Interreg
Danube Transnational Programme
DanuP-2-Gas

Output T2.2

# Pre-feasibility Study (Romania)

WP T2: Project main output

May, 2022

Project co-funded by the European Union funds (ERDF, IPA)
www.interreg-danube.eu/danup-2-gas

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## DOCUMENT CONTROL SHEET

| Project reference | |
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| Acronym | DanuP-2-Gas |
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| Programme priority specific objective | SO 3.2 Improve energy security and energy efficiency |
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| Project website | www.interreg-danube.eu/danup-2-gas |
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| Short Description |
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| 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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## IMPRINT

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

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- ERDF PP2 Tolna County Development Agency Nonprofit Public Ltd.(HU)
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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. |
| v3.1 | 10.03.2022. | M. Šundrica, M. Ban, D. Đurđević, M. Vašak, F. Rukavina, A. Karneluti | UNIZG-FER, SDEWES, EIHP | Selection of prospective locations for the pre-feasibility study for Croatia, manual take-up of data prepared for the Atlas in the optimization solver |
| v3.2 | 29.03.2022 | M.Vašak, M. Šundrica, F. Rukavina, A. Karneluti | UNIZG-FER | Case studies executed and explained for Croatia with OT version 1 |

# 1. METHODOLOGY

Infrastructure and Biomass database given within the Atlas are prerequisite for any use of Optimization tool (OT). After the selection or manual entry of sources, connection points, etc. is done, optimization can be started.

# 2. CASE STUDIES

The case studies were conducted using data related to biomass and infrastructure from all over the country by combining biomass depots and energy infrastructure elements from nearby counties that correspond to both national historical regions and administrative development regions.

The main regions targeted were Moldova, which corresponds to the North East Development Region; Muntenia South Development Region; Transylvania Central

Development Region but also the Oltenia Region or the western part of the country, the Banat and Crisana regions.

There were also some exceptional cases where elements from the counties of Calarasi and Constanta were chosen, which are not part of the same region but have a very good connectivity in terms of road, rail and water navigation being neighboring.

## 2.1 SUMMARY

For each one of cases studies (IP, REP and GF), variations of methane prices and subsidies are considered. In the Table 1, case summaries are given:

*Table 1. Simulation cases*

| | Conservative prices of methane | | | Higher prices of methane | | |
|---|---|---|---|---|---|---|
| | No increase<br>No increase<br>IP | No increase<br>No increase<br>REP | No increase<br>No increase<br>GF | 10x winter<br>5x summer<br>IP | 10x winter<br>5x summer<br>REP | 15x winter<br>10x summer<br>GF |
| No subsidy | No production, Fig. 1 | No production Fig. 2 | No production Fig. 3 | No production Fig. 4 | Periodic production [a] Fig. 5 | Periodic production [b] Fig. 6 |
| Subsidy of 50 % | No production Fig. 7 | No production Fig. 8 | No production Fig. 9 | Periodic production Fig. 10 | Continuous production Fig. 11 | Continuous production [b] Fig. 12 |

[a] simulation for period of 01 January to 30 June

[b] simulation for period of 01 February to 31 May

## 2.2 RESULTS WITHOUT SUBSIDIES

Figure 1 shows an investment of almost 58 million euros, with a pay-off period of 20 years while savings amount to 33.7 million euros. The values 0 in the case of the "Net production without investment" tab mean that no consumption is recorded.

**Investment specifications**

| | Element | Price | | Size | |
|---|---|---|---|---|---|
| Processes | Dry anaerobic digestor | 20,091,787.83 | € | 0.956752 | kg/s |
| | Wet anaerobic digestor | 20,294,266.87 | € | 1.034713 | 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 | 353,728.10 | € | 0.020808 | kg/s |
| | Gasification + water gas shift plan | 114,277.29 | € | 0.114277 | kg/s |
| | Combined heat and power (CHP) | 11,564,289.70 | € | 1.652041 | kg/s |
| | Carbon capture plant | 0.00 | € | 0.000000 | mol/s |
| | Electrolyser | 2,671,585.37 | € | 1,068.63 | kW |
| | Demineralizer | 267,445.36 | € | 14.076072 | mol/s |
| | Precipitation collector | 2,000.00 | € | 1,000.00 | m³ |
| | Methanation reactor | 768,550.13 | € | 2.364770 | mol/s |
| | Heat exchanger | 1,436,504.60 | € | 14,365.0460 | kW |
| | **Total for processes** | **57,564,435.25** | **€** | | |
| Storages | Dry biomass storage | 0.00 | € | 0.0000 | kg |
| | Wet biomass storage | 0.00 | € | 0.0000 | kg |
| | Biochar storage | 27,726.97 | € | 1,848.4648 | kg |
| | Water storage tank | 20.60 | € | 1,030.1119 | mol |
| | Oxygen storage tank | 53.68 | € | 134.2061 | mol |
| | Hydrogen storage tank | 0.00 | € | 0.0000 | mol |
| | Carbon dioxide storage tank | 33.39 | € | 41.7401 | mol |
| | Methane storage tank | 0.00 | € | 0.0000 | mol |
| | **Total for storages** | **27,834.65** | **€** | | |
| Connections enlargement | Electrical connection | 0.00 | € | 0.00 | MW |
| | Gas connection | 0.00 | € | 0.00 | MW |
| | Water connection | 1.83 | € | 0.91 | m³/h |
| | **Total for connections** | **1.83** | **€** | | |
| | **Total investment** | **57,592,271.73** | **€** | | |
| | **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 | 122,601,308.22 | € | 98,540.00 | MWh |
| | Net consumption without investment | 122,601,308.22 | € | 98,540.00 | MWh |
| | Peak power without investment | 174,854.85 | € | 171,426.32 | kW |
| | Consumed by P2G | -48,210,482.06 | € | -95,075.80 | MWh |
| | Net consumption with investment | 3,273,667.04 | € | 3,464.20 | MWh |
| | Peak power with investment | 71,046.10 | € | 69,653.04 | kW |
| Heat | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Produced IP | 0.00 | € | 589,420.00 | MWh |
| | Net production without investment | 0.00 | € | 589,420.00 | MWh |
| | Consumed by P2G | 0.00 | € | -117,377.75 | MWh |
| | Net production with investment | 0.00 | € | 706,797.75 | MWh |
| Methane | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Consumed by IP | 6,104,600,130.00 | € | 5,402,301.00 | MWh |
| | Net consumption without investment | 6,104,600,130.00 | € | 5,402,301.00 | MWh |
| | Produced by P2G | 446,255.80 | € | 9,057.12 | MWh |
| | Net consumption with investment | 6,094,365,583.36 | € | 5,393,243.88 | MWh |
| Water | Water consumed by P2G | 8,307.58 | € | 7,837.34 | m³ |
| Inputs | Dry biomass bought | 1,196,210.71 | € | 28,576.05 | t |
| | Wet biomass bought | 892,000.00 | € | 32,000.00 | 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 | 93,819,029.18 | € | 1,876,380,583.27 | kg |
| | **Total operational cost without investment** | **6,227,376,293.07** | **€** | | |
| | **Total operational cost with investment** | **6,193,625,843.95** | **€** | | |
| | **Savings with introduction of P2G** | **33,750,449.11** | **€** | | |

Clear results

Fig. 1 Results for IP with conservative prices of methane and no subsidy

In the case of Figure 2 P2G hub is not economically viable for such set of parameters. Therefore, payoff period is not applicable. All this time the negative value of the "Net Consumption without investment" indicator means that there are positive values of production.

**Investment specifications**

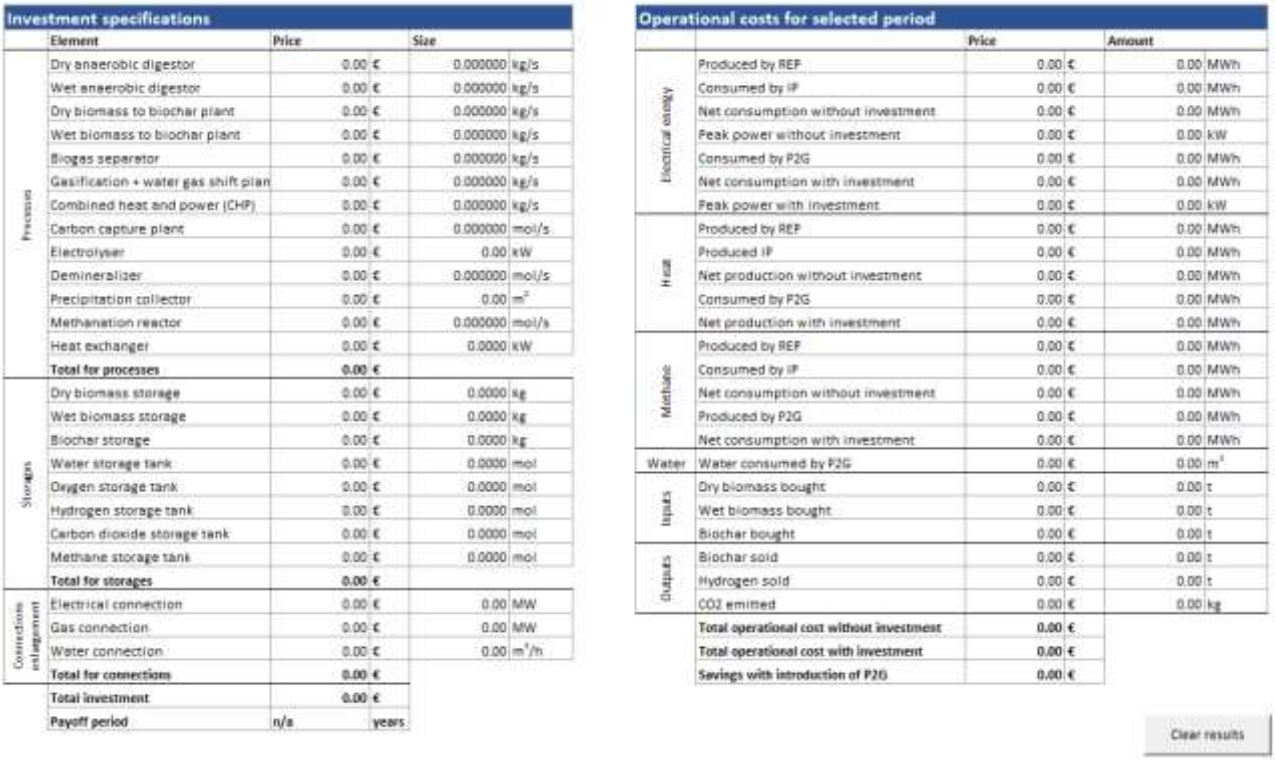
| | Element | Price | | Size | |
|---|---|---|---|---|---|
| Processes | Dry anaerobic digestor | 0.00 | € | 0.000000 | kg/s |
| | Wet anaerobic digestor | 0.00 | € | 0.000000 | kg/s |
| | Dry biomass to biochar plant | 0.00 | € | 0.000000 | kg/s |
| | Wet biomass to biochar plant | 0.00 | € | 0.000000 | kg/s |
| | Biogas separator | 0.00 | € | 0.000000 | kg/s |
| | Gasification + water gas shift plan | 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 inlagement | 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 | 6,553,857.45 | € | 13,000.00 | MWh |
| | Consumed by IP | 0.00 | € | 0.00 | MWh |
| | Net consumption without investment | -6,553,857.45 | € | -13,000.00 | MWh |
| | Peak power without investment | 0.00 | € | 0.00 | kW |
| | Consumed by P2G | 0.00 | € | 0.00 | MWh |
| | Net consumption with investment | -6,553,857.45 | € | -13,000.00 | MWh |
| | Peak power with investment | 0.00 | € | 0.00 | kW |
| Heat | Produced by REP | 0.00 | € | 4,000.00 | MWh |
| | Produced IP | 0.00 | € | 0.00 | MWh |
| | Net production without investment | 0.00 | € | 4,000.00 | MWh |
| | Consumed by P2G | 0.00 | € | 0.00 | MWh |
| | Net production with investment | 0.00 | € | 4,000.00 | 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** | **-6,553,857.45** | **€** | | |
| | **Total operational cost with investment** | **-6,553,857.45** | **€** | | |
| | **Savings with introduction of P2G** | **0.00** | **€** | | |

Clear results

Fig. 2 Results for REP with conservative prices of methane and no subsidy



**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 plan | 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 REF | 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 REF | 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 REF | 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** | € | | |

Clear results

Fig. 3 Results for GF with conservative prices of methane and no subsidy

As will be the other cases regarding Greenfield type investments, regardless of the price of the gas or the possible subsidy granted, it can be perceived that P2G hubs is not as economically viable as Greenfield investments.

**Investment specifications**

| | Element | Price | | Size | |
|---|---|---|---|---|---|
| Processes | Dry anaerobic digestor | 4,661,339.42 | € | 0.221969 | kg/s |
| | Wet anaerobic digestor | 61,758,445.02 | € | 3.087922 | 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 | 6,507,913.68 | € | 0.382818 | kg/s |
| | Gasification + water gas shift plan | 1,046,581.68 | € | 1.046582 | kg/s |
| | Combined heat and power (CHP) | 16,019,679.15 | € | 2.288526 | kg/s |
| | Carbon capture plant | 0.00 | € | 0.000000 | mol/s |
| | Electrolyser | 24,490,011.42 | € | 9,796.00 | kW |
| | Demineralizer | 752,490.70 | € | 39.604774 | mol/s |
| | Precipitation collector | 2,000.00 | € | 1,000.00 | m³ |
| | Methanation reactor | 18,989,352.35 | € | 58.428776 | mol/s |
| | Heat exchanger | 2,014,523.66 | € | 20,145.2366 | kW |
| | **Total for processes** | **136,242,337.09** | **€** | | |
| Storages | Dry biomass storage | 0.00 | € | 0.0000 | kg |
| | Wet biomass storage | 1,018,688.99 | € | 211,737.7990 | kg |
| | Biochar storage | 1,321,406.09 | € | 88,093.7393 | kg |
| | Water storage tank | 173,114.01 | € | 8,655,700.5946 | mol |
| | Oxygen storage tank | 0.00 | € | 0.0000 | mol |
| | Hydrogen storage tank | 21,599,899.96 | € | 12,705,823.5066 | mol |
| | Carbon dioxide storage tank | 2,344,475.87 | € | 2,930,594.8334 | mol |
| | Methane storage tank | 0.00 | € | 0.0000 | mol |
| | **Total for storages** | **26,497,584.92** | **€** | | |
| Connection and segment | Electrical connection | 0.00 | € | 0.00 | MW |
| | Gas connection | 0.00 | € | 0.00 | MW |
| | Water connection | 5.15 | € | 2.57 | m³/h |
| | **Total for connections** | **5.15** | **€** | | |
| | **Total investment** | **162,739,927.16** | **€** | | |
| | **Payoff period** | **20.00** | **years** | | |

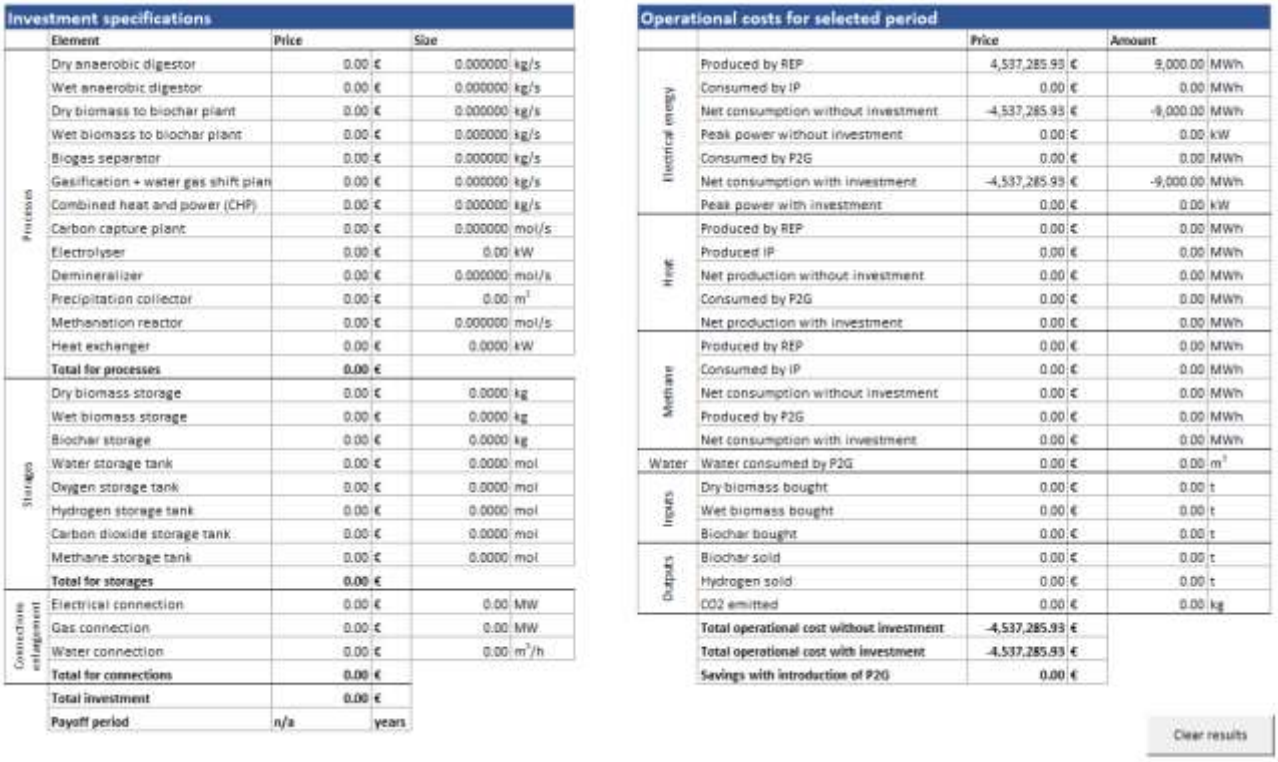
**Operational costs for selected period**

| | | Price | | Amount | |
|---|---|---|---|---|---|
| Electrical energy | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Consumed by IP | 127,475,997.95 | € | 102,458.00 | MWh |
| | Net consumption without investment | 127,475,997.95 | € | 102,458.00 | MWh |
| | Peak power without investment | 181,807.16 | € | 178,242.32 | kW |
| | Consumed by P2G | 22,284,373.77 | € | -16,005.32 | MWh |
| | Net consumption with investment | 81,697,782.97 | € | 86,452.68 | MWh |
| | Peak power with investment | 883,937.02 | € | 866,604.92 | kW |
| Heat | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Produced IP | 0.00 | € | 647,571.00 | MWh |
| | Net production without investment | 0.00 | € | 647,571.00 | MWh |
| | Consumed by P2G | 0.00 | € | -153,499.13 | MWh |
| | Net production with investment | 0.00 | € | 801,070.13 | MWh |
| Methane | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Consumed by IP | 7,436,530,744.27 | € | 5,809,914.00 | MWh |
| | Net consumption without investment | 7,436,530,744.27 | € | 5,809,914.00 | MWh |
| | Produced by P2G | 6,233,526.83 | € | 104,474.60 | MWh |
| | Net consumption with investment | 7,302,803,454.92 | € | 5,705,439.40 | MWh |
| Water | Water consumed by P2G | 23,760.72 | € | 22,415.77 | m³ |
| Inputs | Dry biomass bought | 42,000.00 | € | 7,000.00 | t |
| | Wet biomass bought | 3,136,750.00 | € | 84,500.00 | 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 | 114,551,946.45 | € | 2,291,038,928.98 | kg |
| | **Total operational cost without investment** | **7,564,188,549.38** | **€** | | |
| | **Total operational cost with investment** | **7,503,139,632.07** | **€** | | |
| | **Savings with introduction of P2G** | **61,048,917.31** | **€** | | |

Clear results

Fig. 4 Results for IP with higher prices of methane and no subsidy

In the case of industrial plants, the scenario that predicts a higher cost of gas causes the investment with a pay-off period of 20 years to increase while savings and operating costs decrease. Even so, owning one is still beyond the reach of the average person.



**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 plan | 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** | € | | |
| 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 | |

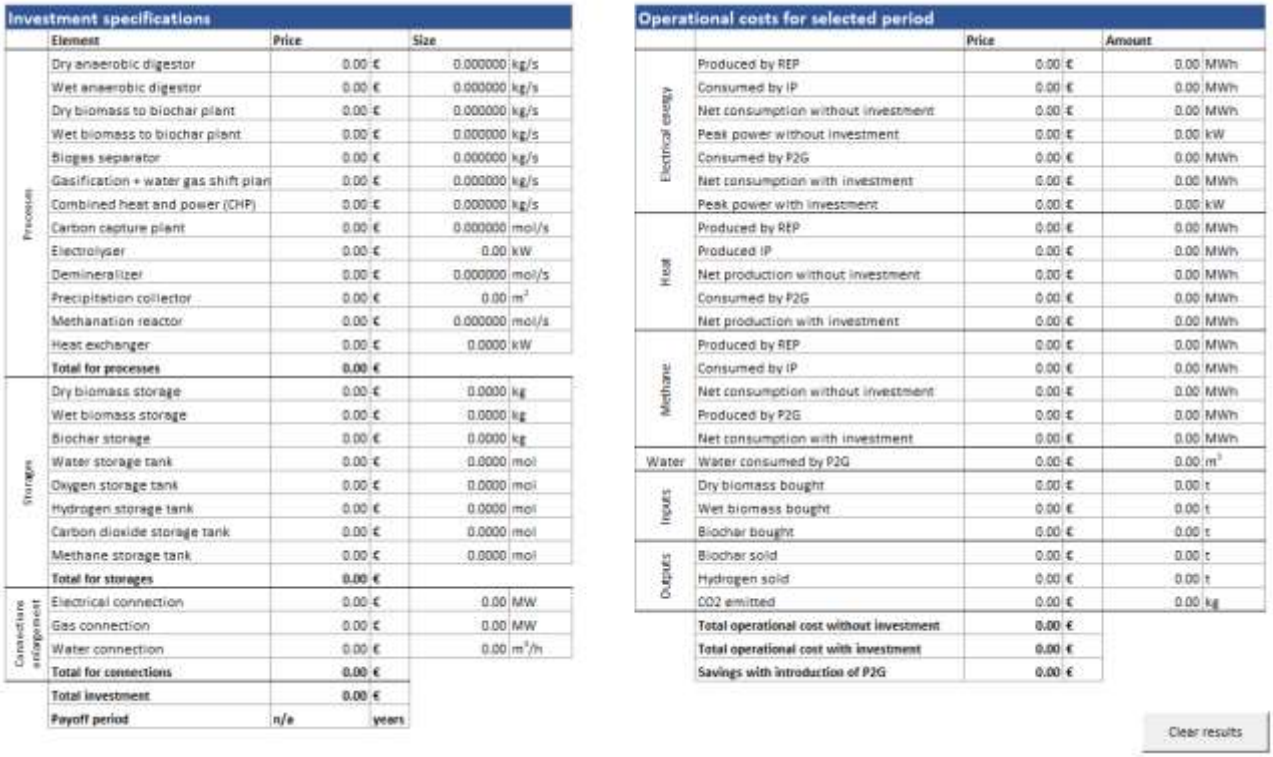
**Operational costs for selected period**

| | | Price | | Amount | |
|---|---|---|---|---|---|
| Electrical energy | Produced by REP | 4,537,285.93 | € | 9,000.00 | MWh |
| | Consumed by IP | 0.00 | € | 0.00 | MWh |
| | Net consumption without investment | -4,537,285.93 | € | -9,000.00 | MWh |
| | Peak power without investment | 0.00 | € | 0.00 | kW |
| | Consumed by P2G | 0.00 | € | 0.00 | MWh |
| | Net consumption with investment | -4,537,285.93 | € | -9,000.00 | 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** | **-4,537,285.93** | € | | |
| | **Total operational cost with investment** | **-4,537,285.93** | € | | |
| | **Savings with introduction of P2G** | **0.00** | € | | |

Clear results

Fig. 5 Results for REP with higher prices of methane and no subsidy

The higher gas price in this scenario (Renewable power plant with high gas price) makes the values of electricity produced but also net consumption with or without investment also decrease. The same decrease is registered for the Operational Costs with or without investment.



**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 plan | 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/e** | | **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** | **€** | | |

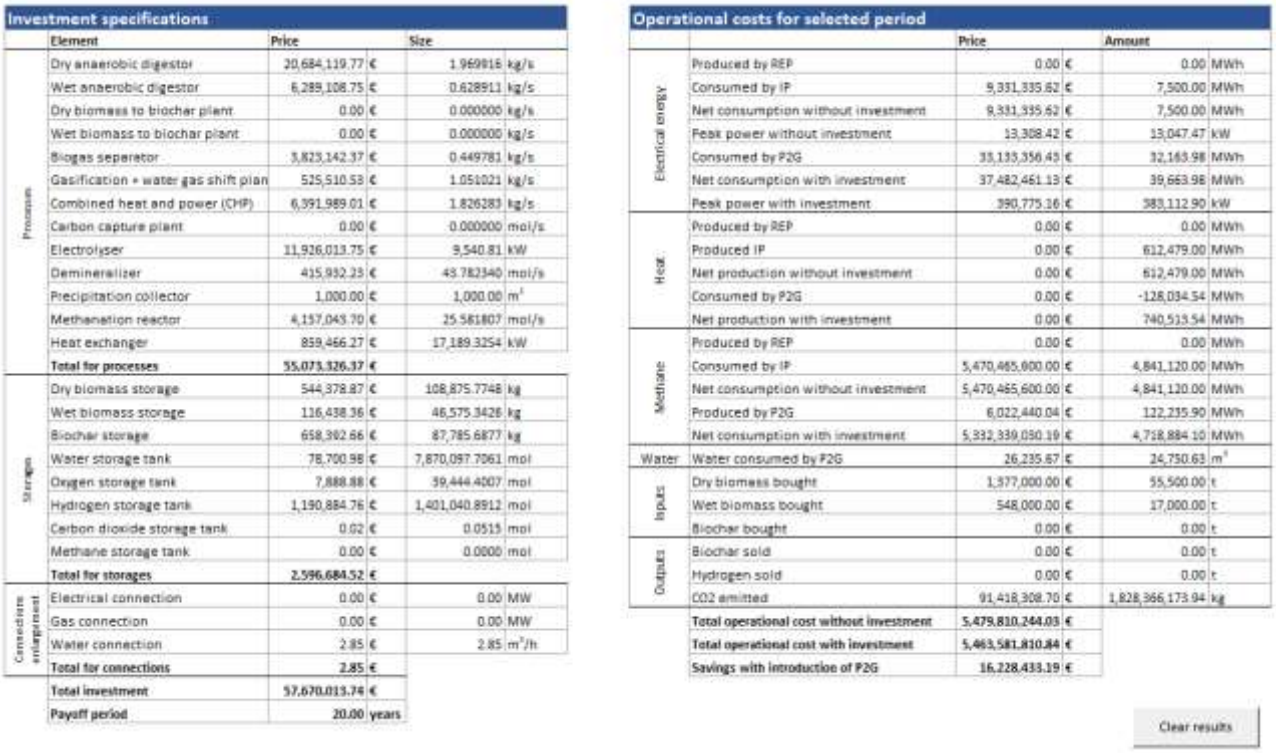
Clear results

Fig. 6 Results for GF with higher prices of methane and no subsidy

For the Greenfield investment it is the same case as figure 3 – it is not viable.

## 2.3 RESULTS WITH SUBSIDIES

In Figures 7 to 12, results for the cases with subsidies are depicted. Although subsidies are considered, with conservative prices of methane there is no economical reason of any investment in biomethane production as it is shown in Figures 7 to 9.



**Investment specifications**

| | Element | Price | | Size | |
|---|---|---|---|---|---|
| Processes | Dry anaerobic digestor | 20,684,119.77 | € | 1.969916 | kg/s |
| | Wet anaerobic digestor | 6,289,108.75 | € | 0.628911 | 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 | 3,823,142.37 | € | 0.449781 | kg/s |
| | Gasification + water gas shift plan | 525,510.53 | € | 1.051021 | kg/s |
| | Combined heat and power (CHP) | 6,391,989.01 | € | 1.826283 | kg/s |
| | Carbon capture plant | 0.00 | € | 0.000000 | mol/s |
| | Electrolyser | 11,926,013.75 | € | 9,540.81 | kW |
| | Demineralizer | 415,932.23 | € | 43.782340 | mol/s |
| | Precipitation collector | 1,000.00 | € | 1,000.00 | $m^3$ |
| | Methanation reactor | 4,157,043.70 | € | 25.581807 | mol/s |
| | Heat exchanger | 859,466.27 | € | 17,189.3254 | kW |
| | **Total for processes** | **55,073,326.37** | **€** | | |
| Storages | Dry biomass storage | 544,378.87 | € | 108,875.7748 | kg |
| | Wet biomass storage | 116,438.36 | € | 46,575.3426 | kg |
| | Biochar storage | 658,392.66 | € | 87,785.6877 | kg |
| | Water storage tank | 78,700.98 | € | 7,870,097.7061 | mol |
| | Oxygen storage tank | 7,888.88 | € | 39,444.4007 | mol |
| | Hydrogen storage tank | 1,190,884.76 | € | 1,401,040.8912 | mol |
| | Carbon dioxide storage tank | 0.02 | € | 0.0515 | mol |
| | Methane storage tank | 0.00 | € | 0.0000 | mol |
| | **Total for storages** | **2,596,684.52** | **€** | | |
| Connections enlargement | Electrical connection | 0.00 | € | 0.00 | MW |
| | Gas connection | 0.00 | € | 0.00 | MW |
| | Water connection | 2.85 | € | 2.85 | $m^3/h$ |
| | **Total for connections** | **2.85** | **€** | | |
| | **Total investment** | **57,670,013.74** | **€** | | |
| | **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 | 9,331,335.62 | € | 7,500.00 | MWh |
| | Net consumption without investment | 9,331,335.62 | € | 7,500.00 | MWh |
| | Peak power without investment | 13,308.42 | € | 13,047.47 | kW |
| | Consumed by P2G | 33,133,356.43 | € | 32,163.98 | MWh |
| | Net consumption with investment | 37,482,461.13 | € | 39,663.98 | MWh |
| | Peak power with investment | 390,775.16 | € | 383,112.90 | kW |
| Heat | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Produced IP | 0.00 | € | 612,479.00 | MWh |
| | Net production without investment | 0.00 | € | 612,479.00 | MWh |
| | Consumed by P2G | 0.00 | € | -128,034.54 | MWh |
| | Net production with investment | 0.00 | € | 740,513.54 | MWh |
| Methane | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Consumed by IP | 5,470,465,600.00 | € | 4,841,120.00 | MWh |
| | Net consumption without investment | 5,470,465,600.00 | € | 4,841,120.00 | MWh |
| | Produced by P2G | 6,022,440.04 | € | 122,235.90 | MWh |
| | Net consumption with investment | 5,332,339,050.19 | € | 4,718,884.10 | MWh |
| Water | Water consumed by P2G | 26,235.67 | € | 24,750.63 | $m^3$ |
| Inputs | Dry biomass bought | 1,377,000.00 | € | 55,500.00 | t |
| | Wet biomass bought | 548,000.00 | € | 17,000.00 | 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 | 91,418,308.70 | € | 1,828,366,173.94 | kg |
| | **Total operational cost without investment** | **5,479,810,244.03** | **€** | | |
| | **Total operational cost with investment** | **5,463,581,810.84** | **€** | | |
| | **Savings with introduction of P2G** | **16,228,433.19** | **€** | | |

Clear results

Fig. 7 Results for IP with conservative prices of methane and subsidy of 50%

In the scenario in which normal gas costs are stipulated, to which is added a subsidy of 50%, the Industrial Plant type investment is very profitable, the values being almost 10 times higher than in the case of figure 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 plan | 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 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** | |

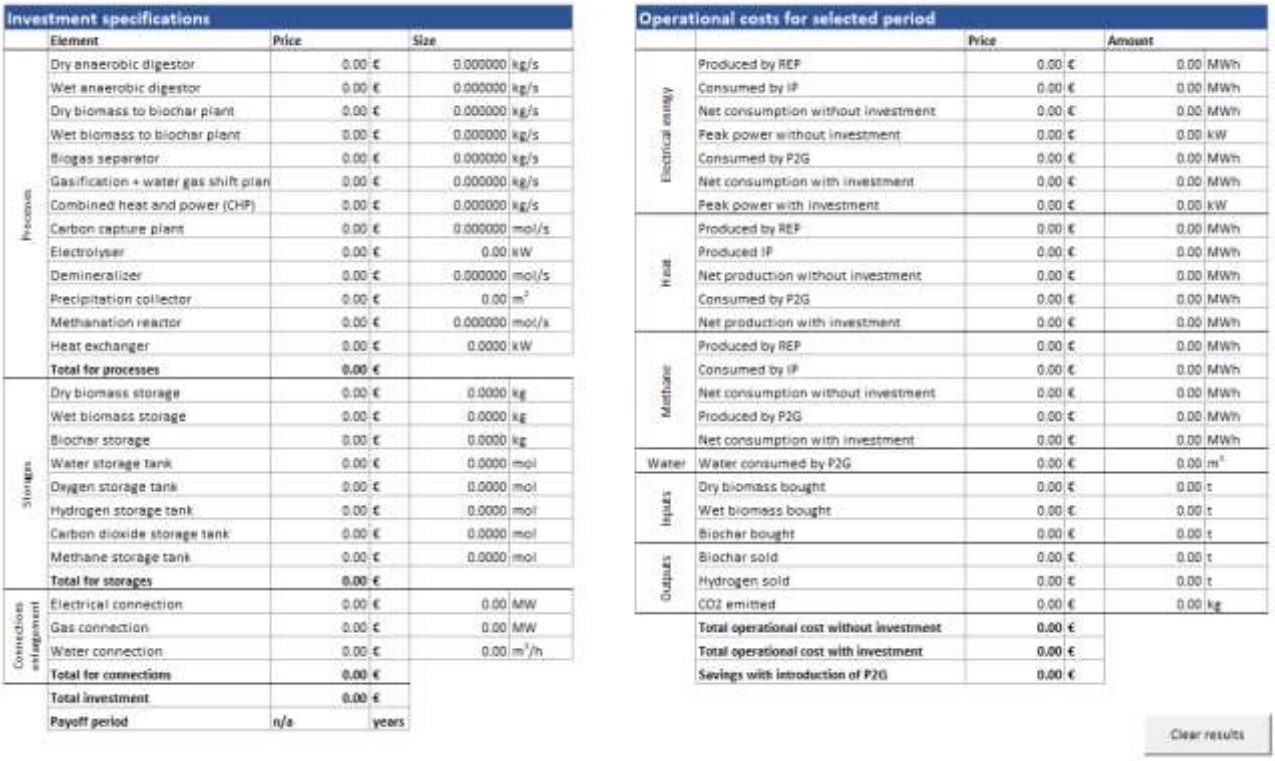
**Operational costs for selected period**

| | | Price | | Amount | |
|---|---|---|---|---|---|
| Electrical energy | Produced by REP | 6,038,037.50 | € | 12,000.00 | MWh |
| | Consumed by IP | 0.00 | € | 0.00 | MWh |
| | Net consumption without investment | -6,038,037.50 | € | -12,000.00 | MWh |
| | Peak power without investment | 0.00 | € | 0.00 | kW |
| | Consumed by P2G | 0.00 | € | 0.00 | MWh |
| | Net consumption with investment | -6,038,037.50 | € | -12,000.00 | MWh |
| | Peak power with investment | 0.00 | € | 0.00 | kW |
| Heat | Produced by REP | 0.00 | € | 8,000.00 | MWh |
| | Produced IP | 0.00 | € | 0.00 | MWh |
| | Net production without investment | 0.00 | € | 8,000.00 | MWh |
| | Consumed by P2G | 0.00 | € | 0.00 | MWh |
| | Net production with investment | 0.00 | € | 8,000.00 | MWh |
| Methane | Produced by REP | -1,955,471.55 | € | 10,000.00 | MWh |
| | Consumed by IP | 0.00 | € | 0.00 | MWh |
| | Net consumption without investment | 1,955,471.55 | € | -10,000.00 | MWh |
| | Produced by P2G | 0.00 | € | 0.00 | MWh |
| | Net consumption with investment | 1,955,471.55 | € | -10,000.00 | 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** | **-4,082,565.96** | **€** | | |
| | **Total operational cost with investment** | **-4,082,565.96** | **€** | | |
| | **Savings with introduction of P2G** | **0.00** | **€** | | |

Clear results

Fig. 8 Results for REP with conservative prices of methane and subsidy of 50%

The 50% grant in the case of REP amortizes the operating costs that are similar to those in Figure 2 where the scenario does not provide for a grant. There is also a higher electricity production and a higher consumption than in scenario 5 which translates into higher production.



**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 plan | 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** | |

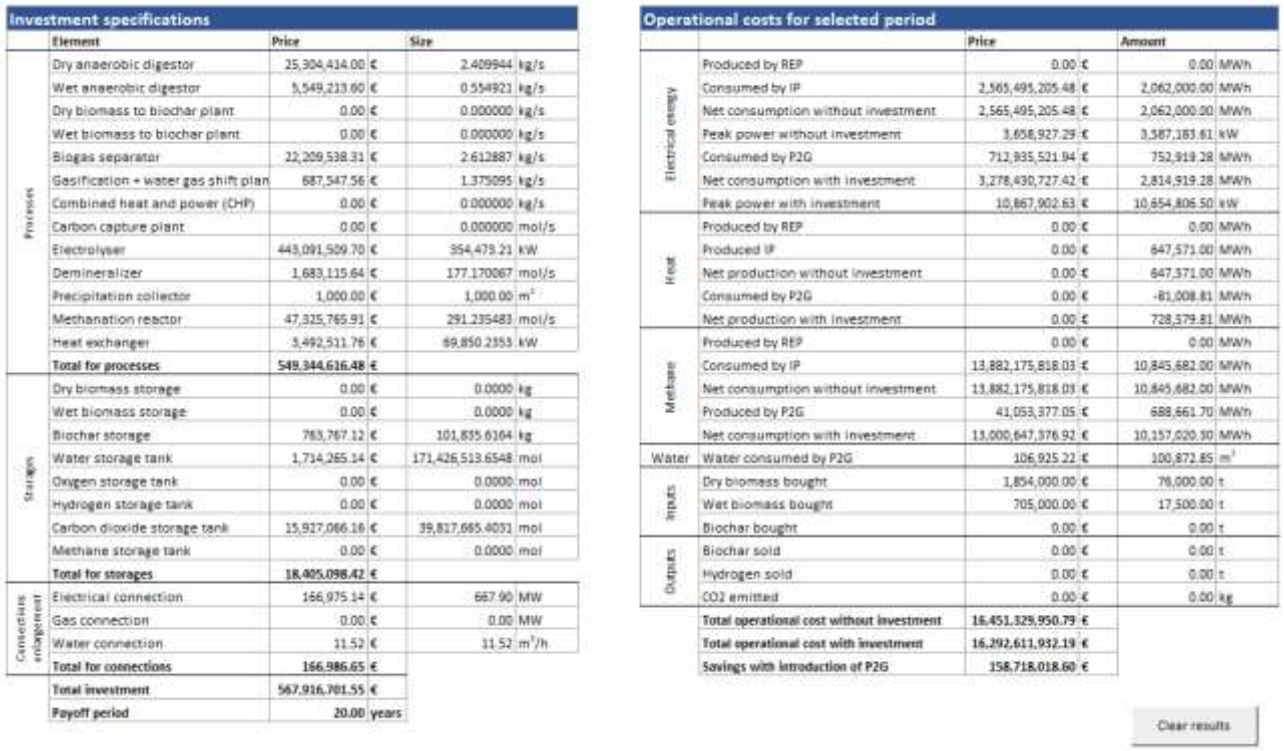
**Operational costs for selected period**

| | | 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** | **€** | | |

Clear results

Fig. 9 Results for GF with conservative prices of methane and subsidy of 50%

Greenfield investments – not economically viable.



**Investment specifications**

| | Element | Price | | Size | |
|---|---|---|---|---|---|
| Processes | Dry anaerobic digestor | 25,304,414.00 | € | 2.409944 | kg/s |
| | Wet anaerobic digestor | 5,549,213.60 | € | 0.554921 | 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 | 22,209,538.31 | € | 2.612887 | kg/s |
| | Gasification + water gas shift plan | 687,547.56 | € | 1.375095 | kg/s |
| | Combined heat and power (CHP) | 0.00 | € | 0.000000 | kg/s |
| | Carbon capture plant | 0.00 | € | 0.000000 | mol/s |
| | Electrolyser | 443,091,509.70 | € | 354,473.21 | kW |
| | Demineralizer | 1,683,115.64 | € | 177.170067 | mol/s |
| | Precipitation collector | 1,000.00 | € | 1,000.00 | $m^2$ |
| | Methanation reactor | 47,325,765.91 | € | 291.235483 | mol/s |
| | Heat exchanger | 3,492,511.76 | € | 69,850.2353 | kW |
| | **Total for processes** | **549,344,616.48** | **€** | | |
| Storages | Dry biomass storage | 0.00 | € | 0.0000 | kg |
| | Wet biomass storage | 0.00 | € | 0.0000 | kg |
| | Biochar storage | 763,767.12 | € | 101,835.6164 | kg |
| | Water storage tank | 1,714,265.14 | € | 171,426,513.6548 | mol |
| | Oxygen storage tank | 0.00 | € | 0.0000 | mol |
| | Hydrogen storage tank | 0.00 | € | 0.0000 | mol |
| | Carbon dioxide storage tank | 15,927,066.16 | € | 39,817,665.4031 | mol |
| | Methane storage tank | 0.00 | € | 0.0000 | mol |
| | **Total for storages** | **18,405,098.42** | **€** | | |
| Connections engagement | Electrical connection | 166,975.14 | € | 667.90 | MW |
| | Gas connection | 0.00 | € | 0.00 | MW |
| | Water connection | 11.52 | € | 11.52 | $m^3/h$ |
| | **Total for connections** | **166,986.65** | **€** | | |
| | **Total investment** | **567,916,701.55** | **€** | | |
| | **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 | 2,565,495,205.48 | € | 2,062,000.00 | MWh |
| | Net consumption without investment | 2,565,495,205.48 | € | 2,062,000.00 | MWh |
| | Peak power without investment | 3,658,927.29 | € | 3,587,183.61 | kW |
| | Consumed by P2G | 712,935,521.94 | € | 752,919.28 | MWh |
| | Net consumption with investment | 3,278,430,727.42 | € | 2,814,919.28 | MWh |
| | Peak power with investment | 10,867,902.63 | € | 10,654,806.50 | kW |
| Heat | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Produced IP | 0.00 | € | 647,571.00 | MWh |
| | Net production without investment | 0.00 | € | 647,371.00 | MWh |
| | Consumed by P2G | 0.00 | € | -81,008.81 | MWh |
| | Net production with investment | 0.00 | € | 728,379.81 | MWh |
| Methane | Produced by REP | 0.00 | € | 0.00 | MWh |
| | Consumed by IP | 13,882,175,818.03 | € | 10,845,682.00 | MWh |
| | Net consumption without investment | 13,882,175,818.03 | € | 10,845,682.00 | MWh |
| | Produced by P2G | 41,053,377.05 | € | 688,661.70 | MWh |
| | Net consumption with investment | 13,000,647,376.92 | € | 10,157,020.30 | MWh |
| Water | Water consumed by P2G | 106,925.22 | € | 100,872.85 | $m^3$ |
| Inputs | Dry biomass bought | 1,854,000.00 | € | 76,000.00 | t |
| | Wet biomass bought | 705,000.00 | € | 17,500.00 | 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** | **16,451,329,950.79** | **€** | | |
| | **Total operational cost with investment** | **16,292,611,932.19** | **€** | | |
| | **Savings with introduction of P2G** | **158,718,018.60** | **€** | | |

Clear results

Fig. 10 Results for IP with higher prices of methane and subsidy of 50%

Although in the scenario in figure 10 the gas prices are higher, the 50% subsidy makes this type of investment profitable even more profitable than in the first scenario (Average gas price and no subsidy)

**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 plan | 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** | | |

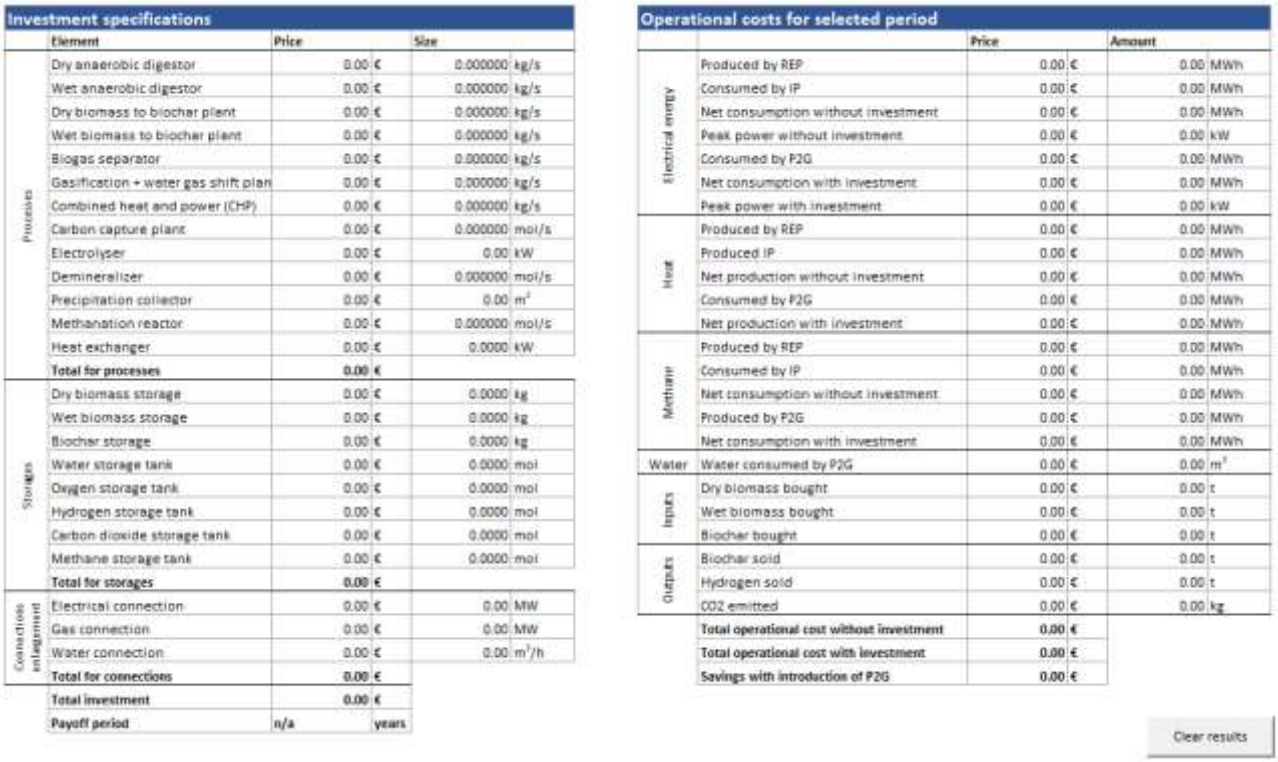
**Operational costs for selected period**

| | | Price | | Amount | |
|---|---|---|---|---|---|
| Electrical energy | Produced by REP | 3,119,652.71 | € | 6,200.00 | MWh |
| | Consumed by IP | 0.00 | € | 0.00 | MWh |
| | Net consumption without investment | -3,119,652.71 | € | -6,200.00 | MWh |
| | Peak power without investment | 0.00 | € | 0.00 | kW |
| | Consumed by P2G | 0.00 | € | 0.00 | MWh |
| | Net consumption with investment | -3,119,652.71 | € | -6,200.00 | 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** | **-3,119,652.71** | **€** | | |
| | **Total operational cost with investment** | **-3,119,652.71** | **€** | | |
| | **Savings with introduction of P2G** | **0.00** | **€** | | |

Clear results

Fig. 11 Results for REP with higher prices of methane and subsidy of 50%

In the case of REP, the trend is maintained, the 50% subsidy amortizing the values from the previous scenarios.



**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 plan | 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** | € | | |

Clear results

Fig. 12 GF with higher prices of methane and subsidy of 50%

Greenfield investments – not economically viable.

# 3. CONCLUSIONS

Regarding Romania, it turns out that the most profitable Power to gas hubs can be linked to Industrial Plants, where investments are viable and durable.

In the case of Renewable Energy Plant, as mentioned above, the negative values in terms of energy consumption with or without investment can be translated as production, however they are not economically viable, just as is the case with investments. Greenfiled type in this field.

However, it is shown that these values may fluctuate depending on the price of methane gas or depending on the existence of a certain subsidy and its percentage / value, for this type of investment.

The existence and the percentage of the subsidy can make the difference and prove to be mathematically, economically more important than the fluctuation of the gas price.

P2G investments are not sustainable in all scenarios.

Taking into account the biomass deposits in Romania, the most profitable areas to invest in biomass are the region of Moldova in the northeast of the country but also Muntenia (Calarasi county) and Constanta county in Dobrogea region, where most biomass is agricultural. The center of the country, Transylvania, is not a bad investment option either, where the biomass is mixed, coming from various sources such as livestock, fruit and forest biomass.

Thus, it is noted that the investments in the P2G field are variable, they are not economically viable in each case and they depend a lot on the price of gas, on the biomass capacity. However, an investment can tip the economic balance in a positive way, even if it would not be 50% as in the presented scenarios, but it would be smaller.