

Output T2.2

Pre-feasibility Study (Bulgaria)

WP T2: Project main output

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



August, 2022

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	August, 2022

Version	Date	Author	Organization	Description
V1	August, 2022	Kiril Raytchev	BSERC	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:

- LP Technology Centre Energy - University of Applied Sciences Landshut (DE)
- ERDF PP1 Energy Agency of Savinjska, Koroška and Šaleška Region (SI)
- ERDF PP2 Tolna County Development Agency Nonprofit Public Ltd.(HU)
- ERDF PP3 Energy Institute at the Johannes Kepler University Linz (AT)
- ERDF PP4 Black Sea Energy Research Centre (BG)
- ERDF PP5 URBASOFIA SRL (RO)
- ERDF PP6 Deggendorf Institute of Technology (DE)
- ERDF PP7 National Recycling Agency of Slovakia (SK)
- ERDF PP8 Institute of Technology and Business in České Budějovice (CZ)
- ERDF PP9 MAHART-Freeport Co. Ltd (HU)
- ERDF PP10 International Centre for Sustainable Development of Energy, Water and Environment Systems (HR)
- ERDF PP11 Energy Institute Hrvoje Požar (HR)
- ERDF PP12 University of Zagreb Faculty of Electrical Engineering and Computing (HR)
- IPA PP1 Regional Agency for Socio – Economic Development – Banat Ltd (RS)

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)

BLANK PAGE

CONTENT

ABBREVIATIONS.....	7
1. METHODOLOGY	8
2. CASE STUDIES.....	10
3. RESULTS.....	12
3.1 POWER TO GAS HUB AS GREEN FIELD INVESTMENT (SCENARIO I).....	12
3.1.1 WITHOUT ANY FORM OF SUBSIDY (0%).....	12
3.1.2 WITH SUBSIDY (50%).....	12
3.1.3 WITH 10x INCREASE of NG PRICE	13
3.2 POWER TO GAS HUB ON THE PREMISIS OF BIG NG CONSUMER (Scenario II).....	14
3.2.1 WITHOUT ANY FORM OF SUBSIDY (0%).....	14
3.2.1 WITH SUBSIDY (50%).....	15
3.2.1 WITH 10x INCREASE of NG PRICE	16
3.3 POWER TO GAS HUB ON THE PREMISIS OF REP (SCENARIO III).....	17
3.3.1 WITHOUT ANY FORM OF SUBSIDY (0%).....	17
3.3.1 WITH SUBSIDY (50%).....	18
3.3.1 WITH 10x INCREASE of NG PRICE	19
4. CONCLUSIONS.....	21
APPENDIX I OPTIMIZATION TOOL PARAMETERS.....	22

FIGURES

Figure 1 Northern Industrial Zone - Gabrovo City (Source: Google Maps)	10
Figure 2 P2G & GF (0% Subsidy)	12
Figure 3 P2G & GF (50% Subsidy)	13
Figure 4 P2G & GF (10x NG price increase)	14
Figure 5 P2G & IP (0% Subsidy)	15
Figure 6 P2G & IP (50% Subsidy).....	16
Figure 7 P2G & IP (10x NG price increase)	17
Figure 8 P2G & REP (0% Subsidy)	18
Figure 9 P2G & REP (50% Subsidy).....	19
Figure 10 P2G & REP (10x NG price increase)	20

TABLES

Table 1 Case Studies Matrix	9
Table 2 Case Studies Results	21

ABBREVIATIONS

10x	Ten-fold
CP	Connection point
GF	Green field
IP	Industrial plant
NG	Natural gas
NIZ	Northern Industrial Zone
OT	Optimization tool
P2G	Power-to-gas
REP	Renewable energy plant
UWWTP	Urban wastewater treatment plant

1. METHODOLOGY

The current Pre-feasibility study is conducted with the help of the D2G Optimization tool (OT) – a software instrument developed under the DanuP-2-Gas project. On the basis of a series of input parameters, present in the Biomass and Infrastructure databases and reports¹, the OT provides data on the optimal parametrization of a potential P2G hub investment. This includes its sizing in terms of power, throughput, yield and the like, as well financial estimates like simple payback period and the amount of investment required.

Three main scenarios are simulated with the objective of making an optimal selection of a P2G hub location. The results from simulations are analysed for economic and technical feasibility:

- Green field (GF) investment scenario

Under this scenario, the P2G hub is located near favourable infrastructure assets like connection points (CPs) to the gas grid, substations with enough free power capacity, transport hubs for supply and delivery of goods, e.g., biochar, as well as biomass sources with cheap and abundant supply possibilities.

- Industrial plant (IP) investment scenario

Under this scenario, the P2G hub is located on the premises of an IP, preferably a big natural gas (NG) consumer. The possibility for NG supply from the P2G hub to the IP is validated.

- Renewable energy plant (REP) investment scenario

Under this scenario, the P2G hub is located on the premises of a REP, preferably a big electrical energy producer. The possibility for REP supply of electrical energy to the P2G hub is validated from economic feasibility perspective.

A set of input parameters of each of the three scenarios are varied within predefined boundaries, which results in the sensitivity analysis part of the current Prefeasibility study:

- 50% subsidy

It is normal for innovative and high-risk projects to be backed up by some form of subsidy. In our case we investigate the results if a 50% subsidy is used.

- Ten-fold (10x) increase of NG prices

Nowadays we witness that such deviations are realistic due to geopolitical conflicts and exploring alternative options for NG supply, including innovative and still expensive ones like P2G, have to be on our radar.

¹ Biomass & Infrastructure Databases & Reports are deliverables under the DanuP-2-Gas project.

The following table summarizes the opportunities for P2G investments that are studied:

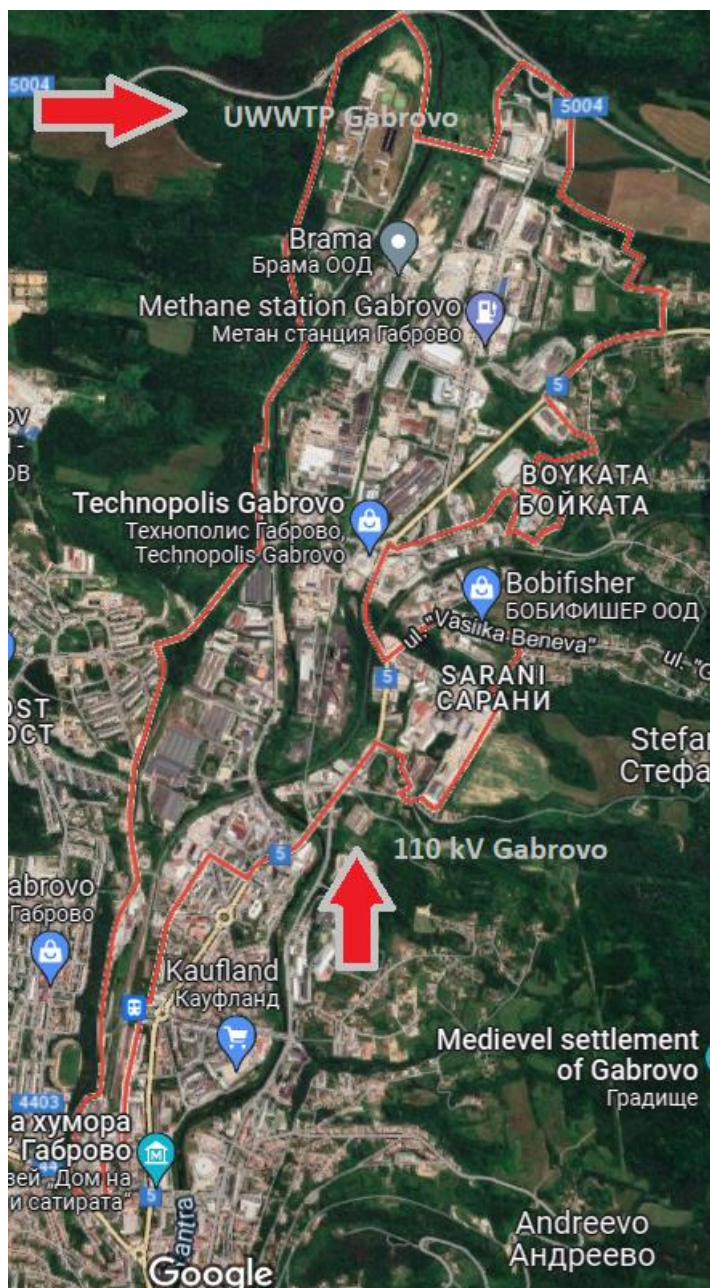
Table 1 Case Studies Matrix

Scenario	0% Subsidy	50% Subsidy	10x NG prices
I.	P2G & GF	P2G & GF	P2G & GF
II.	P2G & IP	P2G & IP	P2G & IP
III.	P2G & REP	P2G & REP	P2G & REP

2. CASE STUDIES

The case studies are designed around available assets located on the premises of the Northern Industrial Zone (NIS) in the city of Gabrovo (see the figure below).

Figure 1 Northern Industrial Zone - Gabrovo City (Source: Google Maps)



The area of the NIZ is marked with a thin red line. The assets of interest for our prefeasibility study are the following:

- Urban Wastewater treatment plant (UWWTP) – Gabrovo

The plant is located in the northern part of the NIZ. It can be used as a biomass supplier of a P2G hub because of its annual output of sewage sludge of the amount of 3,887 tons.

- 110 kV electrical substation – Gabrovo

The electrical substation is located in the bottom half of the map of the NIZ. It can easily be upgraded to have additional capacity of between 10 MW and 50 MW against an investment of between EUR 18,000 and 250,000². As a consequence, the substation can be used as an electrical CP for the P2G hub.

- Photovoltaics (REP)

It is planned that photovoltaics with capacity to produce 16,388.83 MWh annually will be installed on the premises of 38 companies in the NIZ. For the needs of our prefeasibility study we assume that the companies will be able to utilize not more than 50% of that energy and that the rest will be supplied to the P2G hub. In that respect the P2G will act as a balancing agent.

- Big NG consumer – industrial plant (IP), etc.

Citygas Bulgaria JSC is the local gas utility. It owns and operates the gas transmission and distribution grid in several Bulgarian regions, including Gabrovo and the NIZ. A potential P2G hub is in the position of supplying part of the NG for the needs of Citygas' clients. The annual sales³ of the gas utility company for the year 2018 reached 89,228 thousand m³.

² <https://webapps.eso.bg/capacity/>

³ [Link](#)

3. RESULTS

The results of the selection of scenarios are presented in the following sections. All the parameters used for the simulations are available in the Appendix.

3.1 POWER TO GAS HUB AS GREEN FIELD INVESTMENT (SCENARIO I)

Under Scenario I it is assumed that the P2G hub is built on the premises of UWWTP – Gabrovo. In that way no transport cost for biomass supply is paid for the P2G hub operation.

3.1.1 WITHOUT ANY FORM OF SUBSIDY (0%)

The OT estimates that production and sales of hydrogen, oxygen, and biochar are feasible given the parameters supplied. A simple payback period of 5.0 years is calculated.

Figure 2 P2G & GF (0% Subsidy)

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	23 871.53 €	0.096451 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	4 654 947.92 €	1 880.79 kW
	Demineralizer	3 108.72 €	31.401216 mol/s
	Precipitation collector	1 980.00 €	1 000.00 m ²
	Heat exchanger	18 333.33 €	185.19 kW
	Gas compressor station	0.00 €	0.0000 kWe
	Total for processes	4 702 241.50 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	41 250.00 €	8 333.33 kg
	Biochar storage	14 850.00 €	1 000.00 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	1 745.78 €	80.16 m ³
	Total for storages	57 845.78 €	
Connections engagement	Electrical connection	10 668.29 €	2.13 MW
	Gas connection	0.00 €	0.00 MW
	Water connection	12 937.30 €	2.04 m ³ /h
	Total for connections	23 605.59 €	
	Total investment	4 783 692.87 €	
	Payoff period	5.00 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	929 008.97 €	8 392.51 MWh
	Net consumption with investment	929 008.97 €	8 392.51 MWh
	Mean peak power with investment	0.00 €	2.13 MW
Heat	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-804.44 MWh
	Net production with investment	0.00 €	804.44 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	87.87 €	1 273.54 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 508.33 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	1 357 500.00 €	181.00 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	271 500.00 €	181.00 t
	Total revenue from additional sales	1 641 670.00 €	
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		-712 573.15 €	
Savings with introduction of P2G		712 573.15 €	

3.1.2 WITH SUBSIDY (50%)

The OT estimates that production and sales of hydrogen, oxygen, and biochar are feasible given the parameters supplied. Expectedly, the calculated simple payback period decreases to 3.04 years.

Figure 3 P2G & GF (50% Subsidy)

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	24 112.65 €	0.192901 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	2 350 983.80 €	1 880.79 kW
	Demineralizer	1 570.06 €	31.401216 mol/s
	Precipitation collector	1 000.00 €	1 000.00 m ²
	Heat exchanger	9 259.26 €	185.19 kW
	Gas compressor station	0.00 €	0.0000 kWe
	Total for processes	2 386 925.77 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	20 833.33 €	8 333.33 kg
	Biochar storage	7 500.00 €	1 000.00 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	881.71 €	80.16 m ³
	Total for storages	29 215.04 €	
Connections enhancement	Electrical connection	10 755.09 €	2.15 MW
	Gas connection	0.00 €	0.00 MW
	Water connection	12 937.30 €	2.04 m ³ /h
	Total for connections	23 692.39 €	
Total investment		2 439 833.20 €	
Payoff period		3.04 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	928 070.81 €	8 392.51 MWh
	Net consumption with investment	928 070.81 €	8 392.51 MWh
Heat	Mean peak power with investment	0.00 €	2.15 MW
	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-804.44 MWh
	Net production with investment	0.00 €	804.44 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	87.87 €	1 273.54 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
	Total cost of input materials	0.00 €	
Additional sales	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 508.33 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Residues	Hydrogen sold (in bottles)	1 357 500.00 €	181.00 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	271 500.00 €	181.00 t
Total revenue from additional sales		1 641 670.00 €	
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		-713 511.32 €	
Savings with introduction of P2G		713 511.32 €	

3.1.3 WITH 10X INCREASE OF NG PRICE

The OT estimates that production and sales of hydrogen and methane are feasible given the parameters supplied. The calculated simple payback period is estimated to be 7.8 years.

Figure 4 P2G & GF (10x NG price increase)

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	0.00 €	0.000000 kg/s
	Wet anaerobic digester	2 406 250.00 €	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	0.00 €	0.000000 kg/s
	Methanation reactor	1 432 291.67 €	3 404 139 mol/s
	Electrolyser	9 036 075.37 €	3 650.94 kW
	Deminerallizer	4 950.00 €	50.000000 mol/s
	Precipitation collector	1 980.00 €	1 000.00 m ²
	Heat exchanger	119 840.69 €	1 210.51 kW
	Gas compressor station	90 310.83 €	114.0288 kWe
	Total for processes	13 091 698.55 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	49 500.00 €	10 000.00 kg
	Biochar storage	7 425.00 €	500.00 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	1 384.65 €	63.57 m ³
	Total for storages	58 309.65 €	
Connections entailment	Electrical connection	34 414.78 €	6.88 MW
	Gas connection	4 932.60 €	2.74 MW
	Water connection	20 600.00 €	3.25 m ³ /h
	Total for connections	59 947.38 €	
	Total investment	13 209 955.58 €	
	Payoff period	7.78 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	3 186 223.37 €	28 594.97 MWh
	Net consumption with investment	3 186 223.37 €	28 594.97 MWh
	Mean peak power with investment	0.00 €	6.88 MW
Heat	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-5 122.71 MWh
	Net production with investment	0.00 €	5 122.71 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	2 976 000.82 €	11 904.00 MWh
	Net consumption with investment	-2 976 000.82 €	-11 904.00 MWh
Water	Water from the grid consumed by P2G	193.98 €	2 811.32 m ³
	Collected precipitation consumed by P2G	n/a	360.37 m ³
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 810.00 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	1 357 500.00 €	181.00 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	135 750.00 €	90.50 t
	Total revenue from additional sales	1 505 920.00 €	
Residues	Residue from dry anaerobic digester	0.00 €	0.00 t
	Residue from wet anaerobic digester	0.00 €	271.50 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	-1 295 503.47 €	
	Savings with introduction of P2G	1 295 503.47 €	

3.2 POWER TO GAS HUB ON THE PREMISIS OF BIG NG CONSUMER (SCENARIO II)

Under Scenario II it may be again assumed that the P2G hub is built on the premises of UWWTP – Gabrovo. In that way the advantages of Scenario I can be preserved as well as the P2G hub can be connected to the local gas utility – Citygas to sell methane.

3.2.1 WITHOUT ANY FORM OF SUBSIDY (0%)

The OT estimates that production and sales of hydrogen, oxygen, and biochar are feasible given the parameters supplied. The calculated simple payback period is estimated to be 5.0 years.

Figure 5 P2G & IP (0% Subsidy)

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	23 871.53 €	0.096451 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	4 654 947.92 €	1 880.79 kW
	Demineralizer	3 313.77 €	33.472392 mol/s
	Precipitation collector	1 980.00 €	1 000.00 m ³
	Heat exchanger	18 333.33 €	185.19 kW
	Gas compressor station	0.00 €	0.0000 kWe
	Total for processes	4 702 446.54 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	41 250.00 €	8 333.33 kg
	Biochar storage	14 850.00 €	1 000.00 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	1 476.30 €	67.78 m ³
Connections enlargement	Total for storages	57 576.30 €	
	Electrical connection	0.00 €	0.00 MW
	Gas connection	0.00 €	0.00 MW
	Water connection	66.94 €	2.18 m ³ /h
	Total for connections	66.94 €	
	Total investment	4 760 089.79 €	
	Payoff period	4.98 years	

Operational costs for selected period			
		Cost	Amount
Electrical energy	Produced by REP	0.00 €	0.00 MWh
	Consumed by IP	455 121.86 €	4 063.82 MWh
	Net consumption without investment	455 121.86 €	4 063.82 MWh
	Mean peak power without investment	0.00 €	1.19 MW
	Consumed by P2G	929 008.97 €	8 392.51 MWh
	Net consumption with investment	1 384 130.83 €	12 456.34 MWh
Heat	Mean peak power with investment	0.00 €	3.34 MW
	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-804.44 MWh
	Net production with investment	0.00 €	804.44 MWh
Gas (methane) to/from the grid	Produced by REP	0.00 €	0.00 MWh
	Consumed by IP	15 075 068.49 €	471 095.89 MWh
	Net consumption without investment	15 075 068.49 €	471 095.89 MWh
	Produced by P2G	0.00 €	0.00 MWh
Water	Net consumption with investment	15 075 068.49 €	471 095.89 MWh
	Water from the grid consumed by P2G	87.87 €	1 273.54 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 508.33 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	1 357 500.00 €	181.00 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	271 500.00 €	181.00 t
Residues	Total revenue from additional sales	1 641 670.00 €	
	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	15 530 190.35 €	
	Total operational cost with investment	14 817 617.20 €	
	Savings with introduction of P2G	712 573.15 €	

3.2.1 WITH SUBSIDY (50%)

The OT estimates that production and sales of hydrogen, oxygen, and biochar are feasible given the parameters supplied. Expectedly, the calculated simple payback period decreases to 3.0 years.

Figure 6 P2G & IP (50% Subsidy)

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	24 112.65 €	0.192901 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	2 350 983.80 €	1 880.79 kW
	Demineralizer	1 673.62 €	33.472392 mol/s
	Precipitation collector	1 000.00 €	1 000.00 m ³
	Heat exchanger	9 259.26 €	185.19 kW
	Gas compressor station	0.00 €	0.0000 kWe
	Total for processes	2 387 029.33 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	20 833.33 €	8 333.33 kg
	Biochar storage	7 500.00 €	1 000.00 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	745.61 €	67.78 m ³
	Total for storages	29 078.94 €	
Connections enlargement	Electrical connection	0.00 €	0.00 MW
	Gas connection	0.00 €	0.00 MW
	Water connection	66.94 €	2.18 m ³ /h
	Total for connections	66.94 €	
Total investment		2 416 175.21 €	
Payoff period		3.02 years	

Operational costs for selected period			
		Cost	Amount
Electrical energy	Produced by REP	0.00 €	0.00 MWh
	Consumed by IP	455 121.86 €	4 063.82 MWh
	Net consumption without investment	455 121.86 €	4 063.82 MWh
	Mean peak power without investment	0.00 €	1.19 MW
	Consumed by P2G	928 070.81 €	8 392.51 MWh
	Net consumption with investment	1 383 192.67 €	12 456.34 MWh
	Mean peak power with investment	0.00 €	3.35 MW
Heat	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-804.44 MWh
	Net production with investment	0.00 €	804.44 MWh
Gas (methane) to/from the grid	Produced by REP	0.00 €	0.00 MWh
	Consumed by IP	15 075 068.49 €	471 095.89 MWh
	Net consumption without investment	15 075 068.49 €	471 095.89 MWh
	Produced by P2G	0.00 €	0.00 MWh
	Net consumption with investment	15 075 068.49 €	471 095.89 MWh
Water	Water from the grid consumed by P2G	87.87 €	1 273.54 m ³
	Collected precipitation consumed by P2G	n/a	360.37 m ³
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 508.33 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	1 357 500.00 €	181.00 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	271 500.00 €	181.00 t
	Total revenue from additional sales	1 641 670.00 €	
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		15 530 190.35 €	
Total operational cost with investment		14 816 679.03 €	
Savings with introduction of P2G		713 511.32 €	

3.2.1 WITH 10X INCREASE OF NG PRICE

The OT estimates that production and sales of hydrogen, oxygen, biochar, and methane are feasible given the parameters supplied. The calculated simple payback period is estimated to be 5.9 years.

Figure 7 P2G & IP (10x NG price increase)

Investment specifications			
	Element	Cost	Size
Processes	Dry anaerobic digester	0.00 €	0.000000 kg/s
	Wet anaerobic digester	2 432 986.11 €	0.117027 kg/s
	Dry biomass to biochar plant	0.00 €	0.000000 kg/s
	Wet biomass to biochar plant	26 494.77 €	0.107050 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	1 448 206.02 €	3.441963 mol/s
	Electrolyser	4 654 947.92 €	1 880.79 kW
	Demineralizer	3 313.77 €	33.472392 mol/s
	Precipitation collector	1 980.00 €	1 000.00 m ³
	Heat exchanger	103 521.92 €	1 045.68 kW
	Gas compressor station	87 730.53 €	110.7709 kWe
	Total for processes	8 759 181.04 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	49 500.00 €	10 000.00 kg
	Biochar storage	148 500.00 €	10 000.00 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	1 476.30 €	67.78 m ³
	Total for storages	199 476.30 €	
Connections enlargement	Electrical connection	0.00 €	0.00 MW
	Gas connection	0.00 €	0.00 MW
	Water connection	66.94 €	2.18 m ³ /h
	Total for connections	66.94 €	
	Total investment	8 958 724.29 €	
	Payoff period	5.89 years	

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	0.00 €	0.00 MWh
	Consumed by IP	455 121.86 €	4 063.82 MWh
	Net consumption without investment	455 121.86 €	4 063.82 MWh
	Mean peak power without investment	0.00 €	1.19 MW
	Consumed by P2G	1 622 562.39 €	14 589.13 MWh
	Net consumption with investment	2 077 684.25 €	18 652.95 MWh
Heat	Mean peak power with investment	0.00 €	4.77 MW
	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-2 594.85 MWh
	Net production with investment	0.00 €	2 594.85 MWh
Gas (methane) to/from the grid	Produced by REP	0.00 €	0.00 MWh
	Consumed by IP	78 321 643.84 €	471 095.89 MWh
	Net consumption without investment	78 321 643.84 €	471 095.89 MWh
	Produced by P2G	1 496 221.41 €	5 984.89 MWh
	Net consumption with investment	76 514 208.38 €	465 111.00 MWh
Water	Water from the grid consumed by P2G	87.87 €	1 273.54 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 751.67 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	715 147.06 €	95.35 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	219 750.00 €	146.50 t
	Total revenue from additional sales	947 567.06 €	
Residues	Residue from dry anaerobic digester	0.00 €	0.00 t
	Residue from wet anaerobic digester	0.00 €	136.50 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	78 776 765.70 €	
	Total operational cost with investment	77 644 413.45 €	
	Savings with introduction of P2G	1 132 352.25 €	

3.3 POWER TO GAS HUB ON THE PREMISIS OF REP (SCENARIO III)

Under Scenario III it may be again assumed that the P2G hub is built on the premises of UWWTP – Gabrovo, providing that it will be possible to connect it directly to the grid of the planned for investment photovoltaics in the NIZ. In that way: (i) the advantages of Scenario I can be preserved, (ii) the P2G hub can be connected to the local gas utility – Citygas to sell methane, and (iii) the P2G hub can act as a balancing agent for the companies in the NIZ that plan to produce electrical energy.

3.3.1 WITHOUT ANY FORM OF SUBSIDY (0%)

The OT estimates that production and sales of hydrogen, oxygen, and biochar are feasible given the parameters supplied. The calculated simple payback period is estimated to be 4.2 years.

Figure 8 P2G & REP (0% Subsidy)

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	31 828.70 €	0.128601 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	4 654 947.92 €	1 880.79 kW
	Demineralizer	3 278.83 €	33.119534 mol/s
	Precipitation collector	1 980.00 €	1 000.00 m ²
	Heat exchanger	18 333.33 €	185.19 kW
	Gas compressor station	0.00 €	0.0000 kWe
	Total for processes	4 710 368.79 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	41 250.00 €	8 333.33 kg
	Biochar storage	14 850.00 €	1 000.00 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	1 512.27 €	69.43 m ³
Connections enlargement	Total for storages	57 612.27 €	
	Electrical connection	0.00 €	0.00 MW
	Gas connection	0.00 €	0.00 MW
	Water connection	13 645.25 €	2.15 m ³ /h
	Total for connections	13 645.25 €	
	Total investment	4 781 626.30 €	
	Payoff period	4.17 years	

Operational costs for selected period			
	Cost	Amount	
Electrical energy	Produced by REP	298 960.90 €	4 144.10 MWh
	Consumed by IP	0.00 €	0.00 MWh
	Net consumption without investment	-298 960.90 €	-4 144.10 MWh
	Mean peak power without investment	0.00 €	0.00 MW
	Consumed by P2G	928 696.25 €	8 392.51 MWh
	Net consumption with investment	475 150.67 €	4 248.41 MWh
	Mean peak power with investment	0.00 €	2.15 MW
Heat	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-804.44 MWh
	Net production with investment	0.00 €	804.44 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	87.87 €	1 273.54 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
	Total cost of input materials	0.00 €	
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 508.33 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	1 357 500.00 €	181.00 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	271 500.00 €	181.00 t
	Total revenue from additional sales	1 641 670.00 €	
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	-298 960.90 €	
	Total operational cost with investment	-1 166 431.46 €	
	Savings with introduction of P2G	867 470.56 €	

3.3.1 WITH SUBSIDY (50%)

The OT estimates that production and sales of hydrogen, oxygen, and biochar are feasible given the parameters supplied. Expectedly, the calculated simple payback period is decreased to 2.6 years.

Figure 9 P2G & REP (50% Subsidy)

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	18 084.49 €	0.144676 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	2 350 983.80 €	1 880.79 kW
	Demineralizer	1 655.98 €	33.119534 mol/s
	Precipitation collector	1 000.00 €	1 000.00 m ²
	Heat exchanger	9 259.26 €	185.19 kW
	Gas compressor station	0.00 €	0.0000 kWe
	Total for processes	2 380 983.52 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	20 833.33 €	8 333.33 kg
	Biochar storage	7 500.00 €	1 000.00 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	763.77 €	69.43 m ³
	Total for storages	29 097.10 €	
Connections enlargement	Electrical connection	0.00 €	0.00 MW
	Gas connection	0.00 €	0.00 MW
	Water connection	13 645.25 €	2.15 m ³ /h
	Total for connections	13 645.25 €	
	Total investment	2 423 725.88 €	
	Payoff period	2.61 years	

Operational costs for selected period			
		Cost	Amount
Electrical energy	Produced by REP	298 960.90 €	4 144.10 MWh
	Consumed by IP	0.00 €	0.00 MWh
	Net consumption without investment	-298 960.90 €	-4 144.10 MWh
	Mean peak power without investment	0.00 €	0.00 MW
	Consumed by P2G	928 539.89 €	8 392.51 MWh
	Net consumption with investment	474 990.24 €	4 248.41 MWh
Heat	Mean peak power with investment	0.00 €	2.16 MW
	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-804.44 MWh
	Net production with investment	0.00 €	804.44 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	87.87 €	1 273.54 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
	Total cost of input materials	0.00 €	
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 508.33 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	1 357 500.00 €	181.00 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	271 500.00 €	181.00 t
Residues	Total revenue from additional sales	1 641 670.00 €	
	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	-298 960.90 €	
	Total operational cost with investment	-1 166 591.88 €	
	Savings with introduction of P2G	867 630.99 €	

3.3.1 WITH 10X INCREASE OF NG PRICE

The OT estimates that production and sales of hydrogen, oxygen, biochar, and methane are feasible given the parameters supplied. The calculated simple payback period is estimated to be 4.2 years.

Figure 10 P2G & REP (10x NG price increase)

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	29 839.41 €	0.120563 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	2 571.76 €	0.002598 kg/s
	Methanation reactor	19 673.96 €	0.046759 mol/s
	Electrolyser	4 654 947.92 €	1 880.79 kW
	Demineralizer	3 278.83 €	33.119534 mol/s
	Precipitation collector	1 980.00 €	1 000.00 m ³
	Heat exchanger	19 490.63 €	196.88 kW
	Gas compressor station	1 240.51 €	1.5663 kWe
	Total for processes	4 733 023.01 €	
Storages	Dry biomass storage	0.00 €	0.00 kg
	Wet biomass storage	49 500.00 €	10 000.00 kg
	Biochar storage	14 850.00 €	1 000.00 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	1 512.27 €	69.43 m ³
	Total for storages	65 862.27 €	
Connections enlargement	Electrical connection	0.00 €	0.00 MW
	Gas connection	67.75 €	0.04 MW
	Water connection	13 645.25 €	2.15 m ³ /h
	Total for connections	13 713.00 €	
	Total investment	4 812 598.28 €	
	Payoff period	4.18 years	

Operational costs for selected period			
		Cost	Amount
Electrical energy	Produced by REP	298 960.90 €	4 144.10 MWh
	Consumed by IP	0.00 €	0.00 MWh
	Net consumption without investment	-298 960.90 €	-4 144.10 MWh
	Mean peak power without investment	0.00 €	0.00 MW
	Consumed by P2G	939 354.34 €	8 486.91 MWh
	Net consumption with investment	485 834.25 €	4 342.81 MWh
	Mean peak power with investment	0.00 €	2.17 MW
Heat	Produced by REP	0.00 €	0.00 MWh
	Produced by IP	0.00 €	0.00 MWh
	Net production without investment	0.00 €	0.00 MWh
	Consumed by P2G	0.00 €	-829.13 MWh
	Net production with investment	0.00 €	829.13 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	20 326.25 €	81.30 MWh
	Net consumption with investment	-20 326.25 €	-81.30 MWh
Water	Water from the grid consumed by P2G	88.61 €	1 284.24 m ³
	Collected precipitation consumed by P2G	n/a €	360.37 m ³
Input materials	Dry biomass bought	0.00 €	0.00 t
	Wet biomass bought	0.00 €	1 676.67 t
	Biochar bought	0.00 €	0.00 t
	Total cost of input materials	0.00 €	
Additional sales	Hydrogen sold (in bottles)	1 352 046.00 €	180.27 t
	Oxygen sold (in bottles)	12 670.00 €	181.00 t
	Methane sold (in bottles)	0.00 €	0.00 t
	Biochar sold	271 500.00 €	181.00 t
	Total revenue from additional sales	1 636 216.00 €	
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 €	2.02 t
	CO2 emitted	0.00 €	0.00 t
	Total cost of residues	0.00 €	
	Total operational cost without investment	-298 960.90 €	
	Total operational cost with investment	-1 170 619.39 €	
	Savings with introduction of P2G	871 658.49 €	

4. CONCLUSIONS

The main results of the investigated scenarios are summarized in the table below. It can be concluded that NG prices has to increase tenfold from their 2018-2019 price levels to make methane production feasible. Otherwise, production of oxygen, hydrogen, and biochar provides healthy financial margins at the prices assumed by the OT.

Table 2 Case Studies Results

Scenario	Main Characteristics	0% Subsidy	50% Subsidy	10x NG prices
I.	Payback	5.0 years	3.0 years	7.8 years
	Investment	EUR 4.8 million	EUR 2.4 million	EUR 13.2 million
	Production Facilities	Oxygen Hydrogen Biochar	Oxygen Hydrogen Biochar	Methane Hydrogen
II.	Payback	5.0 years	3.0 years	5.9 years
	Investment	EUR 4.8 million	EUR 2.4 million	EUR 9.0 million
	Production Facilities	Oxygen Hydrogen Biochar	Oxygen Hydrogen Biochar	Oxygen Hydrogen Biochar Methane
III.	Payback	4.2 years	2.6 years	4.2 years
	Investment	EUR 4.8 million	EUR 2.4 million	EUR 4.8 million
	Production Facilities	Oxygen Hydrogen Biochar	Oxygen Hydrogen Biochar	Oxygen Hydrogen Biochar Methane

APPENDIX I OPTIMIZATION TOOL PARAMETERS

1. P2G & GF with 0% subsidy



DanuP2Gas
Optimization Tool - Bt

2. P2G & GF with 50% subsidy



DanuP2Gas
Optimization Tool - Bt

3. P2G & GF with 10x increase in NG price



DanuP2Gas
Optimization Tool - Bt

4. P2G & IP with 0% subsidy



DanuP2Gas
Optimization Tool - Bt

5. P2G & IP with 50% subsidy



DanuP2Gas
Optimization Tool - Bt

6. P2G & IP with 10x increase in NG price



DanuP2Gas
Optimization Tool - Bt

7. P2G & REP with 0% subsidy



DanuP2Gas
Optimization Tool - Bt

8. P2G & REP with 50% subsidy


DanuP2Gas
Optimization Tool - Bt

9. P2G & REP 10x increase in NG price


DanuP2Gas
Optimization Tool - Bt