

Output T2.2

Pre-feasibility Study (Slovakia)

WP T2: Project main output

REPORT ON THE PRE-FEASIBILITY STUDY



September, 2022

Project co-funded by the European Union funds (ERDF, IPA)

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DOCUMENT CONTROL SHEET

Project reference	
Full title of the project	Innovative model to drive energy security and diversity in the Danube Region via combination of bioenergy with surplus renewable energy
Acronym	DanuP-2-Gas
Programme priority	Priority 3
Programme priority specific objective	SO 3.2 Improve energy security and energy efficiency
Duration	01.07.2020 – 31.12.2022
Project website	www.interreg-danube.eu/danup-2-gas
Project coordinator	TZE

Short Description
The potential for exploitable organic residue for each participating country listing key aspects such as location, amount, transport options and costs.

Document Details	
Title of document	Pre-feasibility Report (Country)
Action	WP T2 Transnational Infrastructure and Biomass assessment & Pre-feasibility Studies
Deliverable	Output T2.2
Delivery date	September 2022

Version	Date	Author	Organization	Description
V1	15.9.2022	Dominika Fukerova	NARA-SK	1 st version

IMPRINT

This document is issued by the consortium formed for the implementation of the DanuP-2-Gas project by the following partners:

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- ERDF PP1 Energy AGency of Savinjska, Koroška and Šaleška Region (SI)
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Responsible Partner for the compilation of this document

LP Technology Centre Energy - University of Applied Sciences Landshut (DE)
ERDF PP1 Energy Agency of Savinjska, Koroška and Šaleška Region (SI)

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1. METHODOLOGY

For the purpose of this document, the main tool used was the Optimisation tool (<https://www.danup2gas.eu/optimizationtool>) and the Atlas of renewable energy, both created during the course of the DanuP-2-Gas project. The objective is to assess the current and theoretical conditions in Slovakia for the investment into Power-to-Gas (P2G) hub. The P2G hubs are configured as either a part of existing renewable or industrial plant, or a greenfield location. In each of these three cases we explore the potential with current prices of gas and 10 times higher gas prices. Each of these cases is then further explored with the amount of 0% subsidy or 50% subsidy. This results in 12 different ($3 \times 2 \times 2 = 12$) situations that are presented in this document with further specifications, comments and assessment.

The sources of data used for the Optimisation tool is the Infrastructure and Biomass tables and reports conducted during the course of the DanuP-2-Gas project. The data is as accurate as the sources of available sources were and may not be 100% exact. For further exploration of the possibilities, more options are available, such as adding the existing market options for Hydrogen, Oxygen, Biochar and Methane. In the presented study cases, these were set to zero.

2. CASE STUDIES

For the purpose of this prefeasibility study, 3 different case scenarios were evaluated, all of them further divided with more theoretical options. The first case is a P2G hub located next to an existing renewable plant (REP) Biomass plant Bučina in Zvolen. This biomass plant produces around 30000 MWh of electricity and heat yearly.

The second case of P2G hub is located next to an existing Industrial plant (IP) Chemosvit with the power of almost 12 MW and consumption of over 60 000 mWh of electric power.

The third case is a greenfield location in the region of Gemer Malohont, near the village Jesenské, where the region has potential for such investment. There is several biomass sources around and few photovoltaic plants.

3. RESULTS

For each one of case studies (IP, REP and GF), two types of gas prices and subsidies are considered. The considered cases are summarized in *Table 1*.

Table 1:

	Conservative prices of methane			10 × Higher prices of methane		
	REP	IP	GF	REP	IP	GF
No subsidy	No investment, Fig. 1	No investment, Fig. 5	No investment, Fig. 9	Possible investments, Fig. 3	Possible investments, Fig. 7	Possible investments, Fig. 11
Subsidy of 50 %	No investment, Fig. 2	No investment, Fig. 6	No investment, Fig. 10	Possible investments, Fig. 4	Possible investments, Fig. 8	Possible investments, Fig. 12

Every solution from Table 1 is obtained using the simulation period of one complete year and electrical consumption/production sampling of 24h. The maximum investment is set to 1 000 000 000 and maximum payoff period to 20years. The market options for hydrogen, oxygen, methane and biochar are set to 0. As seen from the Table 1, the only feasible options for P2G hub in Slovakia are with an increased gas price. With the current gas prices, none of the three locations are economically viable to be extended with the P2G hub. The concrete cases are each commented under the selected Figures.

REP

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	0,00 €	0,000000 kg/s
	Wet anaerobic digester	0,00 €	0,000000 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	0,00 €	0,000000 kg/s
	Methanation reactor	0,00 €	0,000000 mol/s
	Electrolyser	0,00 €	0,00 kW
	Demineralizer	0,00 €	0,000000 mol/s
	Precipitation collector	0,00 €	0,00 m ²
	Heat exchanger	0,00 €	0,00 kW
	Gas compressor station	0,00 €	0,0000 kWe
	Total for processes	0,00 €	
Storages	Dry biomass storage	0,00 €	0,00 kg
	Wet biomass storage	0,00 €	0,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m ³
	Total for storages	0,00 €	
Connections enlargement	Electrical connection	0,00 €	0,00 MW
	Gas connection	0,00 €	0,00 MW
	Water connection	0,00 €	0,00 m ³ /h
	Total for connections	0,00 €	
Total investment		0,00 €	
Payoff period		n/a	years

Operational costs for selected period			
		Cost	Amount
Electrical energy	Produced by REP	6 156 573,30 €	31 304,61 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	-6 156 573,30 €	-31 304,61 MWh
	Mean peak power without investment	0,00 €	0,00 MW
	Consumed by P2G	0,00 €	0,00 MWh
	Net consumption with investment	-6 156 573,30 €	-31 304,61 MWh
	Mean peak power with investment	0,00 €	0,00 MW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	0,00 MWh
	Net production without investment	0,00 €	0,00 MWh
	Consumed by P2G	0,00 €	0,00 MWh
	Net production with investment	0,00 €	0,00 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	0,00 €	0,00 MWh
	Net consumption with investment	0,00 €	0,00 MWh
Water	Water from the grid consumed by P2G	0,00 €	0,00 m ³
	Collected precipitation consumed by P2G	n/a	0,00 m ³
Input materials	Dry biomass bought	0,00 €	0,00 t
	Wet biomass bought	0,00 €	0,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	0,00 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
	Total revenue from additional sales	0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	0,00 t
	Residue from wet anaerobic digester	0,00 €	0,00 t
	Tar from gasification + water gas shift plant	0,00 €	0,00 t
	CO ₂ emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
	Total operational cost without investment	-6 156 573,30 €	
Total operational cost with investment		-6 156 573,30 €	
Savings with introduction of P2G		0,00 €	

Fig. 1 Results for optimal P2G hub next to REP with conservative prices of methane and no subsidy (Results sheet of the Optimization tool)

With the current prices of methane, it is not economically feasible to invest in the P2G near this biomass plant.

Investment specifications		
Element	Cost	Size
Processes	Dry anaerobic digester	0,00 € 0,000000 kg/s
	Wet anaerobic digester	0,00 € 0,000000 kg/s
	Dry biomass to biochar plant	0,00 € 0,000000 kg/s
	Wet biomass to biochar plant	0,00 € 0,000000 kg/s
	Combined heat and power (CHP)	0,00 € 0,00 kWe
	Carbon capture plant	0,00 € 0,000000 mol/s
	Gasification + water gas shift plant	0,00 € 0,000000 kg/s
	Methanation reactor	0,00 € 0,000000 mol/s
	Electrolyser	0,00 € 0,00 kW
	Deminerallizer	0,00 € 0,000000 mol/s
	Precipitation collector	0,00 € 0,00 m ²
	Heat exchanger	0,00 € 0,00 kW
	Gas compressor station	0,00 € 0,0000 kWe
	Total for processes	0,00 €
Storages	Dry biomass storage	0,00 € 0,00 kg
	Wet biomass storage	0,00 € 0,00 kg
	Biochar storage	0,00 € 0,00 kg
	Biogas storage	0,00 € 0,00 kg
	Hydrogen storage tank	0,00 € 0,00 kg
	Oxygen storage tank	0,00 € 0,00 kg
	Methane storage tank	0,00 € 0,00 kg
	Syngas storage tank	0,00 € 0,00 kg
	Carbon dioxide storage tank	0,00 € 0,00 kg
	Water storage tank	0,00 € 0,00 m ³
	Total for storages	0,00 €
Connections enlargement	Electrical connection	0,00 € 0,00 MW
	Gas connection	0,00 € 0,00 MW
	Water connection	0,00 € 0,00 m ³ /h
	Total for connections	0,00 €
Total investment		0,00 €
Payoff period		n/a years

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	6 156 573,30 €	31 304,61 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	-6 156 573,30 €	-31 304,61 MWh
	Mean peak power without investment	0,00 €	0,00 MW
	Consumed by P2G	0,00 €	0,00 MWh
	Net consumption with investment	-6 156 573,30 €	-31 304,61 MWh
	Mean peak power with investment	0,00 €	0,00 MW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	0,00 MWh
	Net production without investment	0,00 €	0,00 MWh
	Consumed by P2G	0,00 €	0,00 MWh
	Net production with investment	0,00 €	0,00 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	0,00 €	0,00 MWh
	Net consumption with investment	0,00 €	0,00 MWh
Water	Water from the grid consumed by P2G	0,00 €	0,00 m ³
	Collected precipitation consumed by P2G	n/a €	0,00 m ³
Input materials	Dry biomass bought	0,00 €	0,00 t
	Wet biomass bought	0,00 €	0,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	0,00 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
	Total revenue from additional sales	0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	0,00 t
	Residue from wet anaerobic digester	0,00 €	0,00 t
	Tar from gasification + water gas shift plant	0,00 €	0,00 t
	CO2 emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
Total operational cost without investment		-6 156 573,30 €	
Total operational cost with investment		-6 156 573,30 €	
Savings with introduction of P2G		0,00 €	

Fig. 2 Results for optimal P2G hub next to REP with conservative prices of methane and 50% subsidy (Results sheet of the Optimization tool)

The investment is not economically viable neither with the subsidy of 50%. With the current prices of methane and no existing market for hydrogen, oxygen and biochar, the Optimisation tool suggest not to invest into any component of P2G hub,

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	2 430 555,56 €	0,115741 kg/s
	Wet anaerobic digester	2 430 555,56 €	0,115741 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	13 888,89 €	0,013889 kg/s
	Methanation reactor	3 187 395,34 €	7,499754 mol/s
	Electrolyser	11 364 755,71 €	4 545,90 kW
	Demineralizer	1 236,87 €	12,368668 mol/s
	Precipitation collector	2 000,00 €	1 000,00 m³
	Heat exchanger	226 658,54 €	2 266,59 kW
	Gas compressor station	48 247,28 €	60,3091 kWe
Total for processes		19 705 293,74 €	
Storages	Dry biomass storage	100 000,00 €	10 000,00 kg
	Wet biomass storage	50 000,00 €	10 000,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m³
Total for storages		150 000,00 €	
Connections enlargement	Electrical connection	317 232,32 €	5,29 MW
	Gas connection	134 954,35 €	6,04 MW
	Water connection	24,74 €	0,80 m³/h
Total for connections		452 211,41 €	
Total investment		20 307 505,14 €	
Payoff period		5,11 years	

Operational costs for selected period				
		Cost	Amount	
Electrical energy	Produced by REP	6 156 573,30 €	31 304,61 MWh	
	Consumed by IP	0,00 €	0,00 MWh	
	Net consumption without investment	-6 156 573,30 €	-31 304,61 MWh	
	Mean peak power without investment	0,00 €	0,00 MW	
	Consumed by P2G	25 470 420,09 €	93 986,79 MWh	
	Net consumption with investment	16 986 870,78 €	62 682,18 MWh	
Mean peak power with investment		28 258,66 €	7,16 MW	
Heat	Produced by REP	0,00 €	0,00 MWh	
	Produced IP	0,00 €	0,00 MWh	
	Net production without investment	0,00 €	0,00 MWh	
	Consumed by P2G	0,00 €	-19 315,90 MWh	
	Net production with investment	0,00 €	19 315,90 MWh	
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh	
	Consumed by IP	0,00 €	0,00 MWh	
	Net consumption without investment	0,00 €	0,00 MWh	
	Produced by P2G	212 555 428,07 €	52 886,76 MWh	
Net consumption with investment		-212 555 428,07 €	-52 886,76 MWh	
Water	Water from the grid consumed by P2G	7 787,40 €	6 425,78 m³	
	Collected precipitation consumed by P2G	n/a €	774,57 m³	
Input materials	Dry biomass bought	97 084,91 €	3 650,00 t	
	Wet biomass bought	0,00 €	3 650,00 t	
	Biochar bought	0,00 €	0,00 t	
Total cost of input materials		97 084,91 €		
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t	
	Oxygen sold (in bottles)	0,00 €	0,00 t	
	Methane sold (in bottles)	0,00 €	0,00 t	
	Biochar sold	0,00 €	0,00 t	
	Total revenue from additional sales		0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	109,50 t	
	Residue from wet anaerobic digester	0,00 €	547,50 t	
	Tar from gasification + water gas shift plant	0,00 €	43,80 t	
	CO2 emitted	0,00 €	0,00 t	
	Total cost of residues		0,00 €	
	Total operational cost without investment		-6 156 573,30 €	
	Total operational cost with investment		-195 435 426,32 €	
Savings with introduction of P2G		189 278 853,02 €		

Fig. 3 Results for optimal P2G hub next to REP with 10× higher prices of methane and no subsidy (Results sheet of the Optimization tool)

The situation changes with the (10×) higher prices of methane. In this scenario it is already feasible to invest into wet and dry anaerobic digester, gasification + water gas shift plant, electrolyser, methanation reactor, heat exchanger gas compressor station and storages for wet and dry biomass, biochar storage and water storage tank. This is an investment of over 20 000 000€ with no subsidy and payoff period 5,11 years. The total savings with the introduction of P2G would be 189 278 853,02€.

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	1 215 277,78 €	0,115741 kg/s
	Wet anaerobic digester	1 215 277,78 €	0,115741 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	6 944,44 €	0,013889 kg/s
	Methanation reactor	1 593 697,67 €	7,499754 mol/s
	Electrolyser	5 682 377,86 €	4 545,90 kW
	Deminerallizer	618,43 €	12,368668 mol/s
	Precipitation collector	1 000,00 €	1 000,00 m ²
	Heat exchanger	113 329,27 €	2 266,59 kW
	Gas compressor station	24 123,64 €	60,3091 kWe
	Total for processes	9 852 646,87 €	
Storages	Dry biomass storage	50 000,00 €	10 000,00 kg
	Wet biomass storage	25 000,00 €	10 000,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m ³
	Total for storages	75 000,00 €	
Connections enlargement	Electrical connection	317 232,32 €	5,29 MW
	Gas connection	134 954,35 €	6,04 MW
	Water connection	24,74 €	0,80 m ³ /h
	Total for connections	452 211,41 €	
	Total investment	10 379 858,28 €	
	Payoff period	5,06 years	

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	6 156 573,30 €	31 304,61 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	-6 156 573,30 €	-31 304,61 MWh
	Mean peak power without investment	0,00 €	0,00 MW
	Consumed by P2G	25 470 420,09 €	93 986,79 MWh
	Net consumption with investment	16 986 870,78 €	62 682,18 MWh
	Mean peak power with investment	28 258,66 €	7,16 MW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	0,00 MWh
	Net production without investment	0,00 €	0,00 MWh
	Consumed by P2G	0,00 €	-19 315,90 MWh
	Net production with investment	0,00 €	19 315,90 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	212 555 428,07 €	52 886,76 MWh
	Net consumption with investment	-212 555 428,07 €	-52 886,76 MWh
Water	Water from the grid consumed by P2G	7 787,40 €	6 425,78 m ³
	Collected precipitation consumed by P2G	n/a €	774,57 m ³
Input materials	Dry biomass bought	97 084,91 €	3 650,00 t
	Wet biomass bought	0,00 €	3 650,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	97 084,91 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
	Total revenue from additional sales	0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	109,50 t
	Residue from wet anaerobic digester	0,00 €	547,50 t
	Tar from gasification + water gas shift plant	0,00 €	43,80 t
	CO2 emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
	Total operational cost without investment	-6 156 573,30 €	
	Total operational cost with investment	-195 435 426,32 €	
	Savings with introduction of P2G	189 278 853,02 €	

Fig. 4 Results for optimal P2G hub next to REP with 10× higher prices of methane and 50% subsidy (Results sheet of the Optimization tool)

The situation is similar than in Figure 3, only the subsidy makes the whole investment smaller and the payoff period shorter. The amount of produced biomethane is over 50 000 mWh per year and the total savings are over 189 000 000 EUR.

IP

Investment specifications		
Element	Cost	Size
Processes	Dry anaerobic digester	0,00 € 0,000000 kg/s
	Wet anaerobic digester	0,00 € 0,000000 kg/s
	Dry biomass to biochar plant	0,00 € 0,000000 kg/s
	Wet biomass to biochar plant	0,00 € 0,000000 kg/s
	Combined heat and power (CHP)	0,00 € 0,00 kWe
	Carbon capture plant	0,00 € 0,000000 mol/s
	Gasification + water gas shift plant	0,00 € 0,000000 kg/s
	Methanation reactor	0,00 € 0,000000 mol/s
	Electrolyser	0,00 € 0,00 kW
	Demineralizer	0,00 € 0,000000 mol/s
	Precipitation collector	0,00 € 0,00 m ²
	Heat exchanger	0,00 € 0,00 kW
	Gas compressor station	0,00 € 0,0000 kWe
	Total for processes	0,00 €
Storages	Dry biomass storage	0,00 € 0,00 kg
	Wet biomass storage	0,00 € 0,00 kg
	Biochar storage	0,00 € 0,00 kg
	Biogas storage	0,00 € 0,00 kg
	Hydrogen storage tank	0,00 € 0,00 kg
	Oxygen storage tank	0,00 € 0,00 kg
	Methane storage tank	0,00 € 0,00 kg
	Syngas storage tank	0,00 € 0,00 kg
	Carbon dioxide storage tank	0,00 € 0,00 kg
	Water storage tank	0,00 € 0,00 m ³
	Total for storages	0,00 €
Connections enlargement	Electrical connection	0,00 € 0,00 MW
	Gas connection	0,00 € 0,00 MW
	Water connection	0,00 € 0,00 m ³ /h
	Total for connections	0,00 €
Total investment		0,00 €
Payoff period		n/a years

Operational costs for selected period		
	Cost	Amount
Electrical energy	Produced by REP	0,00 € 0,00 MWh
	Consumed by IP	16 277 764,05 € 60 065,55 MWh
	Net consumption without investment	16 277 764,05 € 60 065,55 MWh
	Mean peak power without investment	27 078,87 € 6,86 MW
	Consumed by P2G	0,00 € 0,00 MWh
	Net consumption with investment	16 277 764,05 € 60 065,55 MWh
	Mean peak power with investment	27 078,87 € 6,86 MW
Heat	Produced by REP	0,00 € 0,00 MWh
	Produced IP	0,00 € 32,50 MWh
	Net production without investment	0,00 € 32,50 MWh
	Consumed by P2G	0,00 € 0,00 MWh
	Net production with investment	0,00 € 32,50 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 € 0,00 MWh
	Consumed by IP	0,00 € 0,00 MWh
	Net consumption without investment	0,00 € 0,00 MWh
	Produced by P2G	0,00 € 0,00 MWh
	Net consumption with investment	0,00 € 0,00 MWh
Water	Water from the grid consumed by P2G	0,00 € 0,00 m ³
	Collected precipitation consumed by P2G	n/a € 0,00 m ³
Input materials	Dry biomass bought	0,00 € 0,00 t
	Wet biomass bought	0,00 € 0,00 t
	Biochar bought	0,00 € 0,00 t
Total cost of input materials		0,00 €
Additional sales	Hydrogen sold (in bottles)	0,00 € 0,00 t
	Oxygen sold (in bottles)	0,00 € 0,00 t
	Methane sold (in bottles)	0,00 € 0,00 t
	Biochar sold	0,00 € 0,00 t
Total revenue from additional sales		0,00 €
Residues	Residue from dry anaerobic digester	0,00 € 0,00 t
	Residue from wet anaerobic digester	0,00 € 0,00 t
	Tar from gasification + water gas shift plant	0,00 € 0,00 t
	CO ₂ emitted	0,00 € 0,00 t
	Total cost of residues	0,00 €
Total operational cost without investment		16 304 842,92 €
Total operational cost with investment		16 304 842,92 €
Savings with introduction of P2G		0,00 €

Fig. 5 Results for optimal P2G hub next to IP with conservative prices of methane and no subsidy (Results sheet of the Optimization tool)

In the case of current prices of methane and no subsidy, the investment into P2G next to an existing Industrial plant seems not to be feasible.

Investment specifications				Operational costs for selected period			
	Element	Cost	Size		Cost	Amount	
Processes	Dry anaerobic digester	0,00 €	0,000000 kg/s	Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Wet anaerobic digester	0,00 €	0,000000 kg/s		Consumed by IP	16 277 764,05 €	60 065,55 MWh
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s		Net consumption without investment	16 277 764,05 €	60 065,55 MWh
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s		Mean peak power without investment	27 078,87 €	6,86 MW
	Combined heat and power (CHP)	0,00 €	0,00 kWe		Consumed by P2G	0,00 €	0,00 MWh
	Carbon capture plant	0,00 €	0,000000 mol/s		Net consumption with investment	16 277 764,05 €	60 065,55 MWh
	Gasification + water gas shift plant	0,00 €	0,000000 kg/s	Heat	Mean peak power with investment	27 078,87 €	6,86 MW
	Methanation reactor	0,00 €	0,000000 mol/s		Produced by REP	0,00 €	0,00 MWh
	Electrolyser	0,00 €	0,00 kW		Produced IP	0,00 €	32,50 MWh
	Demineralizer	0,00 €	0,000000 mol/s		Net production without investment	0,00 €	32,50 MWh
	Precipitation collector	0,00 €	0,00 m ²		Consumed by P2G	0,00 €	0,00 MWh
	Heat exchanger	0,00 €	0,00 kW		Net production with investment	0,00 €	32,50 MWh
	Gas compressor station	0,00 €	0,0000 kWe	Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Total for processes	0,00 €			Consumed by IP	0,00 €	0,00 MWh
Storages	Dry biomass storage	0,00 €	0,00 kg		Net consumption without investment	0,00 €	0,00 MWh
	Wet biomass storage	0,00 €	0,00 kg		Produced by P2G	0,00 €	0,00 MWh
	Biochar storage	0,00 €	0,00 kg		Net consumption with investment	0,00 €	0,00 MWh
	Biogas storage	0,00 €	0,00 kg	Water	Water from the grid consumed by P2G	0,00 €	0,00 m ³
	Hydrogen storage tank	0,00 €	0,00 kg		Collected precipitation consumed by P2G	n/a	0,00 m ³
	Oxygen storage tank	0,00 €	0,00 kg	Input materials	Dry biomass bought	0,00 €	0,00 t
	Methane storage tank	0,00 €	0,00 kg		Wet biomass bought	0,00 €	0,00 t
	Syngas storage tank	0,00 €	0,00 kg		Biochar bought	0,00 €	0,00 t
	Carbon dioxide storage tank	0,00 €	0,00 kg	Additional sales	Total cost of input materials	0,00 €	
Connections engagement	Water storage tank	0,00 €	0,00 m ³		Hydrogen sold (in bottles)	0,00 €	0,00 t
	Total for storages	0,00 €			Oxygen sold (in bottles)	0,00 €	0,00 t
	Electrical connection	0,00 €	0,00 MW		Methane sold (in bottles)	0,00 €	0,00 t
Connections engagement	Gas connection	0,00 €	0,00 MW	Residues	Biochar sold	0,00 €	0,00 t
	Water connection	0,00 €	0,00 m ³ /h		Total revenue from additional sales	0,00 €	
	Total for connections	0,00 €			Residue from dry anaerobic digester	0,00 €	0,00 t
Total investment		0,00 €			Residue from wet anaerobic digester	0,00 €	0,00 t
Payoff period		n/a	years		Tar from gasification + water gas shift plant	0,00 €	0,00 t
					CO2 emitted	0,00 €	0,00 t
					Total cost of residues	0,00 €	
				Total operational cost without investment		16 304 842,92 €	
				Total operational cost with investment		16 304 842,92 €	
				Savings with introduction of P2G		0,00 €	

Fig. 6 Results for optimal P2G hub next to IP with conservative prices of methane and 50% subsidy (Results sheet of the Optimization tool)

The result from the calculation of possible investment to P2G hub next to an existing industrial plant shows that with the current prices of methane and zero subsidy it is not feasible.

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	2 430 555,56 €	0,115741 kg/s
	Wet anaerobic digester	2 430 555,56 €	0,115741 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	13 888,89 €	0,013889 kg/s
	Methanation reactor	3 187 395,34 €	7,499754 mol/s
	Electrolyser	11 364 755,71 €	4 545,90 kW
	Demineralizer	1 236,87 €	12,368668 mol/s
	Precipitation collector	2 000,00 €	1 000,00 m ²
	Heat exchanger	226 658,54 €	2 266,59 kW
	Gas compressor station	48 247,28 €	60,3091 kWe
	Total for processes	19 705 293,74 €	
Storages	Dry biomass storage	100 000,00 €	10 000,00 kg
	Wet biomass storage	50 000,00 €	10 000,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m ³
	Total for storages	150 000,00 €	
Connections engagement	Electrical connection	337 440,20 €	5,62 MW
	Gas connection	0,00 €	0,00 MW
	Water connection	24,74 €	0,80 m ³ /h
	Total for connections	337 464,93 €	
	Total investment	20 192 758,67 €	
	Payoff period	5,11 years	

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	16 277 764,05 €	60 065,55 MWh
	Net consumption without investment	16 277 764,05 €	60 065,55 MWh
	Mean peak power without investment	27 078,87 €	6,86 MW
	Consumed by P2G	25 470 420,09 €	93 986,79 MWh
	Net consumption with investment	41 748 184,14 €	154 052,34 MWh
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced by IP	0,00 €	32,50 MWh
	Net production without investment	0,00 €	32,50 MWh
	Consumed by P2G	0,00 €	-19 315,90 MWh
	Net production with investment	0,00 €	19 348,40 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	212 555 428,07 €	52 886,76 MWh
	Net consumption with investment	-212 555 428,07 €	-52 886,76 MWh
Water	Water from the grid consumed by P2G	7 787,40 €	6 425,78 m ³
	Collected precipitation consumed by P2G	n/a	774,57 m ³
	Total cost of input materials	319 886,71 €	
Input materials	Dry biomass bought	65 218,14 €	3 650,00 t
	Wet biomass bought	254 668,57 €	3 650,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	319 886,71 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
Residues	Total revenue from additional sales	0,00 €	
	Residue from dry anaerobic digester	0,00 €	109,50 t
	Residue from wet anaerobic digester	0,00 €	547,50 t
	Tar from gasification + water gas shift plant	0,00 €	43,80 t
	CO ₂ emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
	Total operational cost without investment	16 304 842,92 €	
	Total operational cost with investment	-170 410 119,50 €	
	Savings with introduction of P2G	186 714 962,41 €	

Fig. 7 Results for optimal P2G hub next to IP with 10× higher prices of methane and no subsidy (Results sheet of the Optimization tool)

The Optimisation tool suggest to invest in multiple components when the prices of methane go higher. The investment shown above consists of dry and wet anaerobic digestors, gasification + water gas shift plant, methanation reactor, electrolyser, demineraliser, precipitation collector, heat exchanger, gas compressor station, together with dry and wet biomass storages, biochar storage and water storage tank. It is an investment over 20 000 000 and the payoff period is 5,11 years and the P2G hub would produce over 50 000 mWh of biomethane yearly. The total savings would be around 186 714 962 EUR per year.

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	1 215 277,78 €	0,115741 kg/s
	Wet anaerobic digester	1 215 277,78 €	0,115741 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	6 944,44 €	0,013889 kg/s
	Methanation reactor	1 593 697,67 €	7,499754 mol/s
	Electrolyser	5 682 377,86 €	4 545,90 kW
	Deminerallizer	618,43 €	12,368668 mol/s
	Precipitation collector	1 000,00 €	1 000,00 m ²
	Heat exchanger	113 329,27 €	2 266,59 kW
	Gas compressor station	24 123,64 €	60,3091 kWe
	Total for processes	9 852 646,87 €	
Storages	Dry biomass storage	50 000,00 €	10 000,00 kg
	Wet biomass storage	25 000,00 €	10 000,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m ³
	Total for storages	75 000,00 €	
Connections enlargement	Electrical connection	337 440,20 €	5,62 MW
	Gas connection	0,00 €	0,00 MW
	Water connection	24,74 €	0,80 m ³ /h
	Total for connections	337 464,93 €	
Total investment		10 265 111,80 €	
Payoff period		5,06 years	

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	16 277 764,05 €	60 065,55 MWh
	Net consumption without investment	16 277 764,05 €	60 065,55 MWh
	Mean peak power without investment	27 078,87 €	6,86 MW
	Consumed by P2G	25 470 420,09 €	93 986,79 MWh
	Net consumption with investment	41 748 184,14 €	154 052,34 MWh
	Mean peak power with investment	69 450,33 €	17,59 MW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	32,50 MWh
	Net production without investment	0,00 €	32,50 MWh
	Consumed by P2G	0,00 €	-19 315,90 MWh
	Net production with investment	0,00 €	19 348,40 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	212 555 428,07 €	52 886,76 MWh
	Net consumption with investment	-212 555 428,07 €	-52 886,76 MWh
Water	Water from the grid consumed by P2G	7 787,40 €	6 425,78 m ³
	Collected precipitation consumed by P2G	n/a €	774,57 m ³
Input materials	Dry biomass bought	65 218,14 €	3 650,00 t
	Wet biomass bought	254 668,57 €	3 650,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	319 886,71 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
	Total revenue from additional sales	0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	109,50 t
	Residue from wet anaerobic digester	0,00 €	547,50 t
	Tar from gasification + water gas shift plant	0,00 €	43,80 t
	CO ₂ emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
Total operational cost without investment		16 304 842,92 €	
Total operational cost with investment		-170 410 119,50 €	
Savings with introduction of P2G		186 714 962,41 €	

Fig.8 Results for optimal P2G hub next to IP with 10× higher prices of methane and 50% subsidy (Results sheet of the Optimization tool)

The result of simulation with higher prices of methane and 50% subsidy resulted in similar investment suggestion to the Fig. 7. The main difference is the amount of total investment (over 10 000 000) and payoff period 5,06 years.

GF

Investment specifications		
Element	Cost	Size
Processes	Dry anaerobic digester	0,00 € 0,000000 kg/s
	Wet anaerobic digester	0,00 € 0,000000 kg/s
	Dry biomass to biochar plant	0,00 € 0,000000 kg/s
	Wet biomass to biochar plant	0,00 € 0,000000 kg/s
	Combined heat and power (CHP)	0,00 € 0,00 kWe
	Carbon capture plant	0,00 € 0,000000 mol/s
	Gasification + water gas shift plant	0,00 € 0,000000 kg/s
	Methanation reactor	0,00 € 0,000000 mol/s
	Electrolyser	0,00 € 0,00 kW
	Deminerallizer	0,00 € 0,000000 mol/s
	Precipitation collector	0,00 € 0,00 m ²
	Heat exchanger	0,00 € 0,00 kW
	Gas compressor station	0,00 € 0,0000 kWe
Total for processes		0,00 €
Storages	Dry biomass storage	0,00 € 0,00 kg
	Wet biomass storage	0,00 € 0,00 kg
	Biochar storage	0,00 € 0,00 kg
	Biogas storage	0,00 € 0,00 kg
	Hydrogen storage tank	0,00 € 0,00 kg
	Oxygen storage tank	0,00 € 0,00 kg
	Methane storage tank	0,00 € 0,00 kg
	Syngas storage tank	0,00 € 0,00 kg
	Carbon dioxide storage tank	0,00 € 0,00 kg
	Water storage tank	0,00 € 0,00 m ³
Total for storages		0,00 €
Connections and enlargement	Electrical connection	0,00 € 0,00 MW
	Gas connection	0,00 € 0,00 MW
	Water connection	0,00 € 0,00 m ³ /h
	Total for connections	0,00 €
Total investment		0,00 €
Payoff period		n/a years

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Mean peak power without investment	0,00 €	0,00 MW
	Consumed by P2G	0,00 €	0,00 MWh
	Net consumption with investment	0,00 €	0,00 MWh
	Mean peak power with investment	0,00 €	0,00 MW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	0,00 MWh
	Net production without investment	0,00 €	0,00 MWh
	Consumed by P2G	0,00 €	0,00 MWh
	Net production with investment	0,00 €	0,00 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	0,00 €	0,00 MWh
Water	Net consumption with investment	0,00 €	0,00 MWh
	Water from the grid consumed by P2G	0,00 €	0,00 m ³
	Collected precipitation consumed by P2G	n/a €	0,00 m ³
Input materials	Dry biomass bought	0,00 €	0,00 t
	Wet biomass bought	0,00 €	0,00 t
	Biochar bought	0,00 €	0,00 t
Total cost of input materials		0,00 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
Total revenue from additional sales		0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	0,00 t
	Residue from wet anaerobic digester	0,00 €	0,00 t
	Tar from gasification + water gas shift plant	0,00 €	0,00 t
	CO ₂ emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
Total operational cost without investment		0,00 €	
Total operational cost with investment		0,00 €	
Savings with introduction of P2G		0,00 €	

Fig. 9 Results for optimal P2G hub next to GF with conservative prices of methane and no subsidy (Results sheet of the Optimization tool)

With the current prices of methane, it is not economically feasible to invest into P2G hub in the selected Greenfield location. The prices of biomass sources, transportation, grid connections and components themselves are too high to be so that they can be repaid by only selling biomethane for the current market price. Maybe with the additional market possibility for hydrogen or biochar, the situation would be different.

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	0,00 €	0,000000 kg/s
	Wet anaerobic digester	0,00 €	0,000000 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	0,00 €	0,000000 kg/s
	Methanation reactor	0,00 €	0,000000 mol/s
	Electrolyser	0,00 €	0,00 kW
	Demineralizer	0,00 €	0,000000 mol/s
	Precipitation collector	0,00 €	0,00 m ²
	Heat exchanger	0,00 €	0,00 kW
	Gas compressor station	0,00 €	0,0000 kWe
	Total for processes	0,00 €	
Storages	Dry biomass storage	0,00 €	0,00 kg
	Wet biomass storage	0,00 €	0,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m ³
	Total for storages	0,00 €	
Connections enlargement	Electrical connection	0,00 €	0,00 MW
	Gas connection	0,00 €	0,00 MW
	Water connection	0,00 €	0,00 m ³ /h
	Total for connections	0,00 €	
	Total investment	0,00 €	
	Payoff period	n/a	years

Operational costs for selected period			
		Cost	Amount
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Mean peak power without investment	0,00 €	0,00 MW
	Consumed by P2G	0,00 €	0,00 MWh
	Net consumption with investment	0,00 €	0,00 MWh
	Mean peak power with investment	0,00 €	0,00 MW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	0,00 MWh
	Net production without investment	0,00 €	0,00 MWh
	Consumed by P2G	0,00 €	0,00 MWh
	Net production with investment	0,00 €	0,00 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	0,00 €	0,00 MWh
	Net consumption with investment	0,00 €	0,00 MWh
Water	Water from the grid consumed by P2G	0,00 €	0,00 m ³
	Collected precipitation consumed by P2G	n/a	0,00 m ³
Input materials	Dry biomass bought	0,00 €	0,00 t
	Wet biomass bought	0,00 €	0,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	0,00 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
	Total revenue from additional sales	0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	0,00 t
	Residue from wet anaerobic digester	0,00 €	0,00 t
	Tar from gasification + water gas shift plant	0,00 €	0,00 t
	CO2 emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
Total operational cost without investment		0,00 €	
Total operational cost with investment		0,00 €	
Savings with introduction of P2G		0,00 €	

Fig. 10 Results for optimal P2G hub next to GF with conservative prices of methane and 50% subsidy (Results sheet of the Optimization tool)

The situation is the same than in Figure 9 even with the subsidy of 50% for the components of P2G hub. No investment is suggested by Optimisation tool.

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	2 430 555,56 €	0,115741 kg/s
	Wet anaerobic digester	2 430 555,56 €	0,115741 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	13 888,89 €	0,013889 kg/s
	Methanation reactor	3 187 395,34 €	7,499754 mol/s
	Electrolyser	11 364 755,71 €	4 545,90 kW
	Deminerallizer	1 236,87 €	12,368668 mol/s
	Precipitation collector	2 000,00 €	1 000,00 m ²
	Heat exchanger	226 658,54 €	2 266,59 kW
	Gas compressor station	48 247,28 €	60,3091 kWe
	Total for processes	19 705 293,74 €	
Storages	Dry biomass storage	100 000,00 €	10 000,00 kg
	Wet biomass storage	50 000,00 €	10 000,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m ³
	Total for storages	150 000,00 €	
Connections enlargement	Electrical connection	644 232,32 €	10,74 MW
	Gas connection	2 808 861,00 €	6,04 MW
	Water connection	0,00 €	0,80 m ³ /h
	Total for connections	3 453 093,32 €	
	Total investment	23 308 387,06 €	
	Payoff period	5,13 years	

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Mean peak power without investment	0,00 €	0,00 MW
	Consumed by P2G	25 470 420,09 €	93 986,79 MWh
	Net consumption with investment	25 470 420,09 €	93 986,79 MWh
	Mean peak power with investment	42 371,46 €	10,73 MW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	0,00 MWh
	Net production without investment	0,00 €	0,00 MWh
	Consumed by P2G	0,00 €	-19 315,90 MWh
	Net production with investment	0,00 €	19 315,90 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	212 555 428,07 €	52 886,76 MWh
	Net consumption with investment	-212 555 428,07 €	-52 886,76 MWh
Water	Water from the grid consumed by P2G	7 775,19 €	6 425,78 m ³
	Collected precipitation consumed by P2G	n/a	774,57 m ³
Input materials	Dry biomass bought	127 281,18 €	3 650,00 t
	Wet biomass bought	67 575,99 €	3 650,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	194 857,17 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
	Total revenue from additional sales	0,00 €	
Residues	Residue from dry anaerobic digester	0,00 €	109,50 t
	Residue from wet anaerobic digester	0,00 €	547,50 t
	Tar from gasification + water gas shift plant	0,00 €	43,80 t
	CO2 emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
Total operational cost without investment		0,00 €	
Total operational cost with investment		-186 840 004,17 €	
Savings with introduction of P2G		186 840 004,17 €	

Fig. 11 Results for optimal P2G hub next to GF with 10× higher prices of methane and no subsidy (Results sheet of the Optimization tool)

With the higher prices of methane, the production of biomethane and building a P2G in a greenfield location starts to be feasible. The Optimisation tool suggests to invest into both dry and wet digestors and biomass storages, methanation reactor, gasification and water gas shift, electrolyser and other components, see the result sheet. The total production of biomethane would be over 50 000 mWh yearly and with the existing market for hydrogen it could be another output. The total investment would be over 23 000 000 EUR and payoff period 5, 13 years.

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	1 215 277,78 €	0,115741 kg/s
	Wet anaerobic digester	1 215 277,78 €	0,115741 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,00 kWe
	Carbon capture plant	0,00 €	0,000000 mol/s
	Gasification + water gas shift plant	6 944,44 €	0,013889 kg/s
	Methanation reactor	1 593 697,67 €	7,499754 mol/s
	Electrolyser	5 682 377,86 €	4 545,90 kW
	Deminerallizer	618,43 €	12,368668 mol/s
	Precipitation collector	1 000,00 €	1 000,00 m ²
	Heat exchanger	113 329,27 €	2 266,59 kW
	Gas compressor station	24 123,64 €	60,3091 kWe
	Total for processes	9 852 646,87 €	
Storages	Dry biomass storage	50 000,00 €	10 000,00 kg
	Wet biomass storage	25 000,00 €	10 000,00 kg
	Biochar storage	0,00 €	0,00 kg
	Biogas storage	0,00 €	0,00 kg
	Hydrogen storage tank	0,00 €	0,00 kg
	Oxygen storage tank	0,00 €	0,00 kg
	Methane storage tank	0,00 €	0,00 kg
	Syngas storage tank	0,00 €	0,00 kg
	Carbon dioxide storage tank	0,00 €	0,00 kg
	Water storage tank	0,00 €	0,00 m ³
Connections and engagement	Total for storages	75 000,00 €	
	Electrical connection	644 232,32 €	10,74 MW
	Gas connection	2 808 861,00 €	6,04 MW
	Water connection	0,00 €	0,80 m ³ /h
	Total for connections	3 453 093,32 €	
	Total investment	13 380 740,19 €	
	Payoff period	5,07 years	

Operational costs for selected period			
		Cost	Amount
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Mean peak power without investment	0,00 €	0,00 MW
	Consumed by P2G	25 470 420,09 €	93 986,79 MWh
	Net consumption with investment	25 470 420,09 €	93 986,79 MWh
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	0,00 MWh
	Net production without investment	0,00 €	0,00 MWh
	Consumed by P2G	0,00 €	-19 315,90 MWh
	Net production with investment	0,00 €	19 315,90 MWh
Gas (methane) to/from the grid	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	0,00 €	0,00 MWh
	Net consumption without investment	0,00 €	0,00 MWh
	Produced by P2G	212 555 428,07 €	52 886,76 MWh
Water	Net consumption with investment	-212 555 428,07 €	-52 886,76 MWh
	Water from the grid consumed by P2G	7 775,19 €	6 425,78 m ³
	Collected precipitation consumed by P2G	n/a	774,57 m ³
	Dry biomass bought	127 281,18 €	3 650,00 t
Input materials	Wet biomass bought	67 575,99 €	3 650,00 t
	Biochar bought	0,00 €	0,00 t
	Total cost of input materials	194 857,17 €	
Additional sales	Hydrogen sold (in bottles)	0,00 €	0,00 t
	Oxygen sold (in bottles)	0,00 €	0,00 t
	Methane sold (in bottles)	0,00 €	0,00 t
	Biochar sold	0,00 €	0,00 t
Residues	Total revenue from additional sales	0,00 €	
	Residue from dry anaerobic digester	0,00 €	109,50 t
	Residue from wet anaerobic digester	0,00 €	547,50 t
	Tar from gasification + water gas shift plant	0,00 €	43,80 t
	CO ₂ emitted	0,00 €	0,00 t
	Total cost of residues	0,00 €	
	Total operational cost without investment	0,00 €	
	Total operational cost with investment	-186 840 004,17 €	
	Savings with introduction of P2G	186 840 004,17 €	

Fig.12 Results for optimal P2G hub next to GF with 10× higher prices of methane and 50% subsidy (Results sheet of the Optimization tool)

The result is similar than in the figure 11, only with a shorter payoff period.

4. CONCLUSIONS

As seen from the calculations shown above, the Slovak territorial perspectives for introducing the P2G hub with the current prices of methane does not seem economically profitable. Zero investment possibilities were shown for the situations of investing to P2G next to Renewable energy source, Industrial plant and also building it on the greenfield location. The same result was shown when adding a 50% subsidy.

Economically viable calculations started to appear when higher prices of methane were simulated. In all three cases, both for situations with and without subsidy, investments into different P2G components were suggested. The major change for the calculations with subsidy was shorter payoff period.

However, the results may change if the actual existing market possibilities for hydrogen, oxygen, methane and biochar were added. The market with hydrogen is slowly being introduced to Slovakia and we believe that in few years this commodity will be highly demanded. For this reason, we would suggest to potential investors to at least include hydrogen market possibilities into the calculation, maybe also biochar. When simulating calculations with biochar, possible investment appeared also for the current prices of methane.

We would also suggest to revise the data downloaded from the Atlas, since in time the data may change or the potential investor have better overview for a current price for certain infrastructure case. In any case a detailed study of the distribution system operators is needed when the P2G would be connected to the grid and conclusions from this study may be applied into the Optimisation tool.