D.T 4.3.5 ADDITIONAL FEASIBILITY STUDY – CZECH REPUBLIC

Project Title: REEF2W Increased renewable energy and energy efficiency by integrating, combining and empowering urban wastewater and organic waste management systems

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Content

1. Introduction

As part of the REEF2W project, this study examines the possibility of modifying sludge management - or part of the use of biogas at the Olomouc WWTP. The possibility of replacing the existing cogeneration unit processing biogas with a biogas treatment unit for biomethane quality (corresponds to natural gas) and using this biomethane for injection into the natural gas distribution network or as fuel in vehicles with a filling station is investigated.

The project assessment will then be performed with the REEF2W Tool both for the assessment of the economic balance and for the assessment of the impact on the environment.

2. Anaerobic digestion – status quo

Biogas is obtained at conventional WWTPs by anaerobic sludge stabilization technology. Anaerobic sludge stabilization is a technology in which sludge in heated tanks (anaerobic reactors) is stabilized by the action of anaerobic microorganisms in the absence of air. Easily decomposable organic substances are decomposed, thus reducing the amount of dry matter in the sludge, reducing the odor and partial sanitation. A by-product of anaerobic sludge stabilization is biogas.

Digestion tanks are usually implemented as mixing stirred reactors. Heating is most often realized by circulating sludge through an externally located heat exchanger, mixing is ensured most often by injecting biogas, the bubbles of which provide their own mixing effect. The second way is different types of propeller stirrers on the central rods.

In common technology, it is usually used to heat its own stabilization (digestion) tanks. Biogas is usually used for energy. The simplest technology of its use is its combustion in a boiler for heat production. Larger WWTPs with higher biogas production usually use biogas in cogeneration units for the production of electricity and heat. However, the amount of biogas produced at a number of WWTPs does not even cover the actual heat consumption for heating digestion tanks.

The main problem of the energy balance is the very low dry matter of the processed sludge. This also causes problems with the potential lack of heat for the technology, especially in the winter. The solution is usually to increase the dry matter of the sludge by concentrating it. In the digestion tank, the hydraulic retention time is thus increased, the heated amount of material is reduced and the biogas production is consequently higher.

The second possibility to increase biogas production is the intake of external substrates. However, most of the technologies of digestion tanks used at WWTPs in the Czech Republic are unsuitable for this (mixing, pumping, heating) except limited amount of liquid co-substrates.

The digestion tanks of WWTPs are usually very unsuitable, usually for receiving external solid waste. This is mainly due to the unsuitable method of heating and mixing, which is only adapted for the processing of relatively homogeneous and low concentrated sludges.

Only suitable homogeneous materials are suitable as co-substrates under suitable conditions - e.g. distillery effluents, by-products from the production of biofuels (glycerol substrates), wastewater from high COD.

3. Technology of Olomouc WWTP

The Olomouc WWTP is a classic mechanical-biological wastewater treatment plant with an installed capacity of 259,500 PE. The owner of the WWTP is the statutory city of Olomouc and the operator of the treatment plant is MOVO a.s. company.

Mechanical pre-treatment consists of a gravel trap, coarse and fine screens, a longitudinal two-chamber aerated sand trap and two circular settling tanks with a diameter of 40 m.

The activation process is in the arrangement of RDN (regeneration – denitrification – nitrification) with post denitrification and post aeration with internal recirculation in two lines. Each line has 27 sections, 4 sections are used as regeneration of return sludge, the denitrification selector is the inflow of raw wastewater from the UN and return sludge from regeneration. Denitrification consists of 3 - 5 sections, nitrification consists of 12 - 15 sections, post denitrification consists of 2 - 4 sections and post aeration consists of 1 - 2 sections. The nitrification sections are equipped with finely bubbled SANITAIRE aeration and agitators. Air supply is provided by AERZEN blowers (4 × aeration, 2 × regeneration). The return sludge is pumped and discharged to regenerations by means of screw pumps. Internal recirculation is provided by one propeller pump for each line.

Ferrous sulphate is metered into the post denitrification. The outflow from the lines is for 4 settling tanks with a diameter of 40 m (4 × 4870 m3). The technological process of activation lines is controlled from oxygen probes located in the regeneration, nitrification zone and post aeration zone, ammonia analyzers (regeneration zone and effluent) and nitrate probes (2 post denitrification) produced by HACH-LANGE.

3.1. Sludge management of WWTP Olomouc

The sludge management consists of 2 thickening tanks for raw sludge and 3 digestion tanks - circular steel tanks with a volume of 3 × 3200 m^3, 2 thickening tanks for digested sludge and 2 gas tanks for 2 × 1500 m^3. Excess sludge is concentrated on 2 Alfa-Laval thickening centrifuges and pumped into the raw sludge thickening tanks and then into the digestion tank (HV) or directly into the HV. The residence time in VN is 23 days. The average dry matter of mixed sludge entering the HV is 4.2%.

Dewatering of the digested sludge is performed on an Alfa-Laval centrifuge from an input dry matter of 3.1% to an output dry matter of 26.8% (2016). The specific consumption of flocculant is 5.5 kg / ts (2016). The sludge is handed over for disposal to the production of industrial compost.

Primary sludge thickening

The sludge from the settling tanks is discharged into the primary sludge sump and from there pumped into the primary sludge thickening tank with a volume of 2 x 900 m^3. Gravity thickening tanks are open. The average dry matter of primary sludge after concentration is 3.3% (data for 2016).

Secondary sludge thickening

Excess sludge is thickened mechanically on a fully automatic thickening line, which consists of a pair of ALFA-LAVAL centrifuges with accessories.

Digesters

The thickened primary sludge is pumped together with the thickened secondary sludge into digestion tanks. The three digestion tanks with a diameter of 15 m are mixed by circulating pumps and biogas. Sludge collection from HV is performed by overflow of the operating level. The digestion tanks are not equipped with a level sensor to identify problems associated with possible foaming.

Thickened sludge thickening tanks

The digested sludge is drained in gravity open tanks with a volume of 2 x 900 m^3. The sludge passes from the gravity tanks to the 2 x 75 m^3 homogenization tanks, from where it is pumped to the decanting centrifuge.

Sludge dewatering

Dewatering of the digested sludge is performed on an Alfa-Laval centrifuge from an input dry matter of 3.1% to an output dry matter of 26.8% (2016). The specific consumption of flocculant is 5.5 kg / ts (2016).

From the centrifuge, the dewatered sludge is transported by a screw conveyor to a truck and transported to a covered sludge landfill or transported directly from the WWTP. The sludge is handed over for disposal for the production of industrial compost.

Centrifuge parameters: Alfa-Laval, type ALDEC 556. Centrifuge output: 25 m^3 / h, Load: 800 - 900 kg / h.

Covered sludge storage

It is a structure with a rectangular floor plan measuring approximately 23 x 60 m. Around the entire perimeter of the storage area is a monolithic concrete fence wall with a height of approximately 3 m. The wall is interrupted in 5 places by entrances from the external road. The landfill space is free without internal partitions or dividing structures.

The roofing of the sludge landfill is realized by means of a hall prefabricated structure made of steel columns anchored in concrete footings. The longitudinal modulus of the hall columns is 10 x 6.0 m. The transverse span of the connection is 24 m. The roof construction consists of saddle-shaped steel trusses. The roofing is made of profiled metal sheets. The roof is drained by external gutters with downspouts, opening into the sewerage of the WWTP area. The space between the edge of the roof and the head of the enclosure wall (approx. Another 3 m from the 6 m total height of the structure) is completely free without cladding or walling. The inner surface of the hall is illuminated by electric lamps anchored to the columns of the hall. The building does not contain any permanently installed machinery and technological equipment. There is a loader for sludge stratification and for loading sludge for final removal from the WWTP.

Landfill usable area: 1300 m^2

Landfill usable volume: 2,400 m^3

Sludge silo

Sludge management also includes sludge silos, which, however, are not currently used due to operational problems with the transport of sludge to the silos.

3.1. Biogas management of WWTP Olomouc

The produced biogas is accumulated in 2 gas tanks with a volume of 1,500 m^3 and is burned in cogeneration units. The boiler room is also equipped with a natural gas boiler.

At the Olomouc WWTP, biogas (BP) is produced as a by-product during the digestion of sludge in digestion tanks (HV). This BP is collected in gas tanks and is also used for the production of electricity in cogeneration units (CHP) in order to reduce the energy intensity of the entire WWTP operation. In the production of el. energy per CHP, thermal energy is also generated, which is used back to heat digestion tanks and operating buildings. At the Olomouc WWTP, it is also possible to use one CHP unit for natural gas. At present, two KGJ JENBACHER units from 1994 are located at the Olomouc WWTP.

COGENERATION (combined heat and power production):

Technical description:

2 pcs cogeneration unit JENBACHER JMS 312 GS-B.L

Engine type: Stanford 634 H

El. power: 450 kW, max. achieved power after overhaul 420kWe

Heat output: 560 kW

Year of production: 1996, in 2014 a general overhaul of both units took place.

BOILER ROOM:

Technical description:

Total installed capacity of the boiler room: 3,120 MW

Boiler designation:

K1 - 1040 kW, KDVE 100, s / n .: 12523, natural gas

K2 - 1040 kW, KDVE 100, s / n .: 12518, biogas

K2 - 1040 kW, KDVE 100, s / n .: 12520, biogas

Manufacturer: ČKD Dukla

3.2. Sludge management parameters and operational data

There are 3 digestion tanks with a total capacity of 9,600 m^3 available at the WWTP. They are operated at a temperature of 40 ° C in mesophilic mode. Mixing of the digestion tank is ensured hydraulically by sludge recycling (large circulation pumps) and biogas. Sludge collection from HV is ensured by overflow from the tank level. The hydraulic residence time in HV is 23 days. The dry matter of all mixed sludge at the inlet to the HV is 4.2%. Efficiency of removal of organic substances in HV is 55%. In terms of material and hydraulic loading, the digestion tanks could be loaded more, but in this case more serious foaming problems can be predicted. Due to the absence of even an ordinary level sensor in the HV, operation with a higher load in the current state would be risky.

For this project, the average biogas production for the last two years is calculated, with the average methane content in the biogas. Biogas is not expected to have a problematic concentration of sulfur or chlorine compounds.

Efficiency of removal of organic substances in HV is 53%. In terms of material and hydraulic loading, there is some room for receiving a larger number of external substrates. To ensure sufficient residence time required for the growth of anaerobic decomposition microorganisms and the current degree of concentration of the input material, we do not recommend that the additional amount of external substrates exceeds 5,000 m^3. For this project, the average biogas production for the last two years is calculated, with the average methane content in the biogas. Biogas is not expected to have a problematic concentration of sulfur or chlorine compounds.

External substrates are used at the Olomouc WWTP to optimize biogas production. It is mainly the so-called lecitin wastewater, which is dosed directly into the digestion tank. Dosed lecitin waters contain a high proportion of easily decomposable organic matter. Their amount depends on the current availability - 1200 - 3000 t / year.

Parameter	Two years average	Unit
Biogas production	1 964 831	m^3
Methane conc.	67,5	%

The biogas quality is stable. Average methane content calculated by last 2 years is 67,5 %. Complex biogas analysis is at the table following:

Parameter	Average	Unit
H_2S	6,04	mg/m^3
Sorg	0,19	mg/m^3
NH_3	2,49	mg/m^3
HCl	179	mg/m^3
Cl_2	10,49	mg/m^3
Clorg	Not detected	
Cl total	189,5	mg/m^3
Rel. humidity	31,6	%
O_2	0,2	%
CH_4	67,5	%
CO	3	%
CO_2	28	mg/m^3
N_2	4,2	%
siloxany	2,2	mg/m^3

The total balance of biogas production and its use, as well as the amount of heat and electricity produced at the WWTP is presented in the following table:

	2011	2012	2013	2014	2015	2016
Biogas production (m^3)	1 742 860	1 775 790	1 932 685	1 756 360	1 898 672	2 030 990
Biogas production (Nm^3)	1 456 143	1 483 656	1 614 740	1 467 422	1 586 323	1 696 873
Biogas for CHP (KGJ)	1 241 334	1 437 639	1 548 773	1 273 361	1 242 048	1 611 270
Biogas for heat	199 605	20 762	77 362	104 307	290 845	190 792

Biogas unused (flare)	0	0	0	0	0	0
CH_4 (%)	61	61	62,8	64,2	68	67,6
H_2S (ppm)	0,1	0,1	26,15	29,8	29,8	6,04
Natural gas for heat prod.	137 613	152 076	138 335	87 560	93 680	127 254
Electricity from biogas (kWh)	2 393 661	2 893 126	3 190 156	2 747 821	2 764 973	3 138 123
Heat from biogas (GJ)	12 741	13 900	14 348	14 963	17 599	17 166
Heat from biogas – CHP (kWh)	3 539 170	3 826 639	3 985 610	4 156 635	4 889 016	4 768 654
Heat from natural gas (GJ)	5 099	4 654	4 248	2 679	2 867	3 894
Heat from natural gas (kWh)	1 416 390	1 292 749	1 180 002	744 320	796 344	1 081 754

The current heat consumption for the Olomouc WWTP is calculated as the average for the last two years of the sum of heat produced in cogeneration units and heat produced in natural gas boilers.

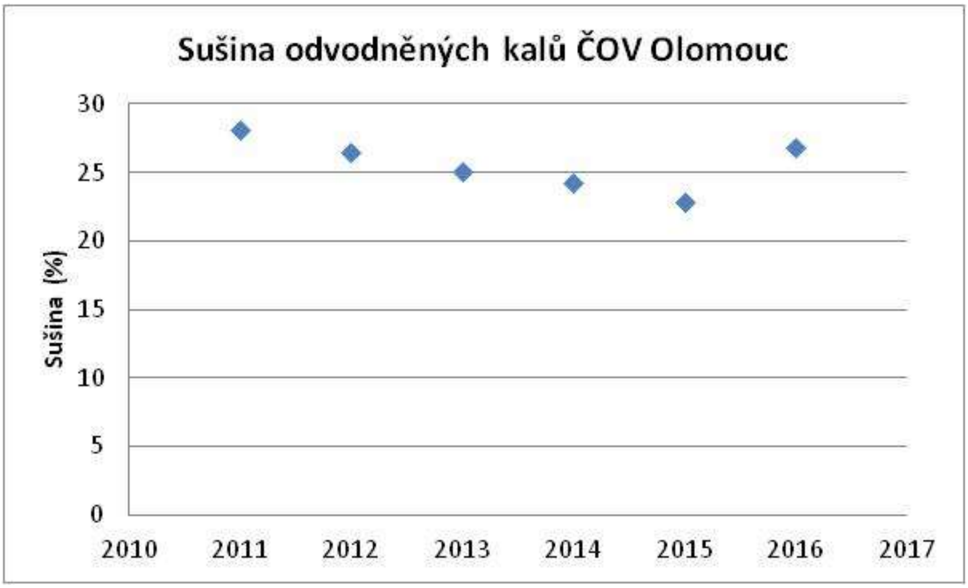
Heat consumption for the Olomouc WWTP is considered in this project: 20,763 GJ. It is understood as the amount of heat that is needed at the WWTP using current technologies, especially to ensure the heating of digestion tanks and heating of operating buildings.

3.3. Sludge production

Anaerobically stabilized sludges with the following properties are produced at the Olomouc WWTP.

Basic balance							
Yearly production (wet)	t	8 069	8 079	8 138	7 475	8 668	8 591
Yearly production (dry)	t	2 273	2 141	2 043	1 794	1 968	2 302
TS	%	28,1	26,5	25,1	24,3	22,8	26,8
Sludge disposal costs - total	Kč	4 357 233	4 362 806	4 394 477	4 036 748	3 027 865	2 921 069
Sludge disposal costs	Kč/t	540	540	540	540	349	340

The dry matter (sušina) of the produced sludge is stable, good quality drainage can be stated.



The quality of sludge in terms of the content of undesirable substances is relatively problematic. Sludges from the Olomouc WWTP contain increased concentrations of heavy metals.

	unit	Limit for agricultural use	average	maximum
Pb	mg/kgsuš	200	38	73
Cd	mg/kgsuš	5	2	3
Cu	mg/kgsuš	500	247	290
Cr	mg/kgsuš	200	37	58
Ni	mg/kgsuš	100	21	26
Zn	mg/kgsuš	2500	1119	1300
Hg	mg/kgsuš	5	2	5,31
As	mg/kgsuš	30	6	18
PCB	μg/ kgsuš	0,6	0,030	0,054
AOX	mg/kgsuš	500	320	327

4. External substrates use

External substrates are used at the Olomouc WWTP to optimize biogas production. It is mainly a lecithin substrate from the production of lecithin. For their reception it is realized directly into the digestion tanks. The amount of substrate depends on the current availability - 1500 - 3000 t / year.

Alternatively, other homogeneous liquid, easily pumpable materials without undesirable impurities (solid particles) can be received via the receiving point. Receipt of other materials is not possible without completely radical modifications of the WWTP.

The processing of biowaste from the city of Olomouc (municipal biodegradable waste), food-waste and possibly biowaste from green maintenance is potentially offered for processing at the WWTP.

The quantity and quality of these bio-wastes is not specified at this stage, but the following can be stated:

- Grass processing requires a specific design of HV / fermenters with very efficient mixing with propeller or paddle mixers. Due to the tendency of the grass mass to create level crusts, the maximum height of the tank is about 6 m. Mixing is suitable, which mechanically directly separates the level crust.

- Processing of grass matter requires the implementation of a specialized intake system of plant matter

- The treatment of gastro-waste is subject to the fulfillment of the conditions of EP Regulation 1069/2009. Ordinary gastro-waste / bio-waste of category 3, bio-waste from international transport of category 1. Category 1 material cannot be processed in the facility at all, it is necessary to incinerate. Category 3 material can be processed.

- For the processing of Category 3 material, it will be necessary to implement a new receiving object with receiving technology (hopper with screw feeder, primary crusher, sump, pump with macerator / secondary crusher, sanitation) located in the hall.

- When processing biowaste (any), mixing with biogas and sludge recirculation is unsuitable, direct heating with heating coils at the tank wall and mixing with propeller stirrers is suitable.

Increase of Nammon concentration in sludge water by biowaste intake

During the anaerobic decomposition of biowaste, the nitrogen contained in them (nitrate, nitrite, organic in proteins) is almost completely converted to a soluble ammoniacal form. This significantly affects the composition of anaerobic biomass (sludge) and in extreme cases (eg when processing large amounts of proteinaceous material) it can also lead to the achievement of Nammon inhibitory concentration and collapse of the anaerobic reactor. However, we do not anticipate this extreme case. However, ammoniacal nitrogen will significantly affect the composition of sludge water from sludge dewatering, where the vast majority of nitrogen will be distributed.

At this stage of the project, the quantity and quality of biowaste expected for processing is not specified. For the purposes of the calculation, we will consider wastes of the nature of gastro-waste, which are generated in significant quantities during the operation of the airport (category 3 according to 1069/2009 EP). The waste will consist of food scraps from restaurants and snacks, a mixture of fats, plant parts and animal parts.

The composition of such material varies in selected installations, according to long-term experience from the operation of biogas plants, we consider the following:

	TS (%)	Org. fraction (% of TS)	N (kg/t)	C:N
Biowaste	20	90	4,8	18:01

It can be stated that the amount of nitrogen released from biowaste can significantly affect the process of sludge water treatment at the WWTP - especially in the activation by the increased amount of NAMMON introduced into the wastewater treatment process.

No significant increase in biogas production or a change in the substrate composition of anaerobic sludge stabilization is expected at the Olomouc WWTP.

From the point of view of longer-term development, it is potentially possible to implement equipment for the treatment of industrial liquid waste at the WWTP, but the quantity and quality of wastewater from this operation will not significantly affect biogas production.

5. Biogas upgrading

Replacement of CHP with equipment for treatment of biogas to natural gas quality brings an increase in the efficiency of the use of RES - energy production from biogas. The produced biomethane is used with maximum efficiency in contrast to biogas, where part of the energy is wasted at certain times of the year (heat in summer). For the production of biomethane, it is necessary to first technologically modify the biogas produced at the WWTP - to get rid of CO2 and other components so that its quality corresponds to natural gas.

For the purposes of treatment of biogas generated in anaerobic fermentation processes, especially at wastewater treatment plants ("WWTP"), but also biogas plants or gas landfills, the following technologies are widespread in operation around the world:

• Physical absorption - is performed by selective dissolution of biogas components in scrubbing liquids.

• Chemical absorption - this method can be used to remove H_2S from biogas. It is performed with organic solvents or anhydrous salts.

• Adsorption - this method can also be used to remove H_2S from biogas. T It is performed using highly porous solids - sorbents or activated carbon. This method is complicated and expensive due to the need to regenerate the sorbent.

• Pressure Swing Adsorption (PSA) - used in combination with adsorption to remove H_2O, H_2S and NH_3 from biogas. The technology therefore includes compressors, chambers, adsorption units. Before starting cleaning with this method, it is necessary to dewater the biogas.

• Separate condensation by compression - this method can remove CO_2 from biogas. The basis of the technology is compression and decompression.

• Freezing systems - cryogenic technology - this method can be used to remove H_2O from biogas. The technology is industrial refrigeration equipment.

• Biodegradation - this method can be used to remove H_2S from biogas. After dissolving in water, microorganisms of the species Thiobacillus and Sulfolobus are used in the presence of oxygen, the output is S and H_2O.

• Molecular sieves (filters) - this method can be used to remove H_2O, CO_2 and H_2S from biogas. Molecular sieves (filters) are used. The method is simple, but it is necessary to perform periodic regeneration of molecular sieves.

• Membrane separation - this method is used to purify gas from CO_2, H_2S and N_2. The above overview shows a wide range of possibilities for the separation of partial components from biogas. However, not all methods are applicable for the purification of raw biogas to natural gas level, as raw biogas contains a wider range of gases that need to be removed.

5.1. PSA technology – molecular sieves

Van der Waals forces are used to separate CO2, which bind CO2 molecules to the surface of a highly porous solid (usually activated carbon). Adsorption takes place at elevated pressure and desorption (absorbent regeneration) at reduced pressure. The pressure conditions in the adsorber thus change repeatedly. In order to produce biomethane smoothly, several adsorbers are usually installed in parallel - each time the adsorber is in a different part of the process.

The sulfur-free biogas (pretreated by activated carbon filter) is compressed to approx. 0.4 - 0.7 MPa and cooled to 10 - 20 ° C and the condensed water is separated off. The biogas thus purified is fed to an adsorber, which contains a so-called molecular sieve formed by very finely ground carbon in extruded form. This absorbent captures CO_2 and the residual content of H_2O and H_2S, as well as a small amount of methane, biomethane with a methane concentration of 95-98% emerges from the upper part of the filter. After saturation of the adsorber, the feed biogas feed is switched to a second set of regenerated filters and the spent molecular sieve must be regenerated. Thus, the technology is not continuous, but by arranging more networks in series, continuous operation is achieved.

5.2. PWA technology – washing by water

The technology uses different solubilities of undesirable components of biogas (CO_2, H_2S, NH_3) compared to methane at different temperatures and pressures (at a pressure of 1 bar and 25 ° C) CO_2 has 25 times more solubility than methane, H_2S almost 80 times and NH_3 more than 20 thousand. times). As it passes through the working medium at elevated pressure, the process liquid is saturated with undesired impurities, while methane passes through and increases its proportion in the exhaust gas. Water is most often used as a working medium (solvent).

The raw biogas is compressed and cooled in two stages and enters the bottom of the absorption column at a temperature of approx. 15 ° C and a pressure of 0.3 - 0.7 MPa. Water is injected into its upper part, which traps the mentioned unwanted gases in the countercurrent shower and the resulting gas leaves with a content of 95 - 98% methane. The disadvantage of the process is that it does not remove other components, ie N_2 and O_2. For higher process efficiency, the column is filled inside with a highly porous material with a large inner surface. Water from the bottom of the column is pumped into the expansion vessel and from there, after release to atmospheric pressure, to the desorption column, where the dissolved gases are released by means of a countercurrent air and with it leave the atmosphere.

Organic solvents (Genosorb, Selexol) based on polyethylene glycol can also be used instead of water for better absorption properties. While maintaining the same absorption capacity, the device reaches much smaller dimensions. The sulfur content of the raw biogas must be less than 300 ppm / Nm^3. Above this value, desulphurisation is necessary again as a pretreatment to the technology itself.

5.3. Membrane separation

Membrane separation uses different permeabilities of individual components in the biogas mixture through a thin membrane. The material for the construction of membrane screens is most often polymers. CO_2, as well as the residual content of H_2S and water vapor (perm), passes more easily through the membrane. Most of the methane remains in front of the membrane and leaves on the pressure side (retentate). The proportion of methane in the retentate depends on the membrane material used, its age and also on the pressure level. Under optimal conditions, the cleaning process takes place at a pressure of 0.7 - 0.9 MPa and 97 - 98% methane content is achieved. Two-stage and multi-stage separation allows higher purification rates and lower methane losses. In addition to the classic "dry" method of membrane treatment, there is also an alternative method of treatment with the so-called "wet membrane", verified, for example, at the Prague WWTP, but with the conclusion that to achieve the required degree of separation the technology would have to be implemented in two stages.

6. Final use of biomethane

To use the manufactured product, it is possible to consider 2 variants:

1) Injection into the gas pipeline system.

2) Production of bioCNG for cars.

6.1. Injection into natural gas distribution system

The conditions for the connection of biomethane production to the distribution system of natural gas are always assessed in the Czech Republic individually and within the given distribution system operator. Specific conditions for injecting biomethane into the distribution network, or transmission system GasNet, s.r.o. non-public and responsible employees of the company declared an individual approach to each request for the connection of its own resource and only on the basis of the submitted project. For this reason, the expected implementation conditions are based on the conditions defined by applicable legislation (especially Decree No. 459/2012 Coll.), Technical standards (TDG 983 01 for the injection station of treated biomethane and quality and measurement requirements, TDG 902 02 for the quality of the injection biogas), as well as the approach of other distribution companies (eg RWE Gas Net has historically used the document "Technical conditions for injecting biomethane into its distribution system and conditions for connecting biogas plants" for similar cases).

6.1.1. Conditions of connecting to natural gas distribution system

The conditions for the connection of gaseous fuels to the distribution system are set for biomethane in particular by Decree No. 459/2012 Coll. and subsequently technical standard TPG 902 02. However, this technical regulation is non-binding, with the exception of some provisions, which are binding, if the requirements have been incorporated into the so-called Gas Distribution System Operator's Rules (PDS Rules) or the Transmission Operator's Rules. gas systems (PPS Rules). The Code, while respecting generally binding legal regulations in the gas industry (Rules for the organization of the gas market), specifies the commercial and technical conditions under which third party access to the gas system is possible. The rules of each distribution system operator are subject to approval by the Energy Regulatory Office and form an integral part of the Gas Distribution Agreement.

The Rules of the Distribution System Operator, which belong to the GasNet Group, also address the issue of transportation of alternative gaseous fuels - ie also produced biomethane. The parameters of TDG 902 02 are only a recommendation and the operator of the relevant distribution system may require stricter values when negotiating the connection of biomethane plants. The method and scope of measurement of individual parameters also depends on the agreement between the relevant distribution system operator and the biomethane producer.

The technical requirement defines the supply equipment of the distribution system as a measuring line, which contains a remotely controlled closure (ball valve) at the inlet, as well as safety elements (safety quick-release valves and non-return valve or non-return valve), gas meter and odorization device. This single-row measuring line is inserted between the biomethane production and the entrance to the production pipeline. Physically, the power supply device can be located in a biomethane production facility (structurally separate space) or it can be designed as a separate facility, e.g. a container. The power supply is also equipped with a telemetry control panel for receiving and transmitting data on the quality of biomethane obtained from the manufacturer, the amount of injected gas and other data from the power supply needed for operation of the control room (including e.g. data on odorization plant operation).

The power supply device provides:

1. reception, processing, evaluation and remote transmission of data on the quality of the supplied biomethane and the operation of the power supply;

2. control of sufficient biomethane inlet pressure;

a) inlet pressure drop control - the non-return valve / valve is opened by the biomethane inlet overpressure;

b) control of the inlet pressure rise - when the agreed maximum value of the inlet pressure is exceeded, the supply device is automatically shut down at the safety quick-release;

3. measurement of the volume of biomethane flowed through;

4. odorization of biomethane.

The actual machine part of the power supply must be built in the PN 40 design and in a dimension that corresponds to the volume of biomethane produced. The connection of the supply device to the outlet of the biomethane production and to the production gas pipeline is solved preferably in the form of above-ground flange connections. The power supply allows automatic, unattended operation. It is equipped with a remote-controlled valve at the inlet for the separation of the power supply and biomethane production in the event of a failure of biomethane supplies to the power supply.

The quality of biomethane must be demonstrated by the manufacturer at the specified frequencies. When putting the power supply system into operation (eg after a shutdown), the biomethane producer shall provide effective cooperation to the employees of the gas pipeline distribution company or its contractual suppliers. The manufacturer will inform the DSO in advance about the planned outages of biomethane supplies to the supply equipment. In the event of a shutdown due to an accident on the biomethane production technology, the biomethane producer will immediately inform the DSO dispatch center about them and their expected length. The same notification obligation of the biomethane producer exists for the resumption of the start of deliveries of biomethane to the supply facility.

When putting the power supply into operation after a shutdown due to the closure of the BRU (due to an increase in inlet pressure above the upper limit) - opening of the BRU, a DSO employee (or his contracted supplier) must always be physically present on site. With a higher frequency of outages with the stated cause, which were not caused by DSO (more than once a month), each further intervention of a DSO employee will be charged to the biomethane producer in the amount according to the current price list of works.

Regarding the quality of the supplied biomethane, the technical requirement defines the so-called "Standard biomethane", which correlates with TDG 902 02 and also defines the procedures for measuring some quantities.

6.1.2. Chemical composition requirements

In general, it is always necessary to ensure the composition of biomethane in the following parameters and the following methods according to Decree No. 459/2012 Coll .:

parameter	Gas distribution system	transportation system and gas storage facilities
methane	≥ 95 % mol	≥ 95 % mol
ethan	≤ 3 % mol.	≤ 3 % mol.
propane	≤3 % mol.	≤ 3 % mol.
sum of butanes	≤ 1 % mol.	≤ 1 % (2 %) mol.

the sum of pentanes and higher hydrocarbons	≤0,5 % mol.	≤0,5 % mol.
dew point of water	≤ -7 °C	≤ -7 °C
dew point of hydrocarbons	0°C	0°C
oxygen	≤ 0,5 % mol	≤ 0,02 % mol
carbon dioxide	≤ 5 % mol	≤ 3 % mol
nitrogen	≤ 2 % mol	≤ 2 % mol
hydrogen	≤ 0, 1 % mol	≤0,01 % mol
total sulfur content	≤ 30 mg/m^3	≤ 30 mg/m^3
sulfane	≤ 5 mg/m^3	≤ 5 mg/m^3
ammonia content	≤ 3 mg/m^3	≤ 3 mg/m^3
halogens (F, Cl)	≤ 1,5 mg/m^3	≤ 1,5 mg/m^3
organic silicon compounds	≤ 5 mg/m^3	≤ 5 mg/m^3
particle size / dust, res	≤ 5 µm	≤ 3 µm
harmful living microorganisms	absent	absent
combustion heat	value in the range <-1%; 1%> average values of combustion heat in the given in the quality zone for the previous month	value in the range <-1%; 1%> average values of combustion heat in the given in the quality zone for the previous month
temperature	from 0 ° C to 20 ° C for <0.4 MPa and from 0 ° C to 40 ° C for> 0.4 MPa	0°C to 40°C
selected volatile aromatic hydrocarbons - benzene, toluene, ethylbenzene, xylene	≤ 10 mg/m^3	≤ 10 mg/m^3

parameter	method
methane	gas chromatography, thermal conductivity detector
ethan	gas chromatography, thermal conductivity detector
propane	gas chromatography, thermal conductivity detector
sum of butanes	gas chromatography, thermal conductivity detector
the sum of pentanes and higher hydrocarbons	gas chromatography, thermal conductivity detector
dew point of water	calibrated operating hygrometer

dew point of hydrocarbons	calibrated hydrocarbon dew point analyzer
oxygen	electrochemically
carbon dioxide	gas chromatography, thermal conductivity detector
nitrogen	gas chromatography, thermal conductivity detector
hydrogen	electrochemically
total sulfur content	Linger's combustion method
sulfane	electrochemically
ammonia content	indophenol method
halogens (F, Cl)	absorption, potentiometrically
organic silicon compounds	gas chromatography, - mass spectrometric detector
particle size / dust, res	gravimetrically
harmful living microorganisms	measurement of bacterial growth on an agar plate
combustion heat	calculation based on the composition of biomethane according to ČSN EN ISO 6976
temperature	resistance thermometer, thermocouple
odor / 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

Due to the classification of sludge from wastewater treatment plants into category 2 according to Decree No. 477/2012 Coll. is the obligation to measure quality according to the following table.

parameter	measurement frequency
methane	continuously
ethan	continuously
propane	continuously
sum of butanes	continuously
the sum of pentanes and higher hydrocarbons	continuously

dew point of water	continuously
dew point of hydrocarbons	one-time - when putting the production into operation and then at least once every 12 months
oxygen	continuously
carbon dioxide	continuously
nitrogen	continuously
hydrogen	one-time - when putting the production into operation and then at least once every 12 months
total sulfur content	one-time - when putting the production into operation and then at least once every 12 months
sulfane	continuously
ammonia content	continuously
halogens (F, Cl)	one-time - when putting the production into operation
organic silicon compounds	one-time - when putting the production into operation
particle size / dust, res	one-time - when putting the production into operation and then at least once every 12 months
harmful living microorganisms	one-time - when putting the production into operation
combustion heat	continuously - arithmetic average of the calculated values for the day
temperature	continuously
selected volatile aromatic hydrocarbons - benzene, toluene, ethylbenzene, xylene	one-time - when putting the production into operation

6.1.1. Physical properties requirements

Pressure

The minimum value of the pressure at the inlet to the supply facility must be determined in specific cases individually so that this overpressure exceeds the pressure loss of the supply facility (approx. 100 kPa), production pipeline (according to reality) and to ensure a pressure drop at the inlet to the distribution system of at least 200 kPa. The maximum value of the pressure at the inlet to the supply device is the minimum pressure + 300 kPa. The biomethane producer adjusts the pressure at the inlet to the supply equipment also according to the instructions of the dispatching workplace of the distribution or transmission system operator according to the current parameters (pressure at the connection point) of the distribution system. The biomethane manufacturer eliminates pressure surges at the inlet to the power supply with a suitable technological solution - a control device.

Temperature

The temperature of the incoming biomethane is contractually determined between the biomethane producer and the operator of the distribution or transmission system. The temperature of the biomethane at the inlet to the power supply must be in the range (+ 3 ° C to + 30 ° C).

Mechanical impurities

Filtration of mechanical impurities (filter with a separation of at least 1 micron) is required at the inlet to the power supply.

Volume and its measurement

The volume of injected Standard Biomethane is measured in the "Feed Device". The volume measurement is performed by a specified meter in the administration and operation of the distribution or transmission systems. The measuring point is also equipped with a converter of state variables (pressure, temperature, compressibility).

Data on the injected volume of Standard Biomethane measured by a specified meter managed and owned by DSO are processed by the telemetry central and regularly transmitted to the biomethane producer for the purposes of balancing the supplies of Standard Biomethane to the distribution or transmission system.

6.1.2. Real possibilities of connection to the natural gas distribution network

Despite the above facts, the fact remains that the owner of the distribution network is obliged under Decree No. 62/2011 Coll., On the conditions of connection to the gas system, to make the network available to alternative suppliers and even have to pay a significant part of connection costs if the quality of the supply is guaranteed. biomethane and if the conditions for connection of the applicant are met, in particular the safe and reliable operation of the superior system will not be endangered. There is no connection to the VTL gas pipeline in the Olomouc WWTP area.

6.2. BioCNG

Due to the intended use in CNG vehicles, it is not necessary to meet the requirements of ČSN EN ISO 13734 (gas quality in distribution networks), but only the requirements of ČSN 656514 "Motor fuels - Biogas for spark ignition engines" for category LH, which are listed below and at the same time the requirements of Decree No. 133/2010 Coll., on requirements for fuels.

The Decree No. 133/2010 Coll. will be amended in 2016 and it is necessary to reflect the expected amendment in the requirements for suppliers. In particular, this is the wording of Annex 3, which, in addition to the above parameters, determines the requirement for a relative density in the range of 0.56 - 0.7 (which is when using a dry air density of 0.72 - 0.903 kg / m3). In tab. 4, there is already a limit requirement for a maximum water content of 32 mg / m3, but Annex No. 3 to the Decree in question defines it as 20 mg / kg. In the given range of densities, the requirement of Annex No. 3 is thus stricter - after recalculation, the limit of 32 mg / m3 subsequently represents the maximum range from 23.12 mg / kg to 28.9 mg / kg. For this reason, it is necessary to add a limit to a water content of 20 mg / kg and a relative density of 0.56 - 0.7.

Annex No. 3 also contains the requirement for calorific value defined as the Wobbe number in the values of 12.7 - 14.5 kWh / m3. In the standard ČSN 656514 it is 44.7 - 46.4 MJ / m3 for type LH and 43.9 - 47.3 MJ / m3 for type H. In this, Annex No. 3 is also slightly stricter, after the conversion it is based on 45.72 - 52.2 MJ / m3 and it is necessary to require a minimum calorific value, expressed as a Wobbe number at the level of min. 45.72 MJ / m3.

Requirements for the composition and quality of fuels and monitoring and monitoring of the composition and quality of fuels sold, sale and dispensing of fuels, records of fuel filling stations are also regulated by the Act on Fuels and Fuel Filling Stations No. 311/2006 Coll. and Government Regulation No. Quality standards for natural gas are set by ČSN 38 6110. Biogas used as fuel for internal combustion engines must be compressed to 20 MPa, while the output from the unit must be at least 25 MPa.

The legislation of CNG stations (conditions for location, design, testing and operation) is regulated by Technical Recommendation GAS - TDG 304 02. The legislation of CNG filling equipment (conditions for location, design, testing and operation) is determined by Technical Recommendation GAS TDG 982 03.

The operation of CNG vehicles is regulated by Decree No. 341/2014 Coll. The technical incompetence of gas equipment is addressed in § 20. ECE Regulation No. 110 applies to testing and type approval of components of motor vehicles using CNG in their propulsion system and type of vehicles in terms of installation of homologated components for the use of CNG for their propulsion. UNECE Regulation No 115 applies to the conversion of vehicles from running on LPG or CNG fuel.

Decree No. 23/2008 Coll., Addresses the equipment of garages for parking CNG vehicles, equipment for servicing or repairing CNG vehicles and parking CNG vehicles in an underground collective garage for public use. Requirements for the equipment of garages and other spaces used for parking, parking and parking of CNG vehicles and the definition of conditions for design, construction and operation are set out in Technical Recommendation GAS - TDG 982 01. Requirements and conditions for operation, repair, maintenance and inspection of CNG vehicles are set out in Technical Recommendation GAS - TDG 982 02.

From the point of view of subsequent operation of BioCNG filling units, the correct tariff setting is important, while the motivation for customers remains the tax advantage of CNG cars in the form of lower excise duty on fuel according to Act No. 261/2007 Coll., On stabilization of public budgets. CNG (including BioCNG), ie for compressed natural gas intended for use in the propulsion of engines according to paragraph a), the following tax rates:

- from 1.1. 2015 to 31 12. 2017, the rate of CZK 68.40 / MWh of combustion heat, i.e. approx. CZK 0.72 / m3;

- from 1.1. 2018 to 31 12. 2019, the rate of CZK 136.80 / MWh of combustion heat, i.e. approx. CZK 1.44 / m3;

- from 1.1.2020 rate CZK 264.80 / MWh of combustion heat, i.e. approx. CZK 2.80 / m3.

When compared with excise duties applied to liquid petroleum fuels (petrol - CZK 12.84 / l, diesel CZK 10.95 / l and partly LPG), these are very low rates, significantly favoring the use of CNG (and thus BioCNG).

In parallel for users of CNG-powered vehicles from 1 January 2009 pursuant to Section 3, Paragraph f) of Act No. 16/1993, Coll. on road tax, a zero tax rate applies to CNG-powered vehicles with a maximum permissible weight of up to 12 tonnes.

7. Proposal of biomethane production in the WWTP Olomouc

Biogas produced at the Olomouc WWTP is used in cogeneration units for the production of electricity and heat. Heat and electricity are used for the WWTP's own consumption. The current self-sufficiency in heat reaches about 83%, the current self-sufficiency in the field of electricity consumption is 49.2%. It is obvious that in the current arrangement the WWTP does not produce any energy usable for external sources, on the contrary, it does not achieve 100% energy self-sufficiency both in heat and in electricity consumption.

Due to the cessation of operation of the existing CHP, it is now decided whether it is not advantageous to use biogas produced at the WWTP in a different way than in the CHP. Thus, variants of purchase and operation of a new CHP, production of only heat from biogas and use of this heat for sludge drying and a variant of implementation of a biomethane unit are assessed.

The installation of a biomethane production unit at the Olomouc WWTP presupposes the termination of the operation of the CHP so that there is enough biogas for the unit to be treated.

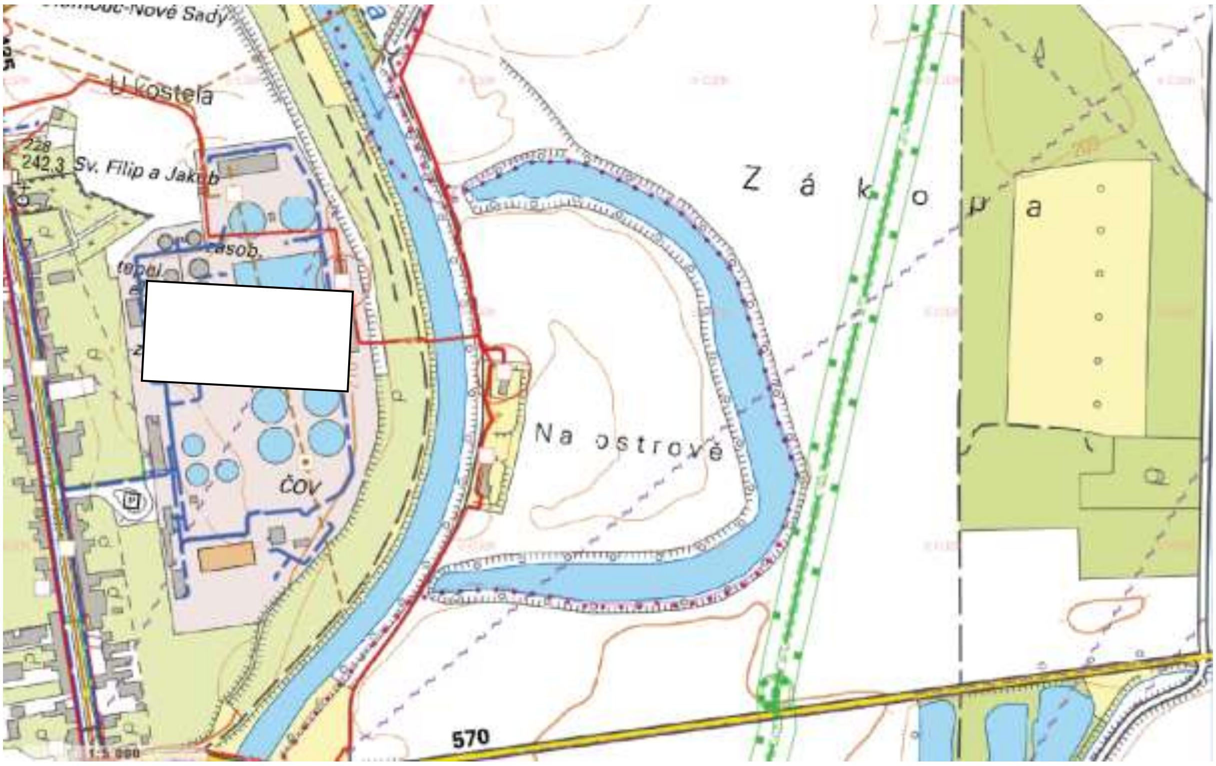
The installation of a biomethane unit assumes a significant reduction in the self-sufficiency of the WWTP both in the area of electricity consumption (current self-sufficiency in EE consumption 49.2%) and in the area of heat (current self-sufficiency approx. 83%).

The deficit in the production of electricity and heat will have to be compensated by purchasing these commodities from the grid (EE and ZP for heat production).

7.1. Connection of WWTP to the distribution system

The existing STL / NTL biogas supply to the WWTP cannot be used to connect a possible biomethane injection unit. The reason is the low capacity of the connection and the small consumption realized from it. A possible biomethane injection unit could supply more gas to the connection than the actual consumption, which could cause emergencies at the connection.

The connection of the WWTP can be seen in the following network drawing:



The use of a VTL network is necessary for the injection of biomethane into the distribution system. It is not located in the WWTP area.

The nearest VTL distribution system is 2 branches from the backbone VTL gas pipeline Olomouc South DN500 leading to the localities of Nové Sady and Nové Dvory. The nearest connection of the WWTP is possible approx. 500 m at the VTL branch (DN300) to the Nové Dvory locality.

7.2. BioCNG filling station for cars

It is possible to build a filling station directly in the WWTP area. The WWTP has a good transport connection to the capacity city road, Dolní Novosadská Street. From this main road it leads directly to the Olomouc WWTP site. Traffic is led through the development of the suburbs of Olomouc.

Access to the WWTP site is shown in the following figure, including the potential location of the pumping station:

The own bioCNG filling station can be located near the existing entrance to the WWTP and it is possible to separate it from the WWTP's own area and separate it so that cars arriving at the filling station do not have to enter the WWTP's own area. However, this solution is problematic in terms of connection to the biogas infrastructure of the WWTP, where it is relatively problematic to implement the line of biogas or produced biomethane up to this point.

The second variant is the implementation of a pumping station in the place of easier placement of the biomethane unit. The disadvantage is the potential movement of vehicles around the WWTP.

7.3. Biogas upgrading technology

For the Olomouc WWTP, it is possible to consider a biogas treatment unit with an input capacity of approximately 1,355,895 m3 of raw biogas.

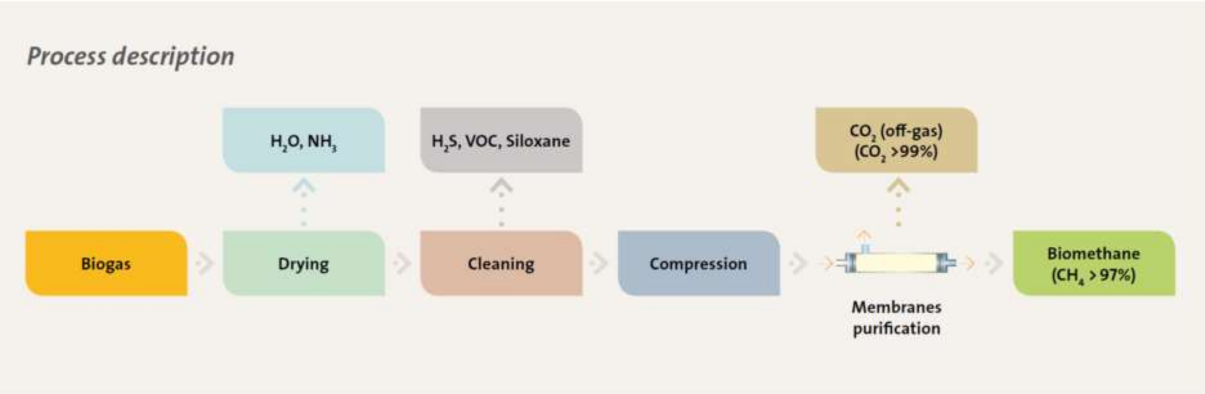
Biogas amount	1355895	m3/year
Biogas amount	3714,8	m3/d
Biogas amount	154,8	m3/h
Methane amount	104,5	m3/h

For small outputs, we currently consider the efficient use of units with membrane treatment technologies and possibly with PSA molecular sieve technology.

Other technologies are not suitable for these small outputs - this is especially true for water or amine scrubbing.

The biogas treatment technology will be located on an open area in the WWTP area, where the biogas will be supplied via a new connection from the existing energy center. Biogas treatment technology will be placed in containers except for some peripheral equipment (compressor coolers, etc.).

The study itself is prepared for the use of membrane technology. Membrane technology requires basic biogas pretreatment. Usually, cooling and drying of the biogas is performed, and subsequently the residual biogas contamination with undesired components (especially H2S and NH3) is removed on the activated carbon filters.



After pre-purification of biogas, the pre-purified biogas is compressed to pressure according to the used technology (10 - 20 bar) and is subjected to membrane separation. The CO2 is separated together with a very small proportion of residual methane (the treatment on membranes is usually multistage) and released into the environment. The produced biomethane is odorized, or secondarily pressurized, and through a measuring device it is led into the network or for use as bioCNG. The target pressure corresponds to a high-pressure line - 22 bar.

The first biomethane unit at BPS EFG Rapotín (Prodeval membrane technology) was implemented in the Czech Republic and commissioned in January 2020.

The equipment of the biogas to biomethane treatment unit can be located in the existing CHP unit room (in case the CHP unit will be removed), or then it will be placed in a standard size ISO20 container - w = 2,438m, d = 6,058 m, h = 2,2348m (or another according to the technology supplier), the container is installed at ground level on concrete blocks.

A biomethane production facility would be able to produce about 100 m^3 of biomethane per hour.

7.4. BioCNG filling station

The solution with the production of biomethane for use as BioCNG does not require connection to the natural gas distribution system. The pumping station is equipped with a pressure tank or tanks. The tank will be placed in a container that contains cylinders with a capacity of about 150 l (one cylinder). However, the location of the facility in the area is relatively problematic due to the location of biogas distribution and the existing infrastructure.

The filling station is a place where vehicles are filled from the dispenser. This station usually contains a compressor, a gas drying device, a buffer pressure tank - these, again in a container design, and a roofed dispenser with a payment terminal (again, the assumption of automatic unattended operation).

TDG G 304 02 of the Czech Gas Association is available for compressed gas filling stations for motor vehicles, which specify the conditions for location, design, testing and operation of CNG high-speed filling stations for motor vehicles, if the inlet overpressure does not exceed 0.03 MPa, the compressor does not exceed 20, 3 / hour and the internal volume of the compressor does not exceed 0.5 m3.

The location of the pumping station with a separate entrance outside the WWTP is shown in the following figure.

BioCNG filling station capacity:

The capacity of the pumping station is based on the capacity of the biomethane treatment unit. The pumping station is thus able to produce / fill approximately 1,714 kg of bioCNG per day.

The location of the pumping station near the biomethane unit is then in the following picture:

Filling station:

The size of tanks in CNG vehicles varies, their approximate size (usually for hybrid models) is given in the following table.

	tank - kg CNG
cars	15
commercial vehicles	25
supplies	35
buses	230
others - special vehicles	100

The daily capacity of the device can thus reach approximately 110 cars or 7 buses or 50 vans.

8. Cost analysis

8.1. Investment

The investment costs will consist of a new biogas line to the biomethane treatment unit, the unit itself and a possible pipeline for connection to the VTL natural gas distribution network.

In the variant with a BioCNG car filling station, the cost of the station itself and the storage capacity of the BioCNG.

Biogas supply pipeline, pipeline bridge	165000	Kč
Biogas to biomethane treatment unit (membrane technology)	21669555	Kč
Pipe connection, excavation, to VTL	750000	Kč
Paved surface for technology	150000	Kč
Gas station 2 stands + BioCNG tank	7500000	Kč
Paved area for the gas station	472500	Kč

8.2. Operational costs and benefits

Operating income:

The operating yield of the biomethane treatment technology when it is injected into the public distribution system of the ZP will consist only of its selling price into the network. There is no operating support for biomethane in the Czech Republic. According to the offers of commercial companies, the current price of biomethane is approximately CZK 15 - 16 / Nm3. This, when converted to GJ, is 422 - 450 CZK / GJ.

It can be stated that this price is relatively low.

The price of BioCNG has not been set, BioCNG is not yet available in the Czech Republic. The current price of CNG is about 25 CZK / kg resp. 17.7 CZK / m3.

	Biomethane ammount	intake - sale to the network	intake - sale BioCNG
	m^3/year	Kč/year	Kč/year
Olomouc	869468	13911483	15389578

Quantity of biomethane intake - sale to the network intake - sale BioCNG

Operational costs:

Operating costs consist of equipment service, operation and electricity consumption.

Unit service	433391,1	Kč/rok
Service	200000	Kč/rok
Electricity consumption	596593,8	Kč/rok
Gas station operator	600000	Kč/rok
Gas station service	180000	Kč/rok
Electricity consumption at the gas station	166000	Kč/rok

A fundamental problem of costs and economic balance is the decommissioning of the CHP

operation for the WWTP itself. Here it is necessary to assume additional costs for the purchase of electricity and heat in the amount of:

Heat	20763	GJ
Electricity (average production in CHP)	2860000	kWh

These costs must be added to the economic balance of the facility.

Heat - purchase of natural gas	7267050	Kč/year
Electricity purchase from the network equivalent of production in CHP	5720000	Kč/year

If we make a balance for both variants, the following summary can be made:

	biomethan into the grid	BioCNG	
Revenues	13911483	15389578	Kč/ year
Costs	14217035	15163035	Kč/ year
Balance	-305552	226543	Kč/ year
Paybeck time	-	131.6	years

It can be stated that the investment is not repayable in either variant.

9. ISA of REEF 2W solution in WWTP Olomouc

9.1. Pilot and applied REEF 2W technology specification

For the Olomouc WWTP there is the biomethane unit for biogas upgrading and vehicle refuelling station designed. The biomethane plant can positively affect the energy efficiency of WWTP and reduce the air pollution generated by transport.

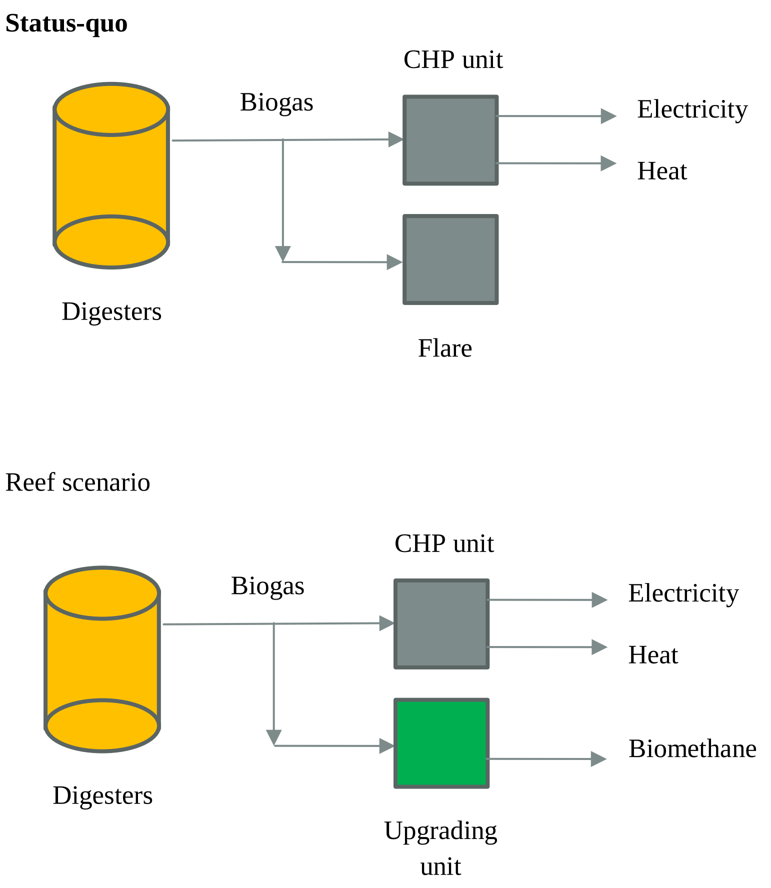


Figure 5.1. Simplified scheme of status quo and Reef technology scenario for Olomouc WWTP

Due to the priorities of the project, the membrane biogas upgrading method was selected for Olomouc project because of lower investment costs of this technology. The technology consists of membrane biogas upgrading unit and bioCNG vehicle filling station.

Simplified scheme of status quo and Reef technology scenario is shown in Figure 5.1.

The upgrading plant for biomethane production is described in detail in the chapter 7.

9.2. General indicator evaluation

Table 1.1: General indicators used for the pre-assessment

Sustainability criteria	General indicator	Measurement	Categories	Status Quo	REEF 2W
Availability of excess energy (Software tool N.1)	Electric excess energy provision	Difference between electric energy production and consumption in kWh	> 0 ≤ 0	≤ 0	≤ 0
	Thermal excess energy provision	Difference between thermal energy production and consumption in kWh	> 0 ≤ 0	> 0	≤ 0
	Excess digester gas provision	Difference between digester gas production and consumption in m³	> 0 ≤ 0	≤ 0	> 0
Availability of energy consumers (Software tool N.2)	Excess electricity demand	Electricity demand in the vicinity of the WWTP and in kWh	> 0 = 0	> 0	> 0
	Excess heat demand	Heat demand in the vicinity of the WWTP and in kWh	> 0 = 0	= 0	= 0
	Excess digester gas demand	Digester gas demand in the vicinity of the WWTP and in kWh	> 0 = 0	= 0	> 0*

* biomethane in this case

Table 5.1 shows that evaluated WWTP has actually excess of heat (in some periods of the year) and part of biogas is burnt in flares. Balance of other energy sources such as electricity is negative.

Implementing biomethane production the surplus heat production for which no demand exists will be eliminated. However, biomethane will be produced which can be beneficially used for gas grid injection or as fuel in public transport.

9.3. Specific indicator evaluation

Table 2.2: Specific indicators used for ISA and their weights

Sustainability criteria	Indicator	Measurement	Categories	Graduation	Status Quo	REEF 2W	Weight
Environmental context	CO_2 emissions reduction for consumed electric energy (internal and external)	%	> 0 = 0	A C	A 0.54	C 0	0,1
	CO_2 emissions reduction for consumed gas (internal and external)	%	> 0 = 0	A C	C 0	C 0.8	0,1
	CO_2 emissions reduction for consumed thermal energy (internal and external)	%	> 0 = 0	A C	A 0.8	C 0	0,1
	Share of renewable electricity (internal and external)	%	> 100 100-40 <40	A B C	B 54	C 0	0,2
	Share of renewable thermal energy (internal and external)	%	> 100 100-40 <40	A B C	A	A	0,2
	Share of renewable gas (internal and external)	%	> 100 100-40 <40	A B C	C	A	0,2
	Sludge production change	Delta t DM / year	<0 0 >0	A B C	B	B	0,1
Social context	Affordable energy	%	Lower Same (+-10 %) Higher	A B C	B	B	0,2

Sustainability criteria	Indicator	Measurement	Categories	Graduation	Status Quo	REEF 2W	Weight
	Number of applied technologies for electric energy provision (*Resilience*)	Quantity	3 1-2 0	A B C	B	C	0,1
	Number of applied technologies for thermal energy provision (*Resilience*)	Quantity	3 1-2 0	A B C	B	C	0,1
	Additional employment	Change of employment, job creation or loss	<0 0 >0	A B C	B	A (1-2)	0,2
	Local environmental welfare	Indication of local welfare change	Positive Neutral Negative	A B C	B	A	0,4
Economic context	Return of Investment (ROI)	Years	<3 3-10 >10	A B C	A default	C (none)	0,5
	Additional income	€	>0 0 <0	A B C	B	A (8000 EUR/year)	0,3
	Energy costs saving	€	>0 0 <0	A B C	B	B	0,2
Technical context (energetic & spatial)	Degree of electric self-sufficiency	Ratio between electric energy production and consumption in %	>75 25-75 <25	A B C	B (54,5)	C (0)	0,2
	Degree of thermal self-sufficiency	Ratio between thermal energy production and	>100 20-100 <20	A B C	B (90)	C (0)	0,1

Sustainability criteria	Indicator	Measurement	Categories	Graduation	Status Quo	REEF 2W	Weight
		consumption in %					
	Degree of externally usable excess heat	Ratio between heat production and consumption in %	> 0 0	A C	C	C	0,1
	Degree of usable excess gas	Ratio between gas production and consumption in %	> 0 0	A C	C	A	0,2
	Electric energy consumption at WWTP	$kWh/PE_{120}.a$	< 20 20 - 50 > 50	A B C	B (33,2)	B (33,2)	0,1
	Thermal energy consumption at WWTP	$kWh/PE_{120}.a$	<30 > 30	A C	A (28)	A (28)	0,1
	Electric energy generation at WWTP (with anaerobic stabilisation)	$kWh/PE_{120}.a$	>20 10-20 <10	A B C	B (18,1)	C (0)	0,1
	Electric energy generation at WWTP (with aerobic stabilisation)	$kWh/PE_{120}.a$	>0 0	A C	NA	NA	0
	Thermal energy generation at WWTP (with anaerobic stabilisation)	$kWh/PE_{120}.a$	>40 20-40 <20	A B C	B 22,7	C 0	0,1
	Thermal energy generation at WWTP (with aerobic stabilisation)	$kWh/PE_{120}.a$	>0 0	A B	NA	NA	0

9.4. Suitability of indicators

In case of Olomouc ISA application all indicators were used, except of "Electric and thermal energy generation at WWTP with aerobic stabilisation". These two indicators are alternatively used when anaerobic digestion could not be used which is not the case of Olomouc WWTP.

Calculation of values for final indicators evaluation was done partly by using of REF 2W tools, partly by using of real data from WWTP Olomouc.

9.5. Multi-criteria decision analysis (MCDA)

To have detailed information about specific parts of ISA (social, environmental, economic and technical) are calculated separately to be used by decision makers for their own analysis and decision. The following formula was used for the evaluation of each criterion.

$$CI_{s,en,ec,tech} = \sum_{i=1}^{n} w_i \, u_i$$

where CI is the composite index of the ISA for social, environmental, economic and technical segment, w is value of indicator and u is weight of indicator.

The result of each ISA criterion is shown in the following table 5.3.

Table 9.3.: The result of multi-criteria decision analysis

Criterion	Composite Index (Status Quo)	Composite Index REEF 2W Technology
Environmental	3.2	2.8
Social	3.0	2.2
Economic	2.0	3.4
Technical	3.1	3.3

Considering the comprehensive environmental, social, economic and technical analysis, the REEF 2W technology – introduction of biomethane production - is beneficial for the selected WWTP only from social point of view. As shown in the table 9.3, REEF 2W scenario has similar composite index in two categories: environmental and technical. However the economic composite index is significantly worse for REEF 2W solution.

10. Conclusion

The project of implementation of a biomethane unit in the premises of the Olomouc WWTP can be assessed as feasible, but in the current economic conditions as very disadvantageous for the WWTP operator.

The main problem is the complete loss of energy self-sufficiency of the WWTP after the decommissioning of the CHP. There would be both a 100% loss of own heat production, which covers the needs of WWTPs and technologies from practically 70%, as well as electricity, which covers the needs of WWTPs from about 55%. This loss cannot be covered by an increase in biogas production, which is already relatively high at the WWTP due to the intake of external substrate (distillery effluents).

All energy for operation, both electrical and thermal, would have to be purchased from external sources. This is disadvantageous both economically and largely ecologically, as the electricity and heat purchased in this way would be largely produced from non-renewable energy sources.

We do not recommend the implementation of a biomethane unit, both in the variant with injection into the network and in the variant with the implementation of a filling station for BioCNG in the Olomouc WWTP site using biogas generated by anaerobic sludge stabilization at this WWTP.

Projekt realizace biomethanové jednotky v areálu ČOV Olomouc je možné hodnotit jako proveditelný, ovšem ve stávajících ekonomických podmínkách jako velmi nevýhodný pro provozovatele ČOV.

Zásadním problémem je úplná ztráta energetické soběstačnosti ČOV po vyřazení KJ z provozu. Zde by došlo jak k 100% ztrátě vlastní výroby tepla, který pokrývá potřeby ČOV a technologií prakticky ze 70%, tak i elektrické energie, která pokrývá potřebu ČOV cca z 55%. Tuto ztrátu není možné pokrýt navýšením produkce bioplynu, která je již na ČOV relativně vysoká díky příjmu externího substrátu (lihovarské výpalky).

Veškerá energie pro provoz a to jak elektrická, tak tepelná by se musela nakupovat z externích zdrojů. To je nevýhodné jak ekonomicky, tak z velké části ekologicky, neboť takto nakupovaná elektřina a teplo by byly z velké části vyráběny z neobnovitelných energetických zdrojů.

Realizaci biomethanové jednotky a to jak ve variantě s vtláčením do sítě, tak ve variantě s realizací plnící stanice pro BioCNG v lokalitě ČOV Olomouc s využitím bioplynu vzniklého anaerobní stabilizací kalů na této ČOV nedoporučujeme.

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70

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