Interreg
Danube Transnational Programme
DanuP-2-Gas

Output T2.2

Pre-feasibility Study (Hungary)

WP T2: Project main output

June 20, 2022

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DOCUMENT CONTROL SHEET

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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	
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V1	…	…	…	1st version

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CONTENT

Version	Date	Author	Organization	Description
v1	27.09.2021	Kiril Raytchev	BSERC	Initial version
v2	22.02.2022	Kiril Raytchev	BSERC	Reflecting Optimization tool current specification
v3	15.03.2022	Kiril Raytchev	BSERC	Replacing pay-off period analysis with gas price deviation one.

1. METHODOLOGY

The main input for the study was the results tables generated by the DanuP2G Optimilization Tool (OT). The inputs to OT were mainly the previously submitted Infrastructure report and table and the Biomass report and table. Other supplementary and explanatory information is also provided in the study, given that these may be internet sources, these sources are indicated in the relevant section.

The Optimilization Tool (OT) is ready for all 18 cases, according to the work package.

More precisely the following three cases:

- P2G hub as a green field project (Green field);
- P2G hub at an industrial plant (IP);
- P2G hub at a renewable energy plant (REP);

For each of these three cases (IP, REP, and Green field) the results include an investigation of:

- Natural gas price
    - current price
    - 5 times the current price
    - 10 time the current price
- with and without subsidies of 50%.

2. CASE STUDIES

2.1 P2G HUB AS A GREEN FIELD PROJECT (GREEN FIELD); KAPOSVÁR

The city of Kaposvár, capital of Somogy county in Southern-west Hungary is a possible location for a greenfield investment[1].

The term greenfield stands for investments implemented on fields that has been, literally, green. The word green also mean new, alluding to new construction projects. Instead of buying an existing facility, a new venture is begun by constructing new facilities. Construction projects may include more than just a facility. They also entail, rather lean on the entire public utility infrastructure.

The economy of Kaposvár has implemented tremendous development in recent years. The economic strategy of the city, the attractive environment for investors and the supportive attitude of the municipality resulted several traditional manufacturing companies expanding their production capacity, as well as industrial companies appear in the industrial parks of the city and announce new investments. Examining the transport geography of Kaposvár, its road and railway connections effectively contribute to the provision of passenger and freight traffic in the area.

Kaposvár is the dominant economic location of Somogy county and Southern Transdanubia, the production and commercial centre, the engine of development. Considering its industrial structure, two distinct lines can be observed. Food plants with a long history and strategic importance, as well as the electrical and machinery

[1] Understanding Greenfield vs. Brownfield Investments (investopedia.com)

industries investments have been made or are in the process of being made. Jobs are successful providing the city's education system with a skilled workforce as a basis for its operation task. Major achievements in this area are the soon-to-be-built Science Park, as well as the local units of notorious higher education institutions (University of Óbuda, Hungarian University of Agricultural and Life Sciences). The iFood Cluster gathers the outstanding actors of the food and agricultural industry in the region.

2.1.1 TRANSPORTATION

The regional relations of Somogy county are twofold: the northern and western edges of the county have adequate accessibility and infrastructural background, while the inner areas, mainly eastern and southern parts have more closed transport links. Kaposvár has good road access, on M7 or M6 motorways from Budapest, 48 km from the M7 motorway, on the M67 motorway from Balatonszemes. I can be reached from Dunaföldvár on the main road 61. From the centre of the region, Pécs, it can be reached on the main road 66, from Nagykanizsa and Dombóvár on the main road 61.

During the spring of 2023, the existing main road 67 bypassing Kaposfüred will be improved with a 2x2 lane road, with a design speed of 110 km / h. The planned M9 motorway between Szekszárd and Kaposvár is in the most advanced planning phase. The railway connection of the city is also ensured, on the railway line 40 (Budapest-Dombóvár-Pécs) to Dombóvár, then from there on the railway line 41 (Dombóvár – Gyékényes). Railway line 41 is after Kaposvár had 3 southern branches, however these were eliminated aggravating the situation of underdeveloped south-eastern districts.

Direct rail connections of Kaposvár:

- Line 35: Kaposvár-Siófok, 100 km, single-track, non-electrified side line
- Line 36: Kaposvár-Fonyód, 54 km, single-track, non-electrified side line
- Line 41: Dombóvár-Gyékényes, 101 km, single-track, electrified main line

As mentioned, there are several industrial zones around the city with plenty of manufacturing companies as potential users of the P2G hub in case the project was implemented as a greenfield investment near Kaposvár. Greenfield industrial investments are being implemented currently too. Industrial parks:

- Eastern Industrial Park (north and south)
- Videoton Industrial Park
- Northern Industrial Park (implemented as a greenfield project in four phases)
- Eastern side of Füredi út

2.1.2 PHYSICAL CONSTANTS

As shown in the figure below, the city is bordered by large green fields, potential locations of a P2G hub for Kaposvár[2].

[2] Kaposvár Pre-feasibility study

1. Figure: Kaposvar Industrial Parks

Source: Own editing

2.1.3 RE ACCESS

From the Eastern Industrial Park to the north, there is the largest solarplant of the country. It is a 100 megawatt solar power plant[3]. It is currently the largest solar power plant in Central Europe, four times the size of the one in Kapuvár, which was previously considered to be the largest similar facility in Hungary.

The amount of energy produced by the solar park almost meets the annual energy needs of the entire population of Kaposvár. The solar power plant was built by the

[3] Óriási napelempark készült el Kaposvár határában - Műszaki Magazin (muszaki-magazin.hu)

National Machinery Import and Export Corporation (CMC), a design company owned by China's state-owned company, China General Technology Group. Construction of the solar park began in June 2019 and was completed in 2021.

Due to such projects, the amount of solar capacity in Hungary is growing rapidly. This is confirmed by the fact that while in 2019 the total capacity of domestic solar systems was 1277 MW, by the end of 2020 this number had already reached 2000 MW. The Kaposvár solar park connected to the grid in 2021 represents an additional 5% increase at the beginning of the year compared to 2020. This is a very good starting point, as the main goal of Hungary's National Renewable Action Plan is to be able to cover 14.65% of the country's electricity needs from renewable sources by 2022.

2.1.4 POWER AND GAS GRID ACCESS

Amount and price of biomass

Biomass is available almost anywhere in the country at varying prices, but the average price is 42 EUR/tonne.

Optimization tool setup and input parameters

- Grid investment prices:
  - Electrical grid:
    - Unit cost for electrical transmission grid connection 2,55 €/kW km
    - Unit cost for electrical distribution grid connection 4,27 €/kW km
    - Capacity cost for electrical transmission grid connection 122 €/kW

- Capacity cost for electrical distribution grid connection 1,63 €/kW

- Gas grid:
  - Unit cost for gas transmission grid connection 90 €/kW km
  - Unit cost for gas distribution grid connection 67 €/kW km
  - Capacity cost for gas transmission grid connection 0,6 €/kW
  - Capacity cost for gas distribution grid connection 0,53 €/kW
- Water grid
  - Unit cost for water grid connection 4,02 €/kW km
  - Capacity cost for water grid connection 1,48 €/kW

2.2 P2G HUB AT AN INDUSTRIAL PLANT (IP) – TVK, TISZAÚJVÁROS

In Tiszaújváros the Tisza Chemical Combine Public Limited Company (TVK Plc. Or TVK) is one of the largest chemical companies in Hungary in terms of turnover. For more than four decades, TVK has been producing raw materials in competitive quality for the plastics processing industry, from which have become consumer and industrial goods an integral part of our daily lives. TVK's shares can be traded on the Budapest Stock Exchange and the over-the-counter trading system (IOB) of the London Stock Exchange.

TVK and Slovnaft a.s. in Bratislava - as part of the integrated MOL Downstream division - are the leader in the petrochemical industry in the Central European region. These two companies are among the top ten players in the polymer market in Europe in terms of joint production capacity. The production of TVK and its Slovakian partner are optimally synchronized by the MOL Group furthermore they are utilized the benefits of integrated polymer sales within the MOL Group.

PRIORITY OBJECTIVES

- Safe operation of plants
- Continuous increase of efficiency
- Implementation of strategic development projects
- Maintain strict control of costs and investments
- Strengthening integrated operations in the Downstream division of MOL Group.

2. Figure:TVK, Tiszaújváros

Source: Debrecen hírei, debreceni hírek | Debrecen és Hajdú-Bihar megye hírei - Dehir.hu

Main activity:

It primarily serves European plastics processing companies with competitive, high-quality polymer products. In addition to main profile, it also sells olefins and other chemical feedstocks to the region's chemical and oil refining industries, including MOL.

The main products of the olefin plants are ethylene and propylene, which are processed into polyethylene and polypropylene in polymer plants. Some of the ethylene produced in the olefin plants is sold to BorsodChem Zrt. under a long-term contract.

TVK is committed to sustainable development. Its environmental performance:

- The waste collection and storage method developed through the implementation of the Central Waste Yard is to the satisfaction of both our business units and our contracted partners. There were no comments or complaints from the public.
- By increasing energy efficiency, reducing specific carbon dioxide emissions, implementing leading technological improvements, optimising energy supply and production, and optimising the availability of demand and service assets, we have achieved specific emissions of 0.989 tonnes CO2/t HVC at the level of the TEC.
- In the course of uniform environmental licensing procedures, permit documentation for review documentation has been compiled and submitted to the EMI-CERC.

The plant is currently expanding, looking for opportunities. MOL Petrolkémia Zrt. and McDermott International Inc. have signed an agreement for basic design, technology license, catalyst and Front End Engineering Design (FEED) for olefin conversion technology (OCT) investment, which will be part of MOL's petrochemical complex in Tiszaújváros, in Hungary. From refinery and olefin plant feedstocks, the new plant will produce a polymer feedstock, propylene, with a capacity of 100,000 tons / year, using the OCT and CDHydro Isobutene Removal process owned by Lummus. The plant will also produce an isobutene-rich fraction.

2.2.1 TRANSPORTATION

It is a settlement located 35 km from Miskolc, at the mouth of the Sajó Tisza; It is located right next to the main road 35 from Nyékládháza to Debrecen, and is connected to Mezőcsát by the 3313 road. A small part of its administrative area is

located on the other side of the Tisza, on the left bank, but that part of the area can be considered uninhabited.

Rail connections of Tiszaújváros:

Line 89: Tiszaújváros–Nyékládháza

Road connections of Tiszaújváros:

Line 35, near Miskolc

Water connections of Tiszaújváros:

through the Tisza River (2nd largest river in Hungary)

2.2.2 AMOUNT AND PRICE OF BIOMASS

Tisza BioTerm Kft., owned by Sinergy Kft. The project was implemented with the support of the European Union and the New Széchenyi Plan for HUF 65 million in 2013.

Biomass is available almost anywhere in the country at varying prices, but the average price is 42 EUR/tonne.

2.2.3 RE ACCESS

The number of sunny hours suitable for energy production in the region of Northern Hungary is 1100-1200 moves around. World market prices for solar panels have fallen sharply in recent years, as a result the interest of domestic investors in solar parks and solar power plants (PV) has increased significantly. In the last few years, a more or less powerful solar power plant has been built in many settlements of the country. In Borsod-Abaúj-Zemplén county, several solar power plant investment projects are under implementation, these are the solar power plant project in Felsőzsolca, which

is being implemented in the investment of MVM Zrt. one of the most powerful PV parks in Hungary.

In the case of Tiszaújváros as well, the implementation of a solar power plant investment with a capacity of at least 6 MW was justified, which allows approx. 4,000 MWh of electricity generation and approx. 3 200 t CO2 emission reductions are achievable. In selecting the location of the investment, it had to be taken into account that: approximately 7-8 hectares of solar power is required in this power range. Since the in the vast majority of solar power plants, it is advisable to connect to the 20 kV network. to install the power plant near a pipeline or substation. Also, it was an important consideration to do so, if possible, the power plant should be located in a brownfield area (eg in an abandoned industrial area). MOL has launched a 3 MW solar power plant on the site of MOL Petrolkémia Zrt. (Formerly TVK) which was already operational at the end of 2018.[4]

China-based Unisun Energy Group has built an 11.6-megawatt solar power plant in Tiszaszőlős. According to their plans, the capacity of the solar power plant installed in the settlement near Lake Tisza can be expanded to at least 50 MW later in several phases. In total, the Chinese company is involved in more than 1 GW of photovoltaic projects worldwide.

2.2.4 POWER AND GAS GRID ACCESS

Tisza II is a thermal power plant in Tiszaújváros. It consists of 4 units of 215 MW (power plant unit) with a total nominal capacity of 860 MW. It has hydrocarbon-fired boilers: the thermal power plant fires natural gas and heating oil, and even in 1982 it was

[4] Tiszaújváros Sustainable Energy And Climate Action Plan (SECAP)

made suitable for firing high-inert natural gas. The power plant covers an area of more than 130 hectares, has its own water extraction and water treatment plant, an oil storage facility with a capacity of more than 80,000 tons, and its own internal industrial track.

3. *Figure: Utilities in the area*

Source[5]: https://ekozmu.e-epites.hu/alkalmazas/lakossag/menu/terkep/tajekoztatas/kozmuterkep

Financial data from the TVK:

- Total fixed assets 140.862 million forints
- All current assets 75.362 million forints

Operational prices and parameters

[5] yellow = hydrocarbons, pink = district heating, red = electricity, blue = water supply, brown = drainage

- Total operating income 401.695 million forints
- Total operating expenses 364.766 million forints

Investment prices

- All sources 216.224 million forints

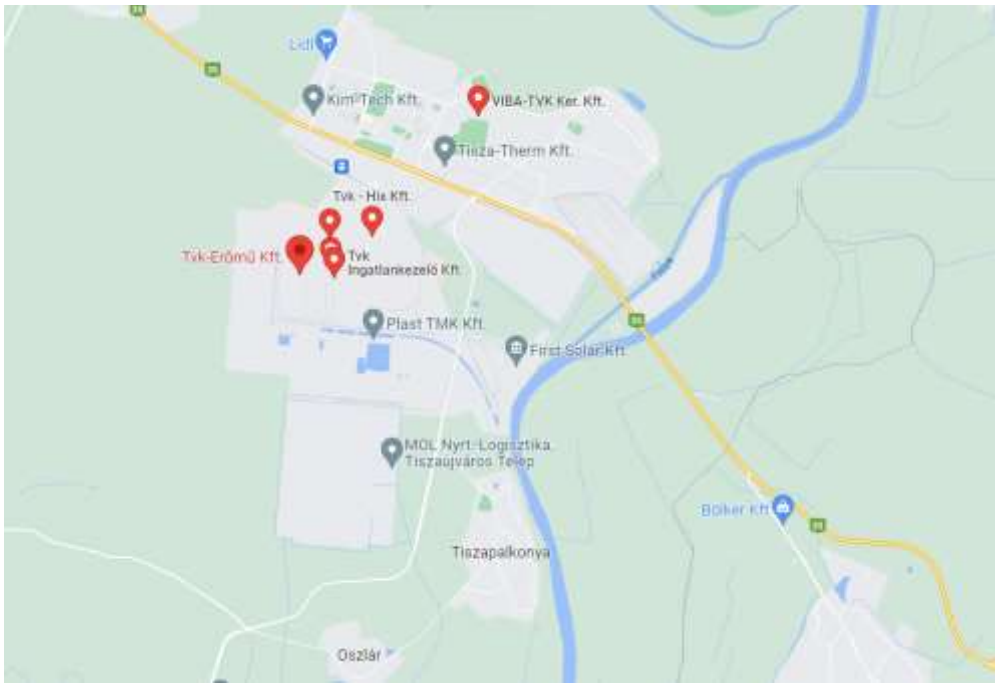
2.2.5 PHYSICAL CONSTANTS

The registered office of the Company is Tiszaújváros (H-3581 Tiszaújváros, TVK-Ipartelep, TVK Central Office Building, building 2119/3)

Tiszaújváros is an industrial city in northern Hungary, in Borsod-Abaúj-Zemplén county. The center of the Tiszaújváros district. It is the fifth most populated town in the county after the county seat. Tiszaújváros has a favorable geographical location. The area is a plain and terraced river valley according to its topography. The city is located in northern Hungary on the eastern edge of the Bükk region, in the area enclosed by the Sajó estuary, the second largest river in Hungary, the largest river in the counties of Tisza and Borsod-Abaúj-Zemplén. Its area of 46.04 km². Tiszaújváros plays a connecting role between three big cities, Miskolc, Debrecen and Nyíregyháza. The establishment of the industrial base began in 1953 with the construction of a 200 MW coal-fired thermal power plant on the border of Tiszapalkonya. With the services of the thermal power plant, electricity and industrial steam, it established the existence of large industrial plants to be built later (eg Tiszai Vegyi Kombinát, Tiszai Refinery, Olefin Factory, Tisza II Thermal Power Plant). The first operating unit of the Tisza Chemical Plant, the gas plant, was put into operation in 1959, the paint factory started operating in 1961 and the fertilizer factory in 1964. The olefin program has given new impetus to the development of the industry. Petrochemical activity began in 1970 with the commissioning of the first polyethylene plant. The major

investment of the Tisza Power Plant, the construction of the Tisza Thermal Power Plant, began in 1971, and was originally planned to be the largest power plant in the country at 2,000 MW, but was built at only 860 MW due to the 1973 oil crisis, making it the third largest power plant in Hungary. It was handed over on September 7, 1979. Construction of the Tisza Petroleum Company (TIFO) began in 1973, and oil refining began in November 1980. In addition to the three factory complexes, the municipality of Tiszaújváros established the 140-hectare Tiszaújváros Industrial Park with a greenfield investment in 1997. The industrial park with full infrastructure has created favourable conditions for industrial and commercial companies. The settled businesses employ more than 10,000 people in the industrial park.

The closing headcount of the TVK Group employees on 31 December 2014 was 981.



4. Figure: Tiszaújváros map

Source: google.com/maps

2.3 REP – PV LOCATION CHARACTERISTICS (P2G HUB AT A RENEWABLE ENERGY PLANT (REP)

In the case of renewable resources, we have a wide range of options to choose from, given that increasing and integrating solar power generation into the grid is one of the most important goals and challenges for the Hungarian energy system in the coming decades, so the calculations were run with solar PV.

Considering that in the next decades solar resources will be available in almost all parts of the country with similar conditions, not a specific location was chosen, but a general hypothetical investment location, which could be located near any solar park in the country.

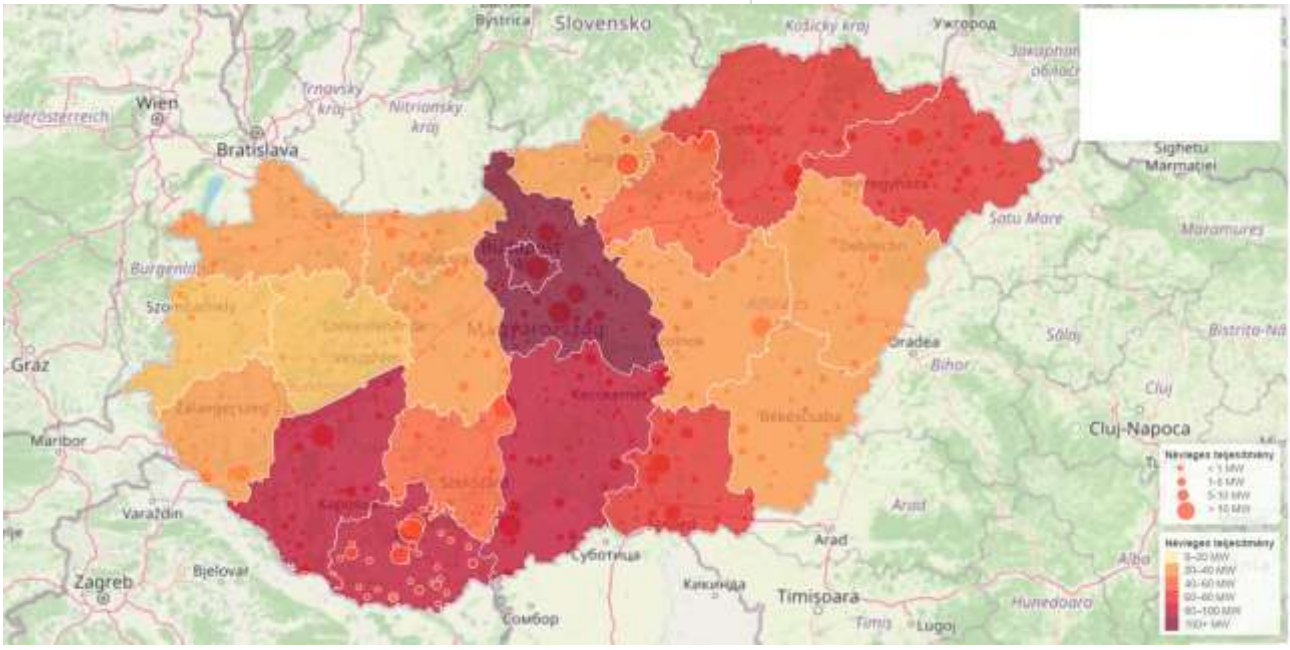
5. Figure: The biggest solar park (100 MW) in Kaposvar, Hungary

Source: Elkészült Kaposvár giganapelemparkja, februártól indul a termelés | Kaposvár Most.hu (kaposvarmost.hu)

2.3.1 CHARACTERISTICS OF THE SETUP

Availability and cost of resources:

The availability of solar power plants in many areas of the country, even on a larger scale, means that entry costs can be almost identical in this respect, so other factors may be the main determinant for the choice of a site.



6. Figure: Solar field map of Hungary (nominal power)

Source: [SolarMap - Interaktív térkép]

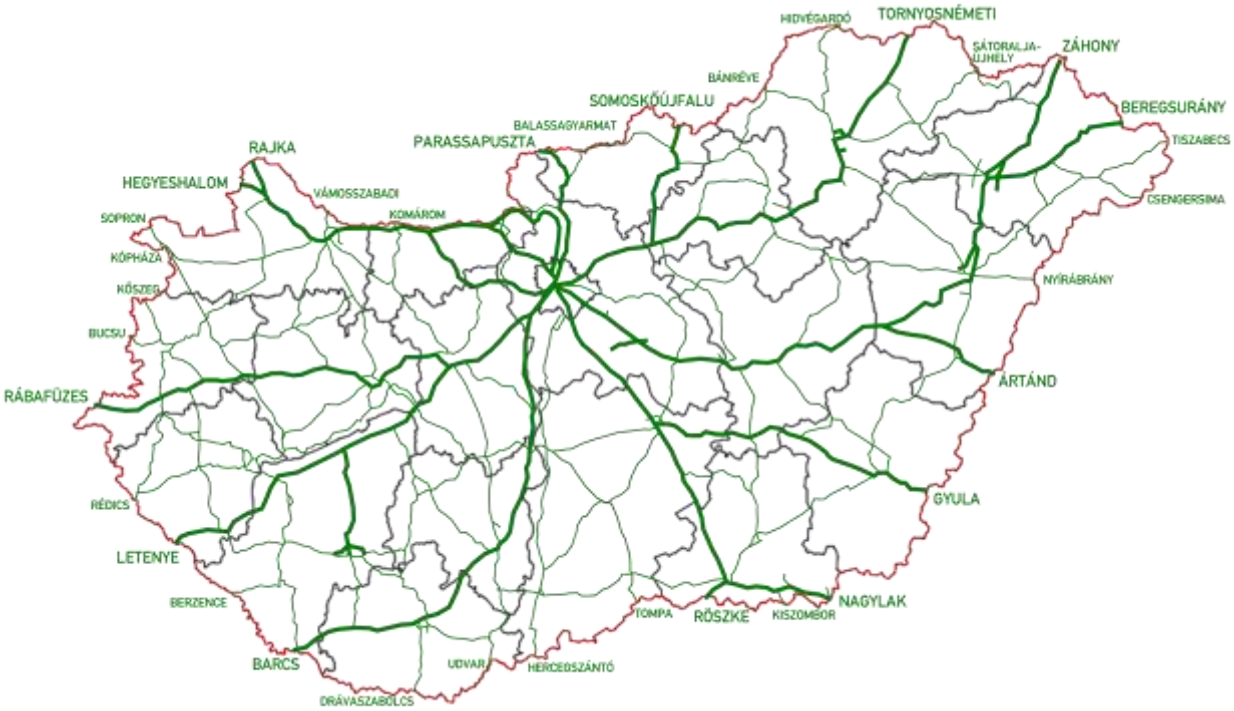
Transportation:

Given that a location with no general precise location was chosen for the analysis, it can be said that rail transport in Hungary has a network with a high density and good accessibility along the main lines.

7. Figure: Main lines of the Hungarian railway network

Source: Térképek | MÁV-csoport (mavcsoport.hu)

In terms of road accessibility, the Hungarian road network is as dense as the rail network, the quality of the network along the main routes has improved a lot in recent years, while the most recent years have seen the most extensive upgrading or major renewal works on the secondary lines, which will be typical in the decade to 2020.



8. Figure: Main routes of the road network in Hungary

Source: [Magyarország főútjai – Wikipédia (wikipedia.org)]

Amount and price of biomass:

Biomass is available almost anywhere in the country at varying prices, but the average price is 42 EUR/tonne.

RE access:

Given that no specific location has been chosen, access to renewable energy sources is flexible and can be adapted to the site.

Power and gas grid access:

The average distance between connection points in the country is 12 km for electricity and 10 km for gas.

Optimization tool setup and input parameters

- Grid investment prices:
  - Electrical grid:
    - Unit cost for electrical transmission grid connection 2,55 €/kW km
    - Unit cost for electrical distribution grid connection 4,27 €/kW km
    - Capacity cost for electrical transmission grid connection 122 €/kW
    - Capacity cost for electrical distribution grid connection 1,63 €/kW
  - Gas grid:
    - Unit cost for gas transmission grid connection 90 €/kW km
    - Unit cost for gas distribution grid connection 67 €/kW km
    - Capacity cost for gas transmission grid connection 0,6 €/kW
    - Capacity cost for gas distribution grid connection 0,53 €/kW
  - Water grid
    - Unit cost for water grid connection 4,02 €/kW km
    - Capacity cost for water grid connection 1,48 €/kW

2.3.2 STATUS QUO OF SOLAR POWER GENERATION IN HUNGARY

After the extremes of March, electricity prices in April were €80-100/MWh lower on the day-ahead markets, with prices fluctuating between €200-250 on the domestic exchange. The price moderation was due to a correction in gas prices and higher

renewable generation, according to the April electricity market report of the Hungarian Energy and Utilities Regulatory Office.[6]

In April 2022, aggregate consumption in the five largest European markets was 2% lower than in the same period of the previous year. Consumption in the Central European region fell by more than this, by 3.2%.

Renewable generation has been growing dynamically, reaching a daily maximum of 1806 MW on 13 April, an absolute record, far exceeding the 1407 MW recorded in August last year.

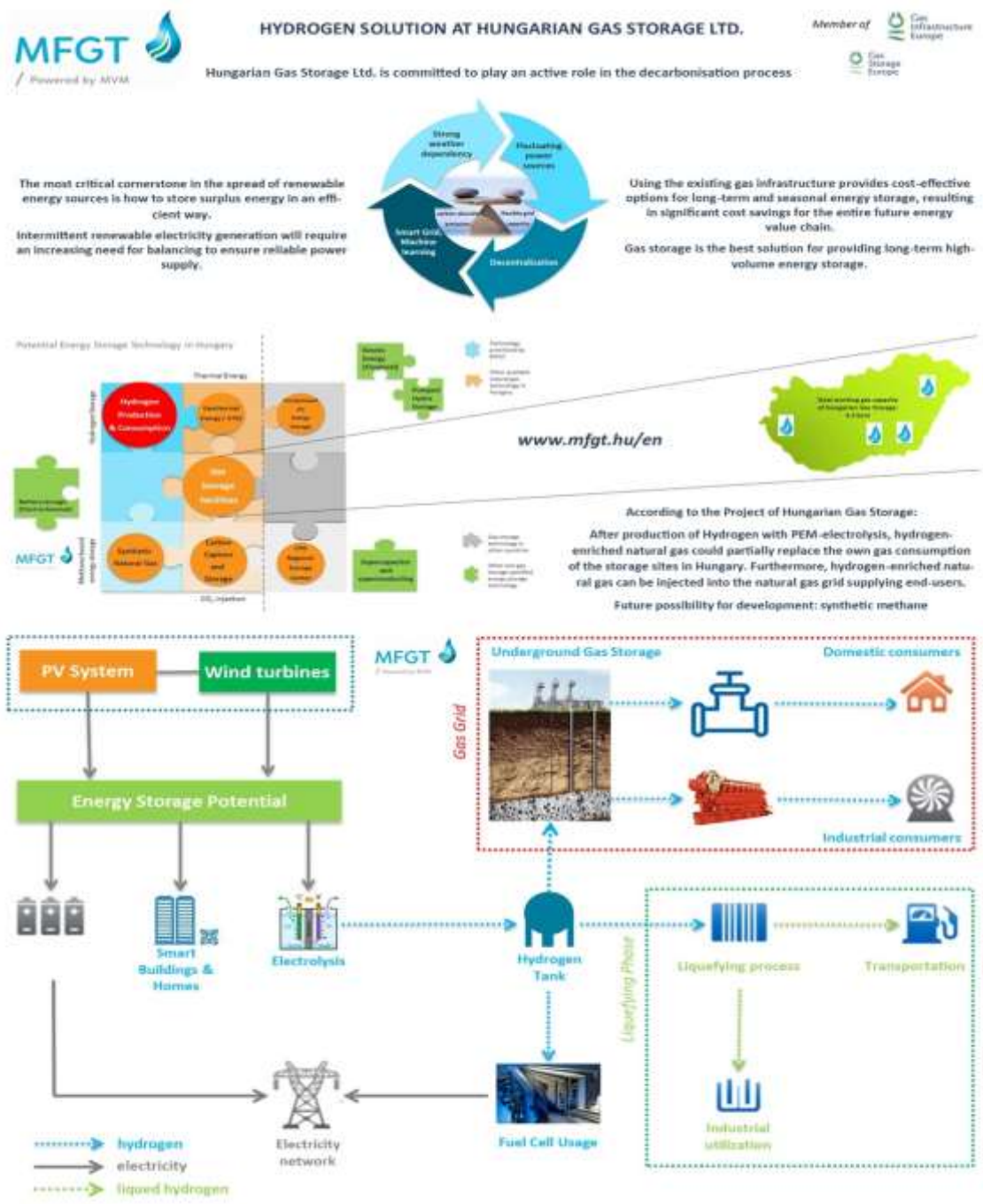
2.4 EXISTING P2G PILOT PROJECT IN HUNGARY

There is also a very significant Power-2-Gas related pilot project currently running in Hungary, the Akvamarin project.

In February 2021, Hungarian Natural Gas Storage Ltd. launched its innovative R&D pilot project, Akvamarin, which will establish a hydrogen production and blending technology at its underground gas storage facility in Kardoskút. The project is a response to the European Union's European Green Deal and aims to sell to consumers and replace the use of own gas. FGSZ Natural Gas Transmission Ltd. is a joint venture of MFGT Zrt.

FGSZ is pleased to be associated with the testing of the transmissibility of the hydrogen gas produced by the project in the transmission system, based on its knowledge, extensive technological background and legal knowledge, as part of a cooperation agreement. The project is expected to be completed by early 2023[7].

[6] www.mekh.hu/csucsot-dontott-a-hazai-naperomuvi-termeles-aprilisban
[7] Akvamarin projekt alapkőletétel (mfgt.hu)



9. Figure: Schematic diagram of the project

Source: Akvamarin (mfgt.hu)

3. RESULTS

3.1 GREEN FIELD

From Figure 4 to Figure 9, we can see cases where a P2G hub could be developed as a greenfield investment, but the calculation shows that such an investment cannot be economically feasible in Hungary, even with 50% subsidy and 10x gas price increase.

3.1.1 RESULTS WITH SUBSIDIES

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		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
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	0,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**0,00**	**€**		
	Total operational cost with investment	**0,00**	**€**		
	Savings with introduction of P2G	**0,00**	**€**		

10. Figure: Results for GF with real gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		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
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	0,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**0,00**	**€**		
	Total operational cost with investment	**0,00**	**€**		
	Savings with introduction of P2G	**0,00**	**€**		

11. Figure: Results for GF with moderate gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		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
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	0,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**0,00**	**€**		
	Total operational cost with investment	**0,00**	**€**		
	Savings with introduction of P2G	**0,00**	**€**		

12. Figure: Results for GF with high gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

3.1.2 RESULTS WITHOUT SUBSIDIES

Investment specifications

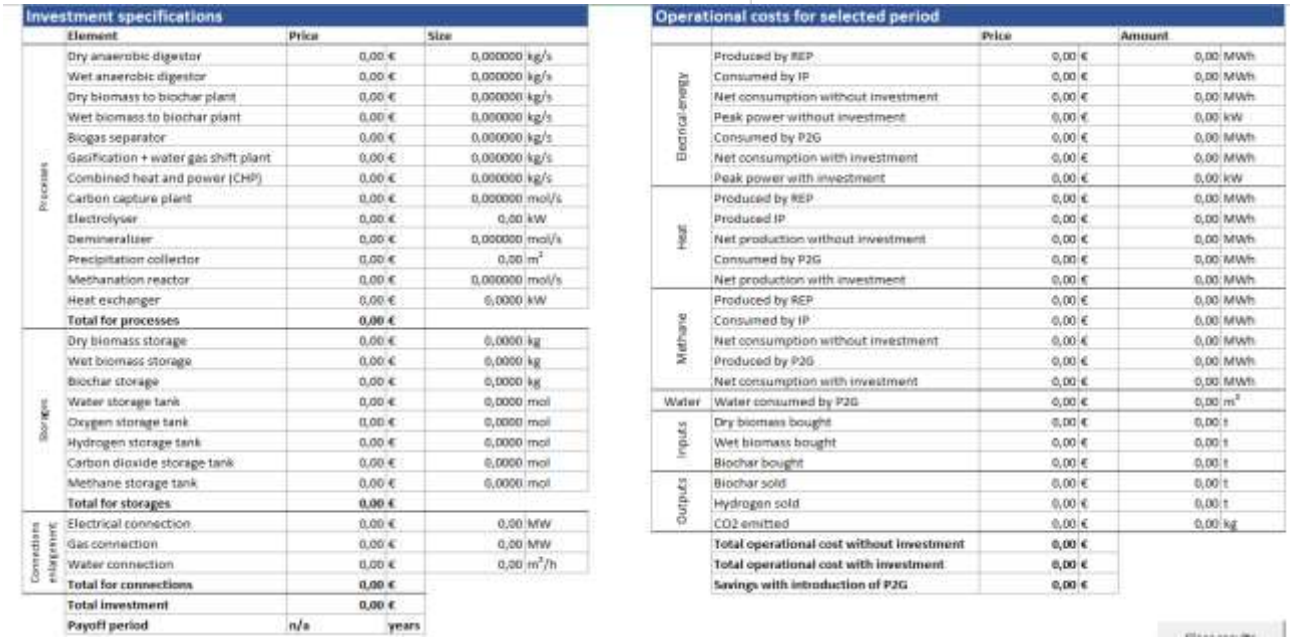
	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	0,00	€	0,000000	kg/s
	Dry biomass to biochar plant	0,00	€	0,000000	kg/s
	Wet biomass to biochar plant	0,00	€	0,000000	kg/s
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	0,00	€	0,000000	mol/s
	Electrolyser	0,00	€	0,00	kW
	Demineraliser	0,00	€	0,000000	mol/s
	Precipitation collector	0,00	€	0,00	m^3
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	Total for storages	**0,00**	**€**		
Connection 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

		Price		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
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	0,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**0,00**	**€**		
	Total operational cost with investment	**0,00**	**€**		
	Savings with introduction of P2G	**0,00**	**€**		

13. Figure: Results for GF with real gas prices of methane and no subsidy

Source: Optimilization Tool v1.1



Investment specifications

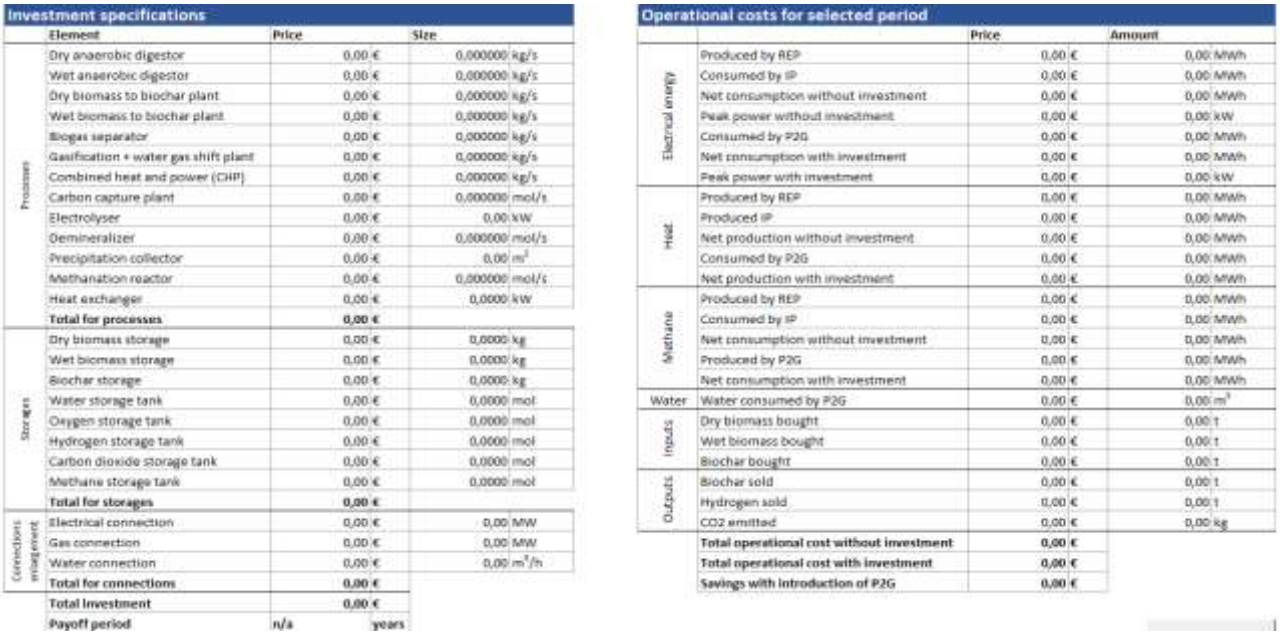
	Element	Price	Size
Processes	Dry anaerobic digestor	0,00 €	0,000000 kg/s
	Wet anaerobic digestor	0,00 €	0,000000 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Biogas separator	0,00 €	0,000000 kg/s
	Gasification + water gas shift plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,000000 kg/s
	Carbon capture plant	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
	Methanation reactor	0,00 €	0,000000 mol/s
	Heat exchanger	0,00 €	0,0000 kW
	Total for processes	**0,00 €**	
Storages	Dry biomass storage	0,00 €	0,0000 kg
	Wet biomass storage	0,00 €	0,0000 kg
	Biochar storage	0,00 €	0,0000 kg
	Water storage tank	0,00 €	0,0000 mol
	Oxygen storage tank	0,00 €	0,0000 mol
	Hydrogen storage tank	0,00 €	0,0000 mol
	Carbon dioxide storage tank	0,00 €	0,0000 mol
	Methane storage tank	0,00 €	0,0000 mol
	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

		Price	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
	Peak power without investment	0,00 €	0,00 kW
	Consumed by P2G	0,00 €	0,00 MWh
	Net consumption with investment	0,00 €	0,00 MWh
	Peak power with investment	0,00 €	0,00 kW
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
Methane	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 consumed by P2G	0,00 €	0,00 m^3
Inputs	Dry biomass bought	0,00 €	0,00 t
	Wet biomass bought	0,00 €	0,00 t
	Biochar bought	0,00 €	0,00 t
Outputs	Biochar sold	0,00 €	0,00 t
	Hydrogen sold	0,00 €	0,00 t
	CO2 emitted	0,00 €	0,00 kg
	Total operational cost without investment	**0,00 €**	
	Total operational cost with investment	**0,00 €**	
	Savings with introduction of P2G	**0,00 €**	

14. Figure: Results for GF with moderate gas prices of methane and no subsidy

Source: Optimilization Tool v1.1



Investment specifications

	Element	Price	Size
Processes	Dry anaerobic digestor	0,00 €	0,000000 kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00 €	0,000000 kg/s
	Gasification + water gas shift plant	0,00 €	0,000000 kg/s
	Combined heat and power (CHP)	0,00 €	0,000000 kg/s
	Carbon capture plant	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
	Methanation reactor	0,00 €	0,000000 mol/s
	Heat exchanger	0,00 €	0,0000 kW
	Total for processes	**0,00 €**	
Storages	Dry biomass storage	0,00 €	0,0000 kg
	Wet biomass storage	0,00 €	0,0000 kg
	Biochar storage	0,00 €	0,0000 kg
	Water storage tank	0,00 €	0,0000 mol
	Oxygen storage tank	0,00 €	0,0000 mol
	Hydrogen storage tank	0,00 €	0,0000 mol
	Carbon dioxide storage tank	0,00 €	0,0000 mol
	Methane storage tank	0,00 €	0,0000 mol
	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

		Price	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
	Peak power without investment	0,00 €	0,00 kW
	Consumed by P2G	0,00 €	0,00 MWh
	Net consumption with investment	0,00 €	0,00 MWh
	Peak power with investment	0,00 €	0,00 kW
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
Methane	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 consumed by P2G	0,00 €	0,00 m^3
Inputs	Dry biomass bought	0,00 €	0,00 t
	Wet biomass bought	0,00 €	0,00 t
	Biochar bought	0,00 €	0,00 t
Outputs	Biochar sold	0,00 €	0,00 t
	Hydrogen sold	0,00 €	0,00 t
	CO2 emitted	0,00 €	0,00 kg
	Total operational cost without investment	**0,00 €**	
	Total operational cost with investment	**0,00 €**	
	Savings with introduction of P2G	**0,00 €**	

15. Figure: Results for GF with high gas prices of methane and no subsidy

Source: Optimilization Tool v1.1

3.2 IP

The case study of industrial installations produced varying results based on the OT calculations, which are presented below.

3.2.1 RESULTS WITH SUBSIDIES

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	0,00	€	0,000000	mol/s
	Electrolyser	0,00	€	0,00	kW
	Demineraliser	0,00	€	0,000000	mol/s
	Precipitation collector	0,00	€	0,00	m^3
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		Amount	
Electrical energy	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	198 000 000,00	€	600 000,00	MWh
	Net consumption without investment	198 000 000,00	€	600 000,00	MWh
	Peak power without investment	438 394,89	€	1 043 797,37	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	198 000 000,00	€	600 000,00	MWh
	Peak power with investment	438 394,89	€	1 043 797,37	kW
Heat	Produced by REP	0,00	€	0,00	MWh
	Produced IP	0,00	€	678 000,00	MWh
	Net production without investment	0,00	€	678 000,00	MWh
	Consumed by P2G	0,00	€	0,00	MWh
	Net production with investment	0,00	€	678 000,00	MWh
Methane	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	140 364 924,00	€	379 000,00	MWh
	Net consumption without investment	140 364 924,00	€	379 000,00	MWh
	Produced by P2G	0,00	€	0,00	MWh
	Net consumption with investment	140 364 924,00	€	379 000,00	MWh
Water	Water consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**338 803 318,89**	**€**		
	Total operational cost with investment	**338 803 318,89**	**€**		
	Savings with introduction of P2G	**0,00**	**€**		

16. Figure: Results for IP with normal gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

In the first case, the calculation in the Optimilization Tool did not show a significant change, assuming normal gas prices and 50% subsidy. In that case, as it is shown in Fig. 16, investment payoff period of 20 years is not enough for any investment in P2G hub.

Investment specifications

	Element	Price	Size
Processes	Dry anaerobic digestor	81 633 371,39 €	7,774607 kg/s
	Wet anaerobic digestor	1 860 867,17 €	0,389067 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Biogas separator	62 100 995,69 €	7,305999 kg/s
	Gasification + water gas shift plant	281 762,91 €	0,563526 kg/s
	Combined heat and power (CHP)	0,00 €	0,000000 kg/s
	Carbon capture plant	0,00 €	0,000000 mol/s
	Electrolyser	180 005 955,47 €	144 004,76 kW
	Demineralizer	4 748 231,80 €	499,813874 mol/s
	Precipitation collector	1 000,00 €	1 000,00 m^2
	Methanation reactor	19 236 830,30 €	118,380494 mol/s
	Heat exchanger	1 419 229,50 €	28 384,5899 kW
	Total for processes	**353 288 044,22 €**	
Storages	Dry biomass storage	0,00 €	0,0000 kg
	Wet biomass storage	0,00 €	0,0000 kg
	Biochar storage	0,00 €	0,0000 kg
	Water storage tank	0,00 €	0,0000 mol
	Oxygen storage tank	0,00 €	0,0000 mol
	Hydrogen storage tank	0,00 €	0,0000 mol
	Carbon dioxide storage tank	0,00 €	0,0000 mol
	Methane storage tank	0,00 €	0,0000 mol
	Total for storages	**0,00 €**	
Connections enlargement	Electrical connection	185 468,30 €	227,57 MW
	Gas connection	0,00 €	0,00 MW
	Water connection	677,00 €	32,49 m^3/h
	Total for connections	**186 145,30 €**	
	Total investment	**353 474 189,51 €**	
	Payoff period	**20,00 years**	

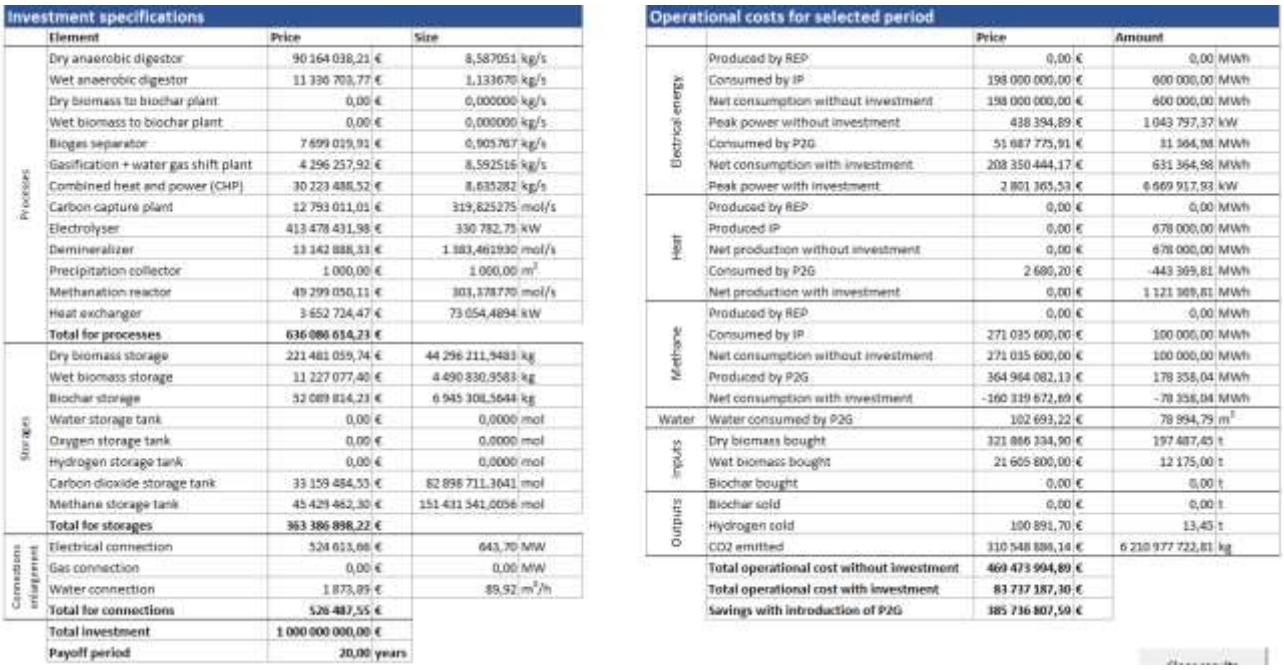
Operational costs for selected period

		Price	Amount
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	198 000 000,00 €	600 000,00 MWh
	Net consumption without investment	198 000 000,00 €	600 000,00 MWh
	Peak power without investment	438 394,89 €	1 043 797,37 kW
	Consumed by P2G	695 482 967,14 €	2 107 524,14 MWh
	Net consumption with investment	893 482 967,14 €	2 707 524,14 MWh
	Peak power with investment	1 650 943,04 €	3 930 816,76 kW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	678 000,00 MWh
	Net production without investment	0,00 €	678 000,00 MWh
	Consumed by P2G	0,00 €	-227 253,95 MWh
	Net production with investment	0,00 €	905 253,95 MWh
Methane	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	534 524 924,00 €	379 000,00 MWh
	Net consumption without investment	534 524 924,00 €	379 000,00 MWh
	Produced by P2G	1 969 618 262,11 €	1 926 047,13 MWh
	Net consumption with investment	-1 582 044 506,20 €	-1 547 047,13 MWh
Water	Water consumed by P2G	303 337,88 €	284 106,06 m^3
Inputs	Dry biomass bought	399 595 960,00 €	245 180,00 t
	Wet biomass bought	21 605 800,00 €	12 175,00 t
	Biochar bought	0,00 €	0,00 t
Outputs	Biochar sold	0,00 €	0,00 t
	Hydrogen sold	0,00 €	0,00 t
	CO2 emitted	0,00 €	0,00 kg
	Total operational cost without investment	**712 961 318,89 €**	
	Total operational cost with investment	**-265 339 498,14 €**	
	Savings with introduction of P2G	**908 302 817,03 €**	

17. Figure: Results for IP with moderate gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

In the next case, a P2G hub investment can be made based on the calculation. The result shows that a large economic saving can be achieved by setting up a P2G hub if gas prices increase by a factor of five.



Investment specifications

	Element	Price	Size
Processes	Dry anaerobic digestor	90 164 038,21 €	8,587051 kg/s
	Wet anaerobic digestor	11 330 703,77 €	1,133670 kg/s
	Dry biomass to biochar plant	0,00 €	0,000000 kg/s
	Wet biomass to biochar plant	0,00 €	0,000000 kg/s
	Biogas separator	7 699 019,91 €	0,905767 kg/s
	Gasification + water gas shift plant	4 296 257,92 €	8,592516 kg/s
	Combined heat and power (CHP)	30 223 488,52 €	8,635282 kg/s
	Carbon capture plant	12 793 011,01 €	319,825275 mol/s
	Electrolyser	413 478 431,98 €	330 782,75 kW
	Demineralizer	13 142 888,33 €	1 183,461930 mol/s
	Precipitation collector	1 000,00 €	1 000,00 m^3
	Methanation reactor	49 299 050,11 €	303,378770 mol/s
	Heat exchanger	3 652 724,47 €	73 054,4894 kW
	Total for processes	**636 086 614,23 €**	
Storages	Dry biomass storage	221 481 059,74 €	44 296 211,9481 kg
	Wet biomass storage	11 227 077,40 €	4 490 830,9583 kg
	Biochar storage	52 089 814,23 €	6 945 308,5644 kg
	Water storage tank	0,00 €	0,0000 mol
	Oxygen storage tank	0,00 €	0,0000 mol
	Hydrogen storage tank	0,00 €	0,0000 mol
	Carbon dioxide storage tank	33 159 484,53 €	82 898 711,3641 mol
	Methane storage tank	45 429 462,30 €	151 431 541,0056 mol
	Total for storages	**363 386 898,22 €**	
Connections enlargement	Electrical connection	524 613,66 €	643,70 MW
	Gas connection	0,00 €	0,00 MW
	Water connection	1 873,89 €	89,92 m^3/h
	Total for connections	**526 487,55 €**	
	Total investment	**1 000 000 000,00 €**	
	Payoff period	**20,00 years**	

Operational costs for selected period

		Price	Amount
Electrical energy	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	198 000 000,00 €	600 000,00 MWh
	Net consumption without investment	198 000 000,00 €	600 000,00 MWh
	Peak power without investment	438 394,89 €	1 043 797,37 kW
	Consumed by P2G	51 687 775,91 €	31 364,98 MWh
	Net consumption with investment	208 350 444,17 €	631 364,98 MWh
	Peak power with investment	2 801 365,53 €	6 669 917,93 kW
Heat	Produced by REP	0,00 €	0,00 MWh
	Produced IP	0,00 €	678 000,00 MWh
	Net production without investment	0,00 €	678 000,00 MWh
	Consumed by P2G	2 680,20 €	-443 369,81 MWh
	Net production with investment	0,00 €	1 121 369,81 MWh
Methane	Produced by REP	0,00 €	0,00 MWh
	Consumed by IP	271 035 600,00 €	100 000,00 MWh
	Net consumption without investment	271 035 600,00 €	100 000,00 MWh
	Produced by P2G	364 964 082,13 €	178 358,04 MWh
	Net consumption with investment	-160 339 672,69 €	-78 358,04 MWh
Water	Water consumed by P2G	102 693,22 €	78 994,79 m^3
Inputs	Dry biomass bought	321 886 334,90 €	197 487,45 t
	Wet biomass bought	21 605 800,00 €	12 175,00 t
	Biochar bought	0,00 €	0,00 t
Outputs	Biochar sold	0,00 €	0,00 t
	Hydrogen sold	100 891,70 €	13,45 t
	CO2 emitted	310 548 886,14 €	6 210 977 722,81 kg
	Total operational cost without investment	**469 473 904,89 €**	
	Total operational cost with investment	**83 737 187,30 €**	
	Savings with introduction of P2G	**385 736 807,59 €**	

18. Figure: Results for IP with high gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

If we increase the price of natural gas by a factor of ten in the parameters of the calculation, even the pre-production of hydrogen becomes an economically viable option. The investment costs of the resulting plant are lower than those of the previous calculation.

3.2.2 RESULTS WITHOUT SUBSIDIES

Investment specifications

	Element	Price	Size	
Processes	Dry anaerobic digestor	155 062 764,15 €	7,383941	kg/s
	Wet anaerobic digestor	31 360 493,19 €	1,568025	kg/s
	Dry biomass to biochar plant	0,00 €	0,000000	kg/s
	Wet biomass to biochar plant	0,00 €	0,000000	kg/s
	Biogas separator	36 088 425,10 €	2,122849	kg/s
	Gasification + water gas shift plant	1 325 876,40 €	1,325876	kg/s
	Combined heat and power (CHP)	55 299 787,34 €	7,899967	kg/s
	Carbon capture plant	0,00 €	0,000000	mol/s
	Electrolyser	107 836 578,82 €	43 134,63	kW
	Demineralizer	3 255 780,01 €	171,356843	mol/s
	Precipitation collector	2 000,00 €	1 000,00	m³
	Methanation reactor	12 562 136,19 €	38,652727	mol/s
	Heat exchanger	6 883 371,88 €	66 833,7188	kW
	Total for processes	**409 477 193,08 €**		
Storages	Dry biomass storage	290 189 812,36 €	29 018 981,2361	kg
	Wet biomass storage	14 576 932,50 €	2 915 386,4998	kg
	Biochar storage	26 440 796,06 €	1 762 719,7371	kg
	Water storage tank	0,00 €	0,0000	mol
	Oxygen storage tank	0,00 €	0,0000	mol
	Hydrogen storage tank	0,00 €	0,0000	mol
	Carbon dioxide storage tank	0,00 €	0,0000	mol
	Methane storage tank	29 205 717,59 €	48 676 195,9803	mol
	Total for storages	**360 413 258,50 €**		
Connections integrement	Electrical connection	231 165,96 €	141,82	MW
	Gas connection	0,00 €	0,00	MW
	Water connection	464,20 €	11,14	m³/h
	Total for connections	**231 630,16 €**		
	Total investment	**770 122 081,75 €**		
	Payoff period	**20,00 years**		

Operational costs for selected period

		Price		Amount	
Electrical energy	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	198 000 000,00	€	600 000,00	MWh
	Net consumption without investment	198 000 000,00	€	600 000,00	MWh
	Peak power without investment	438 394,89	€	1 043 797,37	kW
	Consumed by P2G	14 664 471,91	€	19 211,92	MWh
	Net consumption with investment	204 339 933,02	€	619 211,92	MWh
	Peak power with investment	814 631,21	€	1 939 598,11	kW
Heat	Produced by REP	0,00	€	0,00	MWh
	Produced IP	0,00	€	678 000,00	MWh
	Net production without investment	0,00	€	678 000,00	MWh
	Consumed by P2G	0,00	€	-95 082,07	MWh
	Net production with investment	0,00	€	773 082,07	MWh
Methane	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	37 035 600,00	€	100 000,00	MWh
	Net consumption without investment	37 035 600,00	€	100 000,00	MWh
	Produced by P2G	17 581 695,61	€	86 301,37	MWh
	Net consumption with investment	5 073 369,86	€	13 698,63	MWh
Water	Water consumed by P2G	23 531,78	€	18 101,37	m³
Inputs	Dry biomass bought	67 469 077,46	€	41 537,92	t
	Wet biomass bought	20 870 052,71	€	11 836,57	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	97 500,00	€	13,00	t
	CO2 emitted	68 255 712,83	€	1 365 114 256,60	kg
	Total operational cost without investment	**235 473 994,89**	**€**		
	Total operational cost with investment	**230 237 383,21**	**€**		
	Savings with introduction of P2G	**5 236 611,69**	**€**		

19. Figure: Results for IP with normal gas prices of methane and no subsidy

Source: Optimilization Tool v1.1

For the cases without aid, the first calculation was run with a normal gas price, for which the above result was obtained. The result shows that the first version of the unsubsidised cases already includes the production of hydrogen within the resulting P2G hub.

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	174 431 496,58	€	8,308262	kg/s
	Wet anaerobic digestor	10 498 085,46	€	0,524904	kg/s
	Dry biomass to biochar plant	0,00	€	0,000000	kg/s
	Wet biomass to biochar plant	0,00	€	0,000000	kg/s
	Biogas separator	9 266 894,85	€	0,545111	kg/s
	Gasification + water gas shift plant	64 234,22	€	0,064234	kg/s
	Combined heat and power (CHP)	55 268 912,90	€	7,895559	kg/s
	Carbon capture plant	0,00	€	0,000000	mol/s
	Electrolyser	26 866 171,71	€	10 746,47	kW
	Demmeralizer	709 705,51	€	37,352922	mol/s
	Precipitation collector	0,00	€	0,00	m^3
	Methanation reactor	2 872 636,46	€	8,838881	mol/s
	Heat exchanger	6 679 642,90	€	66 796,4290	kW
	Total for processes	**286 657 780,59**	**€**		
Storages	Dry biomass storage	33 033 821,39	€	3 303 382,1389	kg
	Wet biomass storage	3 294 520,55	€	658 904,1096	kg
	Biochar storage	3 150 231,45	€	210 015,4299	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	86 708 050,39	€	144 513 417,3140	mol
	Total for storages	**126 186 623,77**	**€**		
Connections enlargement	Electrical connection	138 485,40	€	84,96	MW
	Gas connection	0,00	€	0,00	MW
	Water connection	101,19	€	2,43	m^3/h
	Total for connections	**138 584,59**	**€**		
	Total investment	**412 982 988,95**	**€**		
	Payoff period	**20,00**	**years**		

Operational costs for selected period

		Price		Amount	
Electrical energy	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	198 000 000,00	€	600 000,00	MWh
	Net consumption without investment	198 000 000,00	€	600 000,00	MWh
	Peak power without investment	438 394,89	€	1 043 797,37	kW
	Consumed by P2G	31 364 900,58	€	93 176,57	MWh
	Net consumption with investment	228 748 268,07	€	693 176,57	MWh
	Peak power with investment	498 714,07	€	1 187 414,46	kW
Heat	Produced by REP	0,00	€	0,00	MWh
	Produced IP	0,00	€	678 000,00	MWh
	Net production without investment	0,00	€	678 000,00	MWh
	Consumed by P2G	0,00	€	-16 893,18	MWh
	Net production with investment	0,00	€	694 893,18	MWh
Methane	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	141 035 600,00	€	100 000,00	MWh
	Net consumption without investment	141 035 600,00	€	100 000,00	MWh
	Produced by P2G	92 456 239,89	€	90 410,96	MWh
	Net consumption with investment	13 523 961,84	€	9 589,04	MWh
Water	Water consumed by P2G	17 806,01	€	13 696,93	m^3
Inputs	Dry biomass bought	17 032 253,04	€	11 144,41	t
	Wet biomass bought	6 833 083,16	€	4 367,65	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	5 053 157,75	€	101 063 155,02	kg
	Total operational cost without investment	**339 473 994,89**	**€**		
	Total operational cost with investment	**261 600 928,25**	**€**		
	Savings with introduction of P2G	**77 873 066,65**	**€**		

20. Figure: Results for IP with moderate prices of methane and no subsidy

Source: Optimilization Tool v1.1

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	147 378 974,22	€	7,018046	kg/s
	Wet anaerobic digestor	39 636 840,60	€	1,981842	kg/s
	Dry biomass to biochar plant	0,00	€	0,000000	kg/s
	Wet biomass to biochar plant	0,00	€	0,000000	kg/s
	Biogas separator	48 846 228,63	€	2,873308	kg/s
	Gasification + water gas shift plant	731 031,85	€	0,731032	kg/s
	Combined heat and power (CHP)	55 312 007,63	€	7,901715	kg/s
	Carbon capture plant	0,00	€	0,000000	mol/s
	Electrolyser	198 985 040,10	€	79 594,02	kW
	Demmeralizer	4 953 188,63	€	244,904665	mol/s
	Precipitation collector	2 000,00	€	1 000,00	m^3
	Methanation reactor	19 970 292,60	€	61,447054	mol/s
	Heat exchanger	6 684 851,21	€	66 848,5121	kW
	Total for processes	**522 200 455,51**	**€**		
Storages	Dry biomass storage	24 254 368,33	€	2 425 436,8329	kg
	Wet biomass storage	5 848 561,12	€	1 169 712,2249	kg
	Biochar storage	6 757 467,63	€	450 497,8418	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	16 416 012,46	€	20 520 015,5745	mol
	Methane storage tank	264 862 946,30	€	441 438 243,8318	mol
	Total for storages	**318 139 355,84**	**€**		
Connections enlargement	Electrical connection	319 901,12	€	196,26	MW
	Gas connection	0,00	€	0,00	MW
	Water connection	663,44	€	15,92	m^3/h
	Total for connections	**320 564,56**	**€**		
	Total investment	**840 660 375,91**	**€**		
	Payoff period	**20,00**	**years**		

Operational costs for selected period

		Price		Amount	
Electrical energy	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	198 000 000,00	€	600 000,00	MWh
	Net consumption without investment	198 000 000,00	€	600 000,00	MWh
	Peak power without investment	438 394,89	€	1 043 797,37	kW
	Consumed by P2G	52 167 832,08	€	156 215,76	MWh
	Net consumption with investment	249 551 199,57	€	756 215,76	MWh
	Peak power with investment	818 628,43	€	1 949 115,30	kW
Heat	Produced by REP	0,00	€	0,00	MWh
	Produced IP	0,00	€	678 000,00	MWh
	Net production without investment	0,00	€	678 000,00	MWh
	Consumed by P2G	10 053,85	€	-23 864,45	MWh
	Net production with investment	0,00	€	701 664,45	MWh
Methane	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	271 035 600,00	€	100 000,00	MWh
	Net consumption without investment	271 035 600,00	€	100 000,00	MWh
	Produced by P2G	302 844 125,96	€	148 000,00	MWh
	Net consumption with investment	-98 219 716,54	€	-48 000,00	MWh
Water	Water consumed by P2G	28 700,83	€	22 077,56	m^3
Inputs	Dry biomass bought	28 501 369,86	€	18 493,15	t
	Wet biomass bought	11 545 976,71	€	6 968,38	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	22 500,00	€	3,00	t
	CO2 emitted	5 057 097,84	€	101 141 956,82	kg
	Total operational cost without investment	**469 473 994,89**	**€**		
	Total opecational cost with investment	**185 146 459,02**	**€**		
	Savings with introduction of P2G	**284 327 535,88**	**€**		

21. Figure: Results for IP with high gas prices of methane and no subsidy

Source: Optimilization Tool v1.1

The introduction of P2G at high gas prices (10x) in an industrial plant is calculated to have a huge savings potential. In this case, the production of hydrogen will reappear, albeit in small quantities. The return on investment here is 20 years, as in the other Industrial Plant calculations.

3.3 REP

Calculations with renewable energy sources have not led to significant results. The results suggest that an investment in a P2G hub installed next to a solar PV renewable energy source may represent a cost saving, but such an investment, like a greenfield investment, is also not cost-effective in any of the cases studied.

3.3.1 RESULTS WITH SUBSIDIES

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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^3
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	€		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	Total for storages	**0,00**	€		
Connections integrament	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

		Price		Amount	
Electrical energy	Produced by REP	2 522 362,20	€	10 678,00	MWh
	Consumed by IP	0,00	€	0,00	MWh
	Net consumption without investment	-2 522 362,20	€	-10 678,00	MWh
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	-10 678,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**-2 522 362,20**	€		
	Total operational cost with investment	**0,00**	€		
	Savings with introduction of P2G	**-2 522 362,20**	€		

22. Figure: Results for REP with real gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		Amount	
Electrical energy	Produced by REP	2 521 653,54	€	10 675,00	MWh
	Consumed by IP	0,00	€	0,00	MWh
	Net consumption without investment	-2 521 653,54	€	-10 675,00	MWh
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	-10 675,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**-2 521 653,54**	**€**		
	Total operational cost with investment	**0,00**	**€**		
	Savings with introduction of P2G	**-2 521 653,54**	**€**		

23. Figure: Results for REP with moderate gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		Amount	
Electrical energy	Produced by REP	2 521 653,54	€	10 675,00	MWh
	Consumed by IP	0,00	€	0,00	MWh
	Net consumption without investment	-2 521 653,54	€	-10 675,00	MWh
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	-10 675,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**-2 521 653,54**	**€**		
	Total operational cost with investment	**0,00**	**€**		
	Savings with introduction of P2G	**-2 521 653,54**	**€**		

24. Figure: Results for REP with high gas prices of methane and 50% subsidy

Source: Optimilization Tool v1.1

3.3.2 RESULTS WITHOUT SUBSIDIES

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	**€**		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	Total for storages	**0,00**	**€**		
Connections and engagement	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

		Price		Amount	
Electrical energy	Produced by REP	2 521 653,54	€	10 675,00	MWh
	Consumed by IP	0,00	€	0,00	MWh
	Net consumption without investment	-2 521 653,54	€	-10 675,00	MWh
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	-10 675,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**-2 521 653,54**	**€**		
	Total operational cost with investment	**0,00**	**€**		
	Savings with introduction of P2G	**-2 521 653,54**	**€**		

25. Figure: Results for REP with real gas prices of methane and no subsidy

Source: Optimilization Tool v1.1

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	€		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		Amount	
Electrical energy	Produced by REP	2 521 653,54	€	10 675,00	MWh
	Consumed by IP	0,00	€	0,00	MWh
	Net consumption without investment	-2 521 653,54	€	-10 675,00	MWh
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	-10 675,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**-2 521 653,54**	€		
	Total operational cost with investment	**0,00**	€		
	Savings with introduction of P2G	**-2 521 653,54**	€		

26. Figure: Results for REP with moderate gas prices of methane and no subsidy

Source: Optimilization Tool v1.1

Investment specifications

	Element	Price		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	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
	Biogas separator	0,00	€	0,000000	kg/s
	Gasification + water gas shift plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,000000	kg/s
	Carbon capture plant	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
	Methanation reactor	0,00	€	0,000000	mol/s
	Heat exchanger	0,00	€	0,0000	kW
	Total for processes	**0,00**	€		
Storages	Dry biomass storage	0,00	€	0,0000	kg
	Wet biomass storage	0,00	€	0,0000	kg
	Biochar storage	0,00	€	0,0000	kg
	Water storage tank	0,00	€	0,0000	mol
	Oxygen storage tank	0,00	€	0,0000	mol
	Hydrogen storage tank	0,00	€	0,0000	mol
	Carbon dioxide storage tank	0,00	€	0,0000	mol
	Methane storage tank	0,00	€	0,0000	mol
	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

		Price		Amount	
Electrical energy	Produced by REP	2 521 653,54	€	10 675,00	MWh
	Consumed by IP	0,00	€	0,00	MWh
	Net consumption without investment	-2 521 653,54	€	-10 675,00	MWh
	Peak power without investment	0,00	€	0,00	kW
	Consumed by P2G	0,00	€	0,00	MWh
	Net consumption with investment	0,00	€	-10 675,00	MWh
	Peak power with investment	0,00	€	0,00	kW
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
Methane	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 consumed by P2G	0,00	€	0,00	m^3
Inputs	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	0,00	€	0,00	t
	Biochar bought	0,00	€	0,00	t
Outputs	Biochar sold	0,00	€	0,00	t
	Hydrogen sold	0,00	€	0,00	t
	CO2 emitted	0,00	€	0,00	kg
	Total operational cost without investment	**-2 521 653,54**	€		
	Total operational cost with investment	**0,00**	€		
	Savings with introduction of P2G	**-2 521 653,54**	€		

27. Figure: Results for REP with high gas prices of methane and no subsidy

Source: Optimilization Tool v1.1