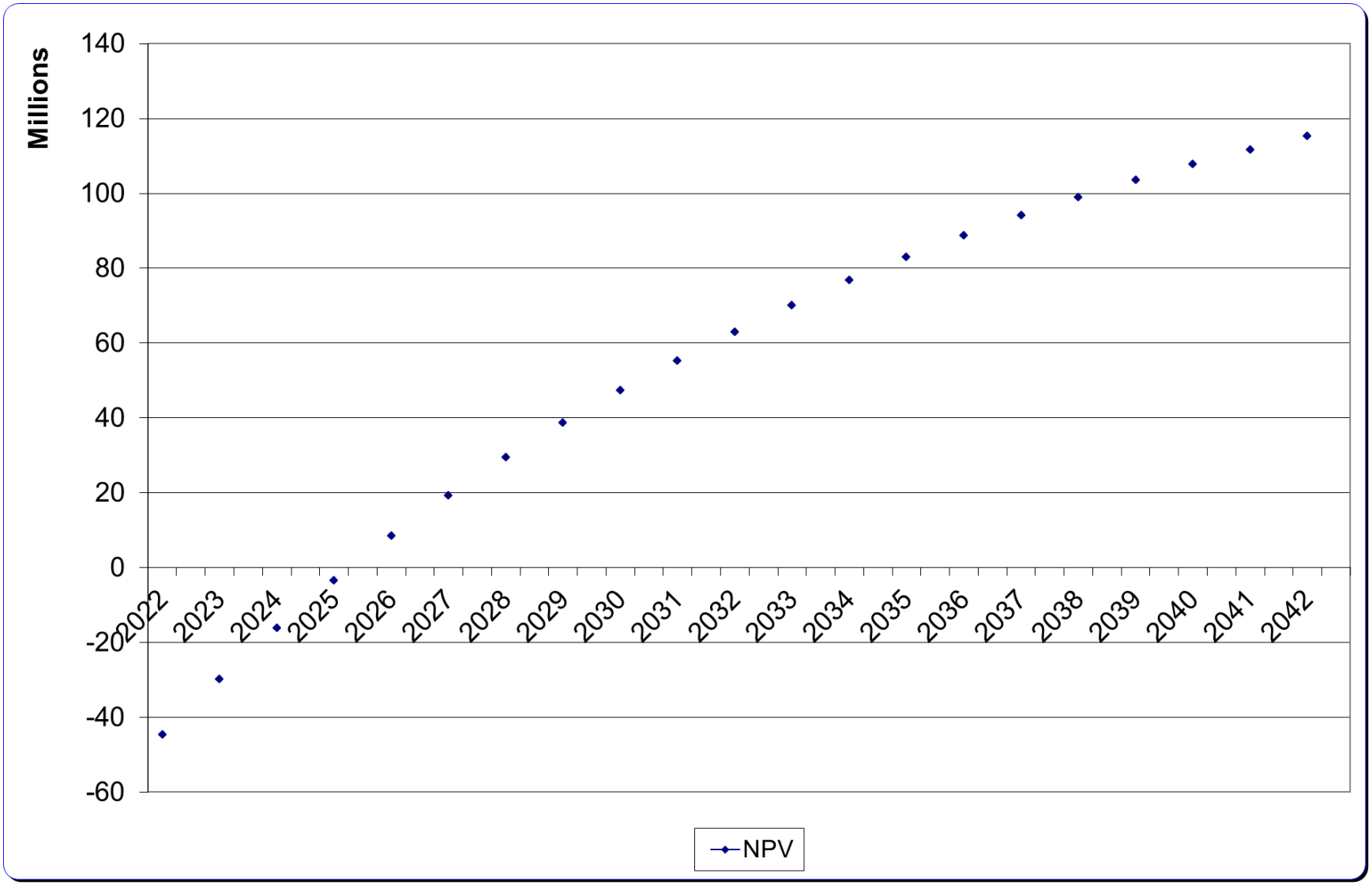
Figure 6: NPV, membrane separation, 85 EUR/ 1 MWh



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4.5.6 Cash-Flow analysis, membrane separation, 120 EUR/ 1 MWh

This analysis is the same as the membrane separation analysis, with the only difference being that the realisation price of biomethane is set at 120 EUR/ 1 MWh (Table 12).

In this variant, a positive profit is achieved in all years of operation of the technology, as well as a stable cash flow. A positive NPV (net present value of the project) is achieved in the second full year of operation of the technology, or in the third year of operation.

The analysis shows that the specific realisation price of biomethane is about 2,2 times the total specific cost of its production.

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Table 12: Cash-Flow analysis, membrane separation, 120 EUR/ 1 MWh

Technicko-ekonomická data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**120**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

Time period	2022		2023		2024		2025		2026		2027	
	total	per 1 Nm[3]	total	per 1 Nm[4]	total	per 1 Nm[5]	total	per 1 Nm[6]	total	per 1 Nm[7]	total	per 1 Nm[8]
Total production MWh	4 893	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.
Total production Nm^3	518 475	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.
Production costs												
Biomass consumption	1 000 000	1,929	3 075 000	1,977	3 151 875	2,026	3 230 672	2,077	3 311 439	2,129	3 394 225	2,182
Process Chemistry and Analysis	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Electricity	1 343 200	2,591	4 130 340	2,655	4 233 599	2,722	4 339 438	2,790	4 447 924	2,860	4 559 123	2,931
Biomass loading	100 000	0,193	307 500	0,198	315 188	0,203	323 067	0,208	331 144	0,213	339 422	0,218
Digestate handling	160 000	0,309	492 000	0,316	504 300	0,324	516 908	0,332	529 830	0,341	543 076	0,349
Oxygen consumption	52 952	0,102	162 827	0,105	166 898	0,107	171 071	0,110	175 347	0,113	179 731	0,116
Repair and maintenance	494 433	0,954	1 520 381	0,977	1 558 390	1,002	1 597 350	1,027	1 637 284	1,053	1 678 216	1,079
Other (1 year with startup)	516 481	0,996	50 679	0,033	51 946	0,033	53 245	0,034	54 576	0,035	55 941	0,036
Insurance	115 368	0,223	354 756	0,228	363 624	0,234	372 715	0,240	382 033	0,246	391 584	0,252
Personnel costs, loader	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Personnel costs, technician	100 000	0,193	307 500	0,198	315 188	0,203	323 067	0,208	331 144	0,213	339 422	0,218
Personnel costs, manager	140 000	0,270	430 500	0,277	441 263	0,284	452 294	0,291	463 601	0,298	475 191	0,306
Total personnel costs	240 000	0,463	738 000	0,474	756 450	0,486	775 361	0,498	794 745	0,511	814 614	0,524
Health and social insurance payment	84 000	0,162	258 300	0,166	264 758	0,170	271 376	0,174	278 161	0,179	285 115	0,183
Property tax	30 000	0,058	92 250	0,059	0	0,000	0	0,000	0	0,000	0	0,000
Depreciation of technology	2 917 932	5,628	8 972 642	5,769	9 196 958	5,913	9 426 882	6,061	9 662 554	6,212	9 904 117	6,367
Depreciation of buildings	107 485	0,207	330 518	0,212	338 781	0,218	347 250	0,223	355 931	0,229	364 830	0,235
Financial costs												
Interests	-156 782	0,302	-445 292	0,286	-406 219	0,261	-365 146	0,235	-321 973	0,207	-276 590	0,178
Financing costs	94 990	0,183	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total costs	7 413 623	14,299	20 930 485	13,456	21 308 985	13,700	21 790 482	14,009	22 282 941	14,326	22 786 583	14,650
	-7 413 623		-20 930 485		-21 308 985		-21 790 482		-22 282 941		-22 786 583	
Biomethane revenues	14 969 547	28,872	45 806 813	29,450	46 722 949	30,039	47 657 408	30,639	48 610 556	31,252	49 582 767	31,877
Revenue heat	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total revenue	14 969 547	28,872	45 806 813	29,450	46 722 949	30,039	47 657 408	30,639	48 610 556	31,252	49 582 767	31,877
Result before tax		7 555 923		24 876 328		25 413 964		25 866 926		26 327 615		26 796 184
Income tax		1 435 625		4 726 502		4 828 653		4 914 716		5 002 247		5 091 275
Result after tax		6 120 298		20 149 825		20 585 311		20 952 210		21 325 368		21 704 909
Loan repayment		-246 222		-763 722		-802 795		-843 867		-887 041		-932 424
Annual profit		5 874 076		19 386 104		19 782 516		20 108 343		20 438 327		20 772 485
Operating Cash Flow		8 899 493		28 689 263		29 318 254		29 882 474		30 456 812		31 041 432
Net present value		-41 352 835		-17 642 700		4 384 538		24 794 670		43 705 953		61 228 033

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Technicko-ekonomická data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		3%	
Revenue escalation		2%	
Discount rate		10%	
Income tax for legal entities		19%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		**120**	**EUR/MWh**
Realization price of heat		0	EUR/GJ

0

2028		2029		2030		2031		2032		2033		2034	
total	per 1 Nm³	total	per 1 Nm³[10]	total	per 1 Nm³[11]	total	per 1 Nm³[12]	total	per 1 Nm³[13]	total	per 1 Nm³[14]	total	per 1 Nm³[15]
14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.
1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.
3 479 080	2,237	3 566 057	2,293	3 655 209	2,350	3 746 589	2,409	3 840 254	2,469	3 936 260	2,531	4 034 666	2,594
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
4 673 101	3,004	4 789 928	3,079	4 909 676	3,156	5 032 418	3,235	5 158 229	3,316	5 287 184	3,399	5 419 364	3,484
347 908	0,224	356 606	0,229	365 521	0,235	374 659	0,241	384 025	0,247	393 626	0,253	403 467	0,259
556 653	0,358	570 569	0,367	584 833	0,376	599 454	0,385	614 441	0,395	629 802	0,405	645 547	0,415
184 224	0,118	188 830	0,121	193 551	0,124	198 389	0,128	203 349	0,131	208 433	0,134	213 644	0,137
1 720 172	1,106	1 763 176	1,134	1 807 255	1,162	1 852 437	1,191	1 898 747	1,221	1 946 216	1,251	1 994 872	1,283
57 339	0,037	58 773	0,038	60 242	0,039	61 748	0,040	63 292	0,041	64 874	0,042	66 496	0,043
401 373	0,258	411 408	0,264	421 693	0,271	432 235	0,278	443 041	0,285	454 117	0,292	465 470	0,299
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
347 908	0,224	356 606	0,229	365 521	0,235	374 659	0,241	384 025	0,247	393 626	0,253	403 467	0,259
487 071	0,313	499 248	0,321	511 729	0,329	524 522	0,337	537 636	0,346	551 076	0,354	564 853	0,363
834 979	0,537	855 854	0,550	877 250	0,564	899 181	0,578	921 661	0,593	944 702	0,607	968 320	0,623
292 243	0,188	299 549	0,193	307 038	0,197	314 713	0,202	322 581	0,207	330 646	0,213	338 912	0,218
90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058
10 151 720	6,527	10 405 513	6,690	10 665 651	6,857	10 932 292	7,028	11 205 600	7,204	11 485 740	7,384	11 772 883	7,569
373 950	0,240	383 299	0,246	392 882	0,253	402 704	0,259	412 771	0,265	423 090	0,272	433 668	0,279
-228 885	0,147	-178 740	0,115	-126 029	0,081	-70 622	0,045	-14 905	0,010	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
23 391 628	15,039	23 918 301	15,377	24 456 829	15,724	25 007 442	16,078	25 572 896	16,441	26 194 690	16,841	26 847 308	17,260
-23 391 628		-23 918 301		-24 456 829		-25 007 442		-25 572 896		-26 194 690		-26 847 308	
50 574 422	32,515	51 585 911	33,165	52 617 629	33,828	53 669 982	34,505	54 743 381	35,195	55 838 249	35,899	56 955 014	36,617
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
50 574 422	32,515	51 585 911	33,165	52 617 629	33,828	53 669 982	34,505	54 743 381	35,195	55 838 249	35,899	56 955 014	36,617
	27 182 795		27 667 610		28 160 800		28 662 540		29 170 485		29 643 558		30 107 706
	5 164 731		5 256 846		5 350 552		5 445 883		5 542 392		5 632 276		5 720 464
	22 018 064		22 410 764		22 810 248		23 216 657		23 628 093		24 011 282		24 387 242
	-980 129		-1 030 274		-1 082 985		-1 138 392		-791 104		0		0
	21 037 935		21 380 490		21 727 263		22 078 265		22 836 989		24 011 282		24 387 242
	31 563 606		32 169 302		32 785 796		33 413 261		34 455 360		35 920 113		36 593 793
	77 425 153		92 432 370		106 336 748		119 219 007		131 295 400		142 740 655		153 340 573

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Technicko-ekonomická data			
Loan interest rate		5%	
Number of instalments per year		12	
Credit frame duration		10	
Expenditure escalation		2,5%	
Revenue escalation		2,0%	
Discount rate		10,0%	
Income tax for legal entities		19,0%	
Production load		92%	
Production load in year 1	33%	4	months
Biomethane realisation price		120	EUR/MWh
Realization price of heat		0	EUR/GJ

0

2035		2036		2037		2038		2039		2040		2041		2042	
total	per 1 Nm[16]	total	per 1 Nm[17]	total	per 1 Nm[18]	total	per 1 Nm[19]	total	per 1 Nm[20]	total	per 1 Nm[21]	total	per 1 Nm[22]	total	per 1 Nm[23]
14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.	14 678	n.a.
1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.	1 555 426	n.a.
4 135 533	2,659	4 238 921	2,725	4 344 894	2,793	4 453 517	2,863	4 564 855	2,935	4 678 976	3,008	4 795 951	3,083	4 915 849	3,160
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
5 554 848	3,571	5 693 719	3,661	5 836 062	3,752	5 981 964	3,846	6 131 513	3,942	6 284 801	4,041	6 441 921	4,142	6 602 969	4,245
413 553	0,266	423 892	0,273	434 489	0,279	445 352	0,286	456 485	0,293	467 898	0,301	479 595	0,308	491 585	0,316
661 685	0,425	678 227	0,436	695 183	0,447	712 563	0,458	730 377	0,470	748 636	0,481	767 352	0,493	786 536	0,506
218 985	0,141	224 459	0,144	230 071	0,148	235 823	0,152	241 718	0,155	247 761	0,159	253 955	0,163	260 304	0,167
2 044 743	1,315	2 095 862	1,347	2 148 259	1,381	2 201 965	1,416	2 257 014	1,451	2 313 439	1,487	2 371 275	1,525	2 430 557	1,563
68 158	0,044	69 862	0,045	71 609	0,046	73 399	0,047	75 234	0,048	77 115	0,050	79 043	0,051	81 019	0,052
477 107	0,307	489 034	0,314	501 260	0,322	513 792	0,330	526 637	0,339	539 803	0,347	553 298	0,356	567 130	0,365
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
413 553	0,266	423 892	0,273	434 489	0,279	445 352	0,286	456 485	0,293	467 898	0,301	479 595	0,308	491 585	0,316
578 975	0,372	593 449	0,382	608 285	0,391	623 492	0,401	639 080	0,411	655 057	0,421	671 433	0,432	688 219	0,442
992 528	0,638	1 017 341	0,654	1 042 775	0,670	1 068 844	0,687	1 095 565	0,704	1 122 954	0,722	1 151 028	0,740	1 179 804	0,759
347 385	0,223	356 069	0,229	364 971	0,235	374 095	0,241	383 448	0,247	393 034	0,253	402 860	0,259	412 931	0,265
90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058	90 000	0,058
12 067 205	7,758	12 368 885	7,952	12 678 108	8,151	12 995 060	8,355	13 319 937	8,564	13 652 935	8,778	13 994 259	8,997	14 344 115	9,222
444 509	0,286	455 622	0,293	467 013	0,300	478 688	0,308	490 655	0,315	502 922	0,323	515 495	0,331	528 382	0,340
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
27 516 240	17,690	28 201 896	18,131	28 904 694	18,583	29 625 061	19,046	30 363 438	19,521	31 120 274	20,008	31 896 030	20,506	32 691 181	21,018
-27 516 240		-28 201 896		-28 904 694		-29 625 061		-30 363 438		-31 120 274		-31 896 030		-32 691 181	
58 094 114	37,349	59 255 996	38,096	60 441 116	38,858	61 649 939	39,635	62 882 937	40,428	64 140 596	41,237	65 423 408	42,061	66 731 876	42,903
0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
58 094 114	37,349	59 255 996	38,096	60 441 116	38,858	61 649 939	39,635	62 882 937	40,428	64 140 596	41,237	65 423 408	42,061	66 731 876	42,903
	30 577 874		31 054 100		31 536 423		32 024 878		32 519 500		33 020 323		33 527 378		34 040 695
	5 809 796		5 900 279		5 991 920		6 084 727		6 178 705		6 273 861		6 370 202		6 467 732
	24 768 078		25 153 821		25 544 502		25 940 151		26 340 795		26 746 461		27 157 176		27 572 963
	0		0		0		0		0		0		0		0
	24 768 078		25 153 821		25 544 502		25 940 151		26 340 795		26 746 461		27 157 176		27 572 963
	37 279 793		37 978 329		38 689 623		39 413 899		40 151 387		40 902 318		41 666 929		42 445 460
	163 157 508		172 249 218		180 669 207		188 467 037		195 688 617		202 376 472		208 569 996		214 305 675

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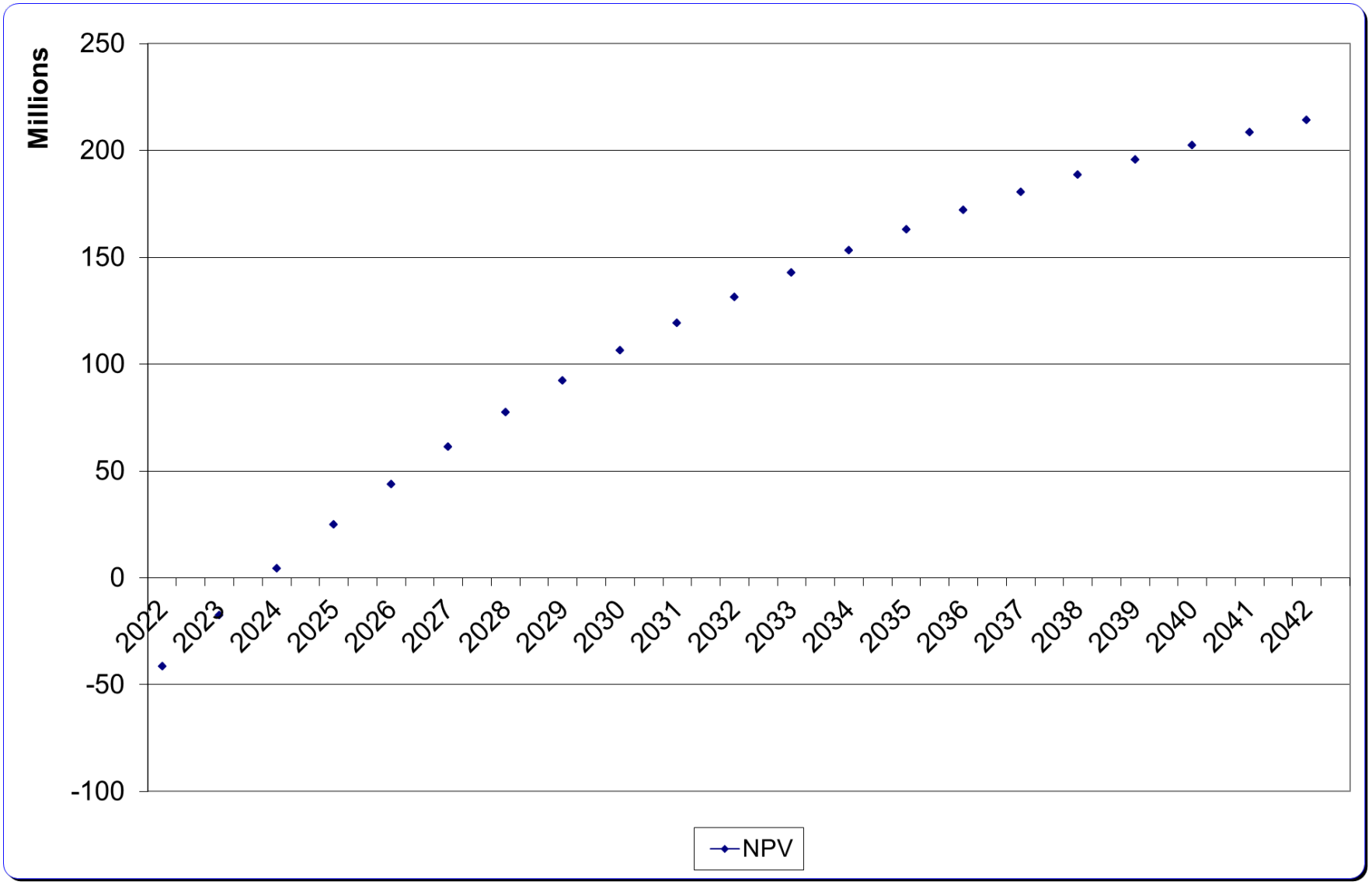
Figure 7: NPV, membrane separation, 120 EUR/ 1 MWh



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5 Subsidies

5.1 Overview of current and possible future subsidy programmes for investment subsidies for the biomethane production line

The production and use of biomethane is a low-emission business activity. This activity is thus actively supported by subsidy programmes.

Currently, the transition from the 2014-2020 programming period to the 2021-2027 programming period is taking place. This transition is characterized by a short gap in suitable calls, practically for all supported activities. The basic character of the transition of programming periods is the closure of the relatively well-known OP PIK programme and the opening of the new OP TAK (Operational Programme Technologies and Applications for Competitiveness 2021-2027). An analogous transformation of programmes is currently also taking place at the State Environmental Fund.

5.1.1 Operational Programme Enterprise and Innovation

The starting point for subsidies from the Ministry of Industry and Trade programme are the conditions of the last, 6th call in the OP PIK programme. The aim of the "Low Carbon Technologies" programme was to support the competitiveness of enterprises and the sustainability of the Czech economy through the introduction of innovative technologies in the field of renewable energy sources and energy management. Increasing the use of more efficient and reliable low-carbon technologies, which are not yet commonly applied in the Czech Republic. The outcome of the projects was the diffusion of modern low-carbon technologies in the field of renewable energy sources and the increase of the Czech Republic's self-sufficiency in raw materials by substituting primary sources. The planned allocation for this call was 100 million CZK (support for enterprises not meeting the definition of small and medium-sized enterprises according to Annex 1 of Commission Regulation (EU) No 651/2014 can be granted up to a maximum of 80% of the allocation for this call). This was a rolling call for proposals, where the receipt of applications for support ran from 15th July 2020 to 18th December 2020. The rate of support corresponded to the difference between the eligible costs and the operating profit from the investment. The operating profit was deducted from the eligible costs, either ex ante or by applying a clawback mechanism. A reasonable operating profit before tax (WACC) of 7,94 % was considered. The minimum amount of the subsidy was 500 thousand CZK. The maximum amount of the WACC was 35 million CZK.

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Table 13: Supported projects in VI. Call for proposals under the OP PIK programme "Low Carbon Technologies"

Application number	Recommended amount of subsidy
CZ.01.3.14/0.0/0.0/20_345/0023746	20.323.911.00 CZK
CZ.01.3.14/0.0/0.0/20_345/0024656	34.684.262.00 CZK
CZ.01.3.14/0.0/0.0/20_345/ 0024632	34.261.100.00 CZK
CZ.01.3.14/0.0/0.0/20_345/ 0024670	34.351.223.00 CZK
CZ.01.3.14/0.0/0.0/20_345/0023317	26.375.420.00 CZK
CZ.01.3.14/0.0/0.0/20_345/0024661	26.530.057.00 CZK
TOTAL	**176.525.973 CZK**

5.1.2 Operational Programme Technology and Applications for Competitiveness

This new operational programme is basically analogous to the programme from the previous programming or budget period.

The programming document for this new operational programme was approved on 4th October 2021. Within this programming document, the activity of biomethane production and use is supported by several specific objectives. The realistic programme objective is *Specific Objective No. 2 - Promotion of energy from renewable sources in accordance with Directive (EU) 2018/2001, including the sustainability criteria set out in the Directive*. This specific objective will support, among others, the following activities related to the production and use of biomethane:

- *Support for the transformation of existing biogas power plants into biomethane plants and the construction of new biomethane plants (biogas purification to natural gas quality, gas carburation, biomethane quality measurement, compression and data transmission), including their connection to the gas grid and/or local infrastructure;*

The dates of announcement in this operational programme are not known, but it can be assumed that they will be continuously opened from 4Q 2021/1Q 2022.

5.1.3 National Recovery Plan

Although the National Renewable Energy Plan is one of the largest subsidy programmes in the history of the country, it does not contain specific targets for the construction and development of fuel-based renewable energy sources.

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5.1.4 State Environmental Fund

Within the framework of the operational programmes of the State Environmental Fund (SEF), it is necessary to mention the operational programme Fair Transformation, which targets, among others, the Usti nad Labem Region. This operational programme also covers the development of clean energy and energy savings. The publication of the detailed conditions of this operational programme is expected in 4Q 2021.

The second operational programme that partially or only marginally affects the project under assessment is the Operational Programme Environment. Under the OP Environment, *Priority Axis 3: Waste and material flows, environmental burdens and risks, area 3.2 - Increase the share of material and energy recovery of waste*. The following activities can be applied for under this programme and may (partly) affect the AD Plant project:

- *construction and modernisation of waste collection, sorting and treatment facilities*
- *sorting and re-sorting lines with associated waste treatment technologies*
- *collection of gastro/kitchen waste*
- *facilities for the thermal treatment of waste, medical and hazardous waste, including their modernisation*
- *construction of biogas plants for the treatment of bio-waste*
- ***construction of biogas micro-oxidation technology using pure oxygen***

It is **necessary to underline the fact** that this subsidy title can appropriately cover all investment activities that will be required by the biogas treatment technology directly **in the operation of an existing biogas plant**.

6 Other - changes in the legislative framework

In this section, the Contractor adds significant legislative changes that may have an impact on the implementation of the project. In this context, it mentions in particular the Energy Act 458/2000 Coll. and the Act on Supported Energy Sources 165/2012 Coll. whose substantial amendment was completed in September 2021.

The amendment to the Energy Act introduced an obligation for the DSO to purchase, under certain conditions, the production pipeline connecting the biomethane production plant. This obligation will come into force on 1 January 2022. It is defined in Article 59, paragraph 11 (section summarising the obligations of the distribution system operator):

(11) If the gas producer operating the biomethane production plant so requests, the distribution system operator to which the biomethane production plant is connected shall be obliged to purchase the production pipeline and related process facilities from the gas producer at a price corresponding to the value of the facilities included in the price of the related gas service. The obligation to purchase the production pipeline pursuant to the first sentence shall not arise if the gas producer has not awarded the construction of the production pipeline in a tender procedure pursuant to the Act governing public procurement or if the production pipeline has been established in violation of the connection conditions or

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technical requirements for the construction of the production pipeline laid down in the implementing legislation.

7 Annex

Attachment 1: Methods of measurement and determination of biomethane quality parameters

Name	Method
Methane	gas chromatography, thermal conductivity detector
Ethane	gas chromatography, thermal conductivity detector
Propane	gas chromatography, thermal conductivity detector
Sum of Butanes	gas chromatography, thermal conductivity detector
Sum of Pentanes and higher hydrocarbons	gas chromatography, thermal conductivity detector
Dew Point of Water	calibrated operating hygrometer
Dew Point of Hydrocarbons	calibrated analyser of Dew Point of Hydrocarbons
Oxygen	electrochemically
Carbon dioxide	gas chromatography, thermal conductivity detector
Nitrogen	gas chromatography, thermal conductivity detector
Hydrogen	electrochemically
Total Sulphur content	The Lingener combustion method
Sulphane	electrochemically
Ammonia content	indophenol method
Halogens (F, Cl)	absorption, potentiometrically
Organic Silicon compounds	gas chromatography, - mass spectrometric detector
Particle size/dust, rust	gravimetrically
Harmful living microorganisms	measurement of bacterial growth on agar plates
Gross Calorific Value	calculation based on biomethane composition according to EN ISO 6976
Temperature	resistance thermometer, thermocouple
Odour/ possibility of covering it with odorant	olfactometric measurement according to EU EN 13 725
Selected Volatile Organic Compounds (Benzene, Toluene, Ethylbenzene, Xylene)	gas chromatography, flame ionization detector

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Attachment 2: Minimum frequency of measurement of biomethane quality parameters.

Name	Frequency of Measurement		
	Biomass group 1	**Biomass group 2**	**Biomass group 3**
Methane	Continuously	Continuously	Continuously
Ethane	Continuously	Continuously	Continuously
Propane	Continuously	Continuously	Continuously
Sum of Butanes	Continuously	Continuously	Continuously
Sum of Pentanes and higher hydrocarbons	Continuously	Continuously	Continuously
Dew Point of Water	Continuously	Continuously	Continuously
Dew Point of Hydrocarbons	once - when the plant is put into operation and at least once every 12 months	once - when the plant is put into operation and at least once every 12 months	once - when the plant is put into operation and at least once every 12 months
Oxygen	Continuously	Continuously	Continuously
Carbon dioxide	Continuously	Continuously	Continuously
Nitrogen	Continuously	Continuously	Continuously
Hydrogen	once - when the plant is put into operation and at least once every 12 months	once - when the plant is put into operation and at least once every 12 months	once - when the plant is put into operation and at least once every 12 months
Total Sulphur content	once - when the plant is put into operation	once - when the plant is put into operation and at least once every 12 months	once - when the plant is put into operation and at least once every 12 months
Sulphane	Continuously	Continuously	Continuously
Ammonia content	Continuously	Continuously	Continuously
Halogens (F, Cl)	not measured	once - when the plant is put into operation	once - when the plant is put into operation and at least once every 12 months
Organic Silicon compounds	not measured	once - when the plant is put into operation	once - when the plant is put into operation and at least once every 12 months
Particle size/dust, rust	once - when the plant is put into operation	once - when the plant is put into operation and at least once every 12 months	once - when the plant is put into operation and at least once every 12 months
Harmful living microorganisms	once - when the plant is put into operation	once - when the plant is put into operation	once - when the plant is put into operation
Gross Calorific Value	continuous arithmetic	continuous arithmetic	continuous arithmetic

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	average of the calculated values for a given day	average of the calculated values for a given day	average of the calculated values for a given day
Temperature	Continuously	Continuously	Continuously
Odour/ possibility of covering it with odorant	not measured	once - when the plant is put into operation	once - when the plant is put into operation and at least once every 12 months

Explanatory notes:

Biomass group 1 is all biomass types classified in category 1 and, from category 2 onwards, biomass types listed under points (a) to (e) under Decree No. 459/2012 Coll.[6]

Biomass group 2 are those types of biomass classified in category 2 listed under points (f) to (k) under Decree No. 459/2012 Coll.

Biomass group 3 are those types of biomass classified in category 2 listed under points (l) to (n) under Decree No. 459/2012 Coll.

The frequency of measurements for single-measurement biomethane quality parameters may be higher if the measured values approach the limit value specified in Annex 1 to this Decree by less than 5 %, the shortest frequency being once every 3 months.

[6] ., Decree No. 459/2012 Coll., Decree on requirements for biomethane, the method of measuring biomethane and the quality of biomethane supplied to the transmission system, distribution system or underground gas storage facilities.

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