

innovations in the **BIOMETHANE** uni**VERSE**



Deliverable:	Summary on the Design of the Pilot Plants
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Executive Summary

Deliverable 2.3 is the Summary on the Design of the Pilot Plants and is intended as a synthesis of the individual design reports (Deliverable 2.2 “Report on Design of the Pilot Plants”), which outlined the demonstration activities for the innovative biomethane production technology pathways currently being implemented at the five demo sites of the BIOMETHAVERSE project (in France, Greece, Italy, Sweden, and Ukraine). D2.3 addresses WP2, “Demonstration of Innovative Biomethane Pathways”, and work under the Task 2.2 “Design and Implementation of demonstration activities”.

This deliverable includes information covering the implementation of the innovative technologies, illustrating the different biomethane production pathways to be demonstrated at the pilot scale over a period of 49 months. The Summary on the Design of the Pilot Plants is intended to facilitate easy understanding for investors, plant developers, policymakers, and the scientific community.

1. BIOMETHAVERSE in a nutshell

BIOMETHAVERSE (Demonstrating and Connecting Production Innovations in the **BIOMETHA**ne uni**VERSE**) aims to diversify the technology basis for biomethane production in Europe, increase its cost-effectiveness, contribute to the uptake of biomethane technologies, and support the priorities of the SET Plan Action 8.

To this purpose five innovative biomethane production pathways, which include one or a combination of thermochemical, biochemical, electrochemical and biological conversion processes, will be demonstrated and implemented at plant scale in five European countries: France, Greece, Italy, Sweden, and Ukraine (**Figure 1.1** BIOMETHAVERSE countries and partners).

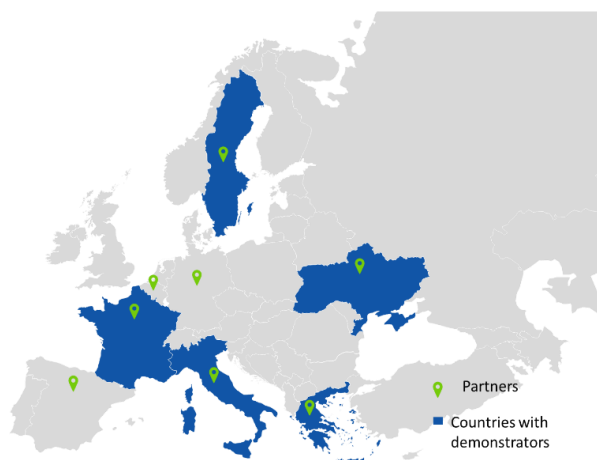


Figure 1.1 BIOMETHAVERSE countries and partners

The main objectives of the BIOMETHAVERSE project are:

- Demonstrate increased cost-effectiveness and innovative biomethane production.
- Increase biomethane sustainability by reducing GHG emissions.
- Ensure replicability and upscaling of the demonstrated biomethane production pathways.
- Ensure market penetration of the demonstrated technologies and producing policy recommendations.

In the BIOMETHAVERSE demonstrators, the CO₂ effluent in the biogas from anaerobic digestion (AD) or from gasification are combined directly with renewable power or in synergy with hydrogen to increase the overall biomethane yield, via thermochemical processes or by exploiting the biomethanation microbial potential.

The five innovative technological concepts address sustainability and circularity as a whole, where waste, emission, and energy leakage are minimized by closing the energy and material loops while aiming at reducing the overall biomethane production costs and increasing its production. In particular, all demonstrated production routes go beyond conventional technologies, contributing towards the European security of energy supply increasing the biomethane production potential by about 60%. Using a participatory process involving stakeholders, BIOMETHAVERSE will ensure the replicability of demonstrated technologies and to facilitate the market uptake for the five demonstrators by developing a strategic vision for project developers and insights guidance to for policy makers. The five innovative technological concepts that will be demonstrated and implemented are listed in the Table 1.1 and an overview of the concepts is given in the Figure 1.2.

Table 1.1 Innovative technological pathways in BIOMETHAVERSE and the related demonstration plants

Innovative Technological Pathway	Country and Demo leader
<i>In-situ</i> and <i>Ex-situ</i> Electro Methanogenesis (EMG): Electricity enhanced biomethane production	France-ENGIE
<i>Ex-situ</i> Thermochemical/catalytic Methanation (ETM): Thermochemical/catalytic upgrading of biogas using renewable hydrogen	Greece -BLAG
<i>Ex-Situ</i> Biological Methanation (EBM): Biological upgrading of biogas using renewable hydrogen, including feedstock pre-treatment via ozonolysis	Italy-CAP
<i>Ex-Situ</i> Syngas Biological methanation (ESB): biological methanation of syngas from thermal gasification with renewable hydrogen	Sweden-RISE
<i>In-situ</i> Biological Methanation (IBM): Renewable hydrogen integration in the AD reactor	Ukraine-MHP

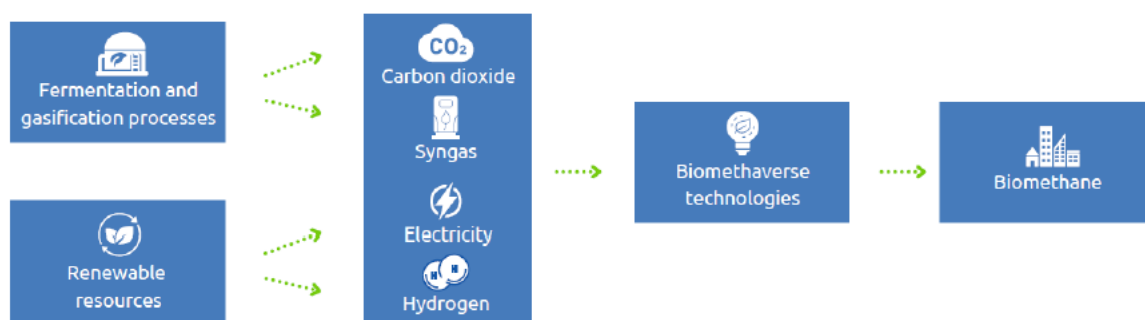
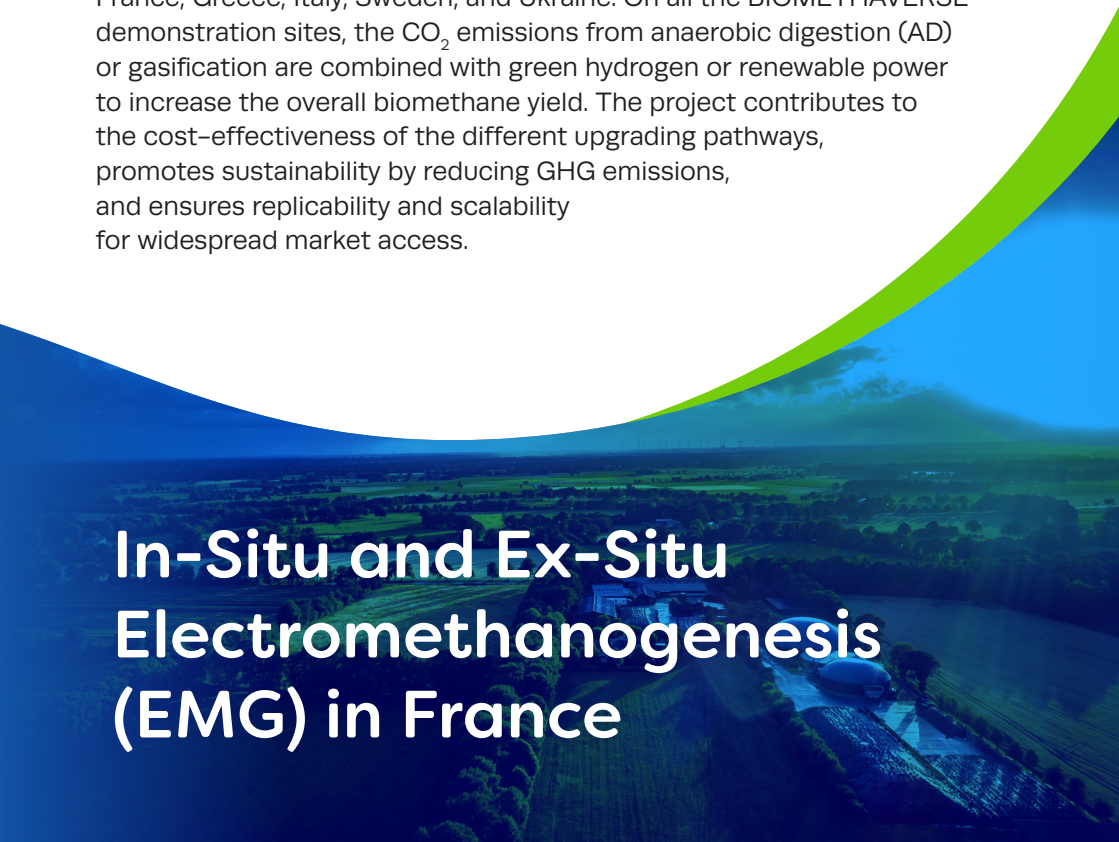


Figure 1.2 Overview of innovative technological concepts in BIOMETHAVERSE

Innovations in bio-methanation technologies: demo-sites from the Biomethaverse project

The BIOMETHAVERSE project aims to diversify the technological basis for biomethane production in Europe. Five innovative biomethane production pathways are currently the subject of demonstration sites in France, Greece, Italy, Sweden, and Ukraine. On all the BIOMETHAVERSE demonstration sites, the CO₂ emissions from anaerobic digestion (AD) or gasification are combined with green hydrogen or renewable power to increase the overall biomethane yield. The project contributes to the cost-effectiveness of the different upgrading pathways, promotes sustainability by reducing GHG emissions, and ensures replicability and scalability for widespread market access.



In-Situ and Ex-Situ Electromethanogenesis (EMG) in France

ENGIE pilot scale

Eppeville, Hauts de France region (France)

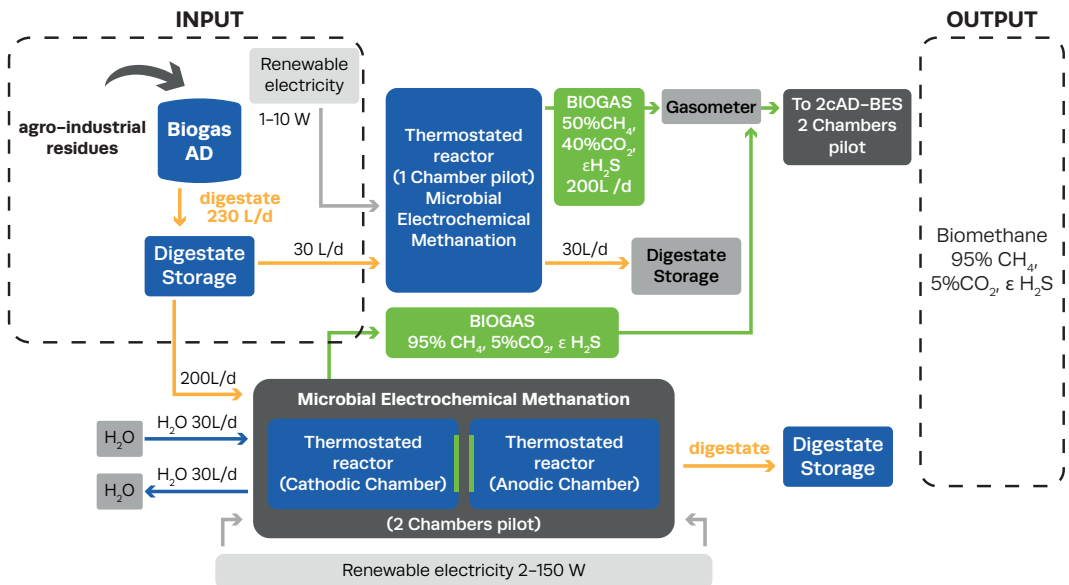
The ENGIE AD plant is located at Eppeville, in the Hauts de France region; it occupies an area of 2.5 ha, and produces 30 million m³ (30 GWh) of biomethane per year. The plant's capacity of 30 GWh is enough gas to meet the consumption needs of 2,500 homes. Up to 350 Nm³/h are injected into the natural gas grid. Biogas is produced continuously in stirred tank reactors under mesophilic conditions using 50,940 tonnes/year of agro-industrial and agricultural residues. The plant has a total digestion volume of 6,000 m³ (comprising 2 main digesters of 2,280 m³ and 1 post-digester of 2,280 m³, with over 50 days of HRT). The digestate storage capacity of the unit is 27,000 m³ and the digestate is valorised through land-spreading over 6,000 ha of farmland (31 farms).

Basic facts:

- **Location** (city and country): Eppeville, Hauts de France region, France
- **Feedstocks used**: agro-industrial residues (50,940 tonnes/yr)
- **Plant production capacity** (m³/h biogas): 350
- **Digester volume** (m³): 2,280 x 3
- **Operational start date**: 2016
- **Upgrading technology**: membrane



Microbial electrosynthesis of CH_4 , or electro-methanogenesis (EMG), is a bioelectrochemical process: it produces biomethane via electroactive microbes, which use CO_2 as a carbon source in a system powered by an electric current. The pilot consists of two consecutive sub-systems, both based on electro-methanogenesis. In the first configuration (the single-chamber reactor 1c-AD-BES), referred to as a bioelectrochemically enhanced anaerobic digester, electrodes biased under a given voltage are directly immersed in the digestate. The electrodes increase overall biogas production by promoting both oxidative and reductive processes in the AD. The second system (the double-chamber reactor 2c-AD-BES) has two compartments, with a proton exchange membrane between the electrodes. Biogas from 1c-AD-BES flows onto the cathode, where protons are reduced to H_2 and combined with CO_2 to form CH_4 using micro-organisms introduced to the system via the digestate stream. The 2c-AD-BES reactor can be used to upgrade biogas to high purity biomethane (>95%), and to bioelectrocatalytically convert residual CO_2 from biogas in power to gas applications.



Timeline

The technology is set to progress from TRL 4 to TRL 6 by the end of the project.



Facts: Design and Implementation

1/4

What are the most important influencing process parameters, and how are they investigated in the lab tests?

For both systems the applied voltage significantly influences the process. In 1C-ADBES, the application of an optimal voltage steers the electrode colonisation by the micro-organisms towards an optimal CH_4 production rate. In 2C-ADBES, the voltage is linked to the biogas flow rate. In this setup, the voltage must be sufficient for complete CO_2 conversion, but low enough to avoid surplus H_2 production. Managing mixing conditions also poses significant challenges due to the presence of electrodes. Potential solutions are being explored, including digestate recirculation or relocating the mixer within the reactors.

2/4

What are the main technical or operational challenges faced during the implementation process?

The primary challenges concern the digestate stream, which must be continuous for both reactors, and the acid consumption. Because a stable pH of around 7 is required in the cathodic chamber, acid addition may be necessary to keep the microbiology in optimal conditions. To mitigate this need, the digestate flow must be adapted so as to restrict the pH increases during the HRT process to small variations. In the one-chamber reactor, it is anticipated that continuous feeding by liquid digestate would impact the biogas production flowrate. Optimisation of this parameter is ongoing at pre-pilot scale (10L).

3/4

Are there specific safety aspects to be considered and how are they being addressed?

The safety of the installation is assessed in a similar way to full scale AD plants. The main difference lies in the presence of electrically connected electrodes within the reactor. In absence of oxygen, the ATEX risk is absent; however, low gaseous pressure could allow oxygen to enter, thus introducing the ATEX risk. Specific automated safeguards linking the biogas pressure with electrode connection must be installed.

4/4

How much can this innovation increase the biomethane output and reduce production costs?

It is anticipated that this innovation could increase the production rate of a standard biogas plant producing 250 Nm³/hr by as much as 40%. The numbers below were calculated based on a full-size plant integrating electro-methanogenesis; the table includes a baseline reference scenario (i.e. biogas plant only) and 3 improved scenarios: (i) Biogas plant + 1c-AD-BES (ii) biogas plant + 2c-AD-BES, (iii) biogas plant + 1c-AD-BES + 2c-AD-BES. For ease of comparison, the same increase of +40% CH₄ production rate was applied in each of these scenarios.

	Unit	Biogas plant	Biogas plant + 1c-AD-BES	Biogas plant + 2c-AD-BES	Biogas plant + 1c-AD-BES + 2c-AD-BES
CH ₄ production	Nm ³ /h	250	350 (+40%)	350 (+40%)	350 (+40%)
CO ₂ emissions	Nm ³ /h	189	264 (+40%)	89 (-53%)	176 (-7%)
CAPEX	EUR	9,044	11,039 (+22%)	8,973 (-1%) ^a	11,886 (+31%)
OPEX	EUR/yr	1,038	1,169 (+13%)	1,051 (+1%)	1,170 (+13%)
LCOE	EUR / MWh _{HHV} ⁻¹	87	72 (-17%) ^b	59 (-32%) ^b 80 (-8%) ^c	71 (-18%) ^b 82 (-5%) ^c

^aCAPEX decrease linked to replacement of the conventional upgrading technology with the cheaper 2C-ADBES (1,500,000 EUR CAPEX). Excluding (°) and including (°) OPEX for an acid injection of 0.2 kg/m³ CH₄

Partners



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Innovations in bio-methanation technologies: demo-sites from the Biomethaverse project

The BIOMETHAVERSE project aims to diversify the technological basis for biomethane production in Europe. Five innovative biomethane production pathways are currently the subject of demonstration sites in France, Greece, Italy, Sweden, and Ukraine. On all the BIOMETHAVERSE demonstration sites, the CO₂ emissions from anaerobic digestion (AD) or gasification are combined with green hydrogen or renewable power to increase the overall biomethane yield. The project contributes to the cost-effectiveness of the different upgrading pathways, promotes sustainability by reducing GHG emissions, and ensures replicability and scalability for widespread market access.



Ex-Situ Thermochemical/ catalytic Methanation (ETM) in Greece

Biogas Lagada S.A. Industrial biogas plant Kolchiko, Lagada (Greece)

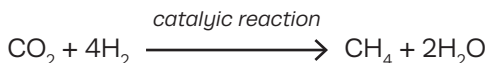
The Biogas Lagada S.A. (BLAG) plant is owned by the Ergoplanning Group of Companies. The comprehensive business model also encompasses four modern livestock enterprises that support the plant's operations. The plant processes 70,000 tonnes of livestock residues and agro-industrial waste annually, reaching a yearly biogas production of 4.2 million m³. Material entering the primary digester (4,000 m³) generates 70–75% of the biogas over a period of about 20 days, after which the feedstock is moved to a secondary digester (4,000 m³) for an additional 20 days, where it produces the remaining 25–30%. The biogas, produced at 500 m³/hr, undergoes dehydration and desulphurisation before fueling a cogeneration engine that provides 998 kW of electricity (8,400 MWh/yr) to the grid and 1,064 kW/hr of thermal energy in the form of hot water for internal operations. The resulting digestate is pasteurised and stored for approximately 120 days before being used as organic soil improver across 2,000 ha of agricultural land.

Basic facts:

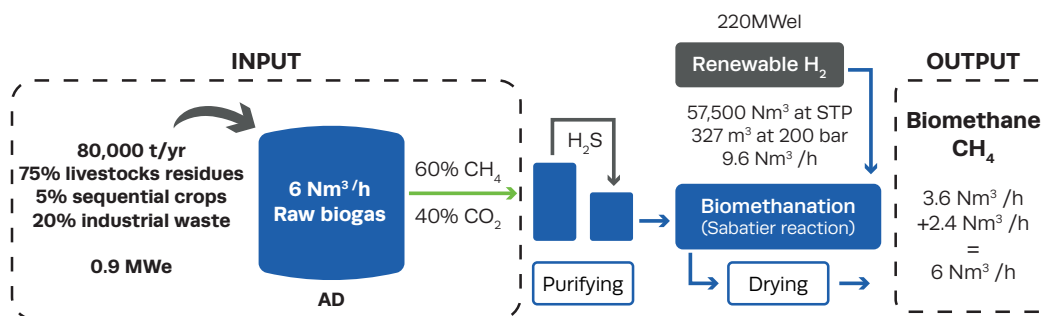
- **Location** (city and country): Kolchiko – Lagadas, Central Macedonia region, Greece
- **Feedstocks used**: livestock residues and agro-industrial waste (70,000 tonnes/yr)
- **Plant production capacity** (m³/h biogas): 290
- **Digester volume** (m³): 4,500 x 2
- **Operational start date**: 2016
- **Upgrading technology**: not yet applicable



This innovative project converts biogenic CO₂ in raw biogas into biomethane by reacting it with renewable H₂ in a catalytic reactor, following the equation:

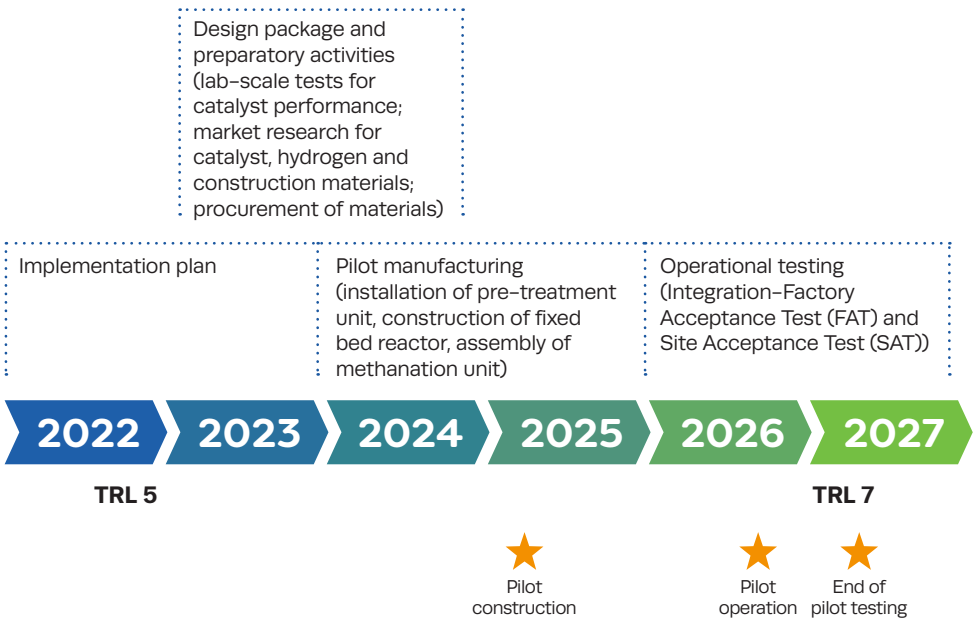


The biomethane produced meets pipeline quality gas standards (96–98 vol-% CH₄) and requires no further enhancement. The pilot plant uses fixed bed reactors and tube heat exchangers for biomethane production. The biogas from the Lagada plant contains CH₄ (55–60%) and CO₂ (40–45%), along with traces of O₂ (0.2–0.8%), N₂ (0.8–3%) and H₂S (1–200ppm). The biogas purification and desulfurisation process comprises three-steps: (i) reduction of H₂S to below 1 ppm via the use of iron hydroxide pellets; (ii) capture of sulfur-containing compounds (i.e. mercaptans) using activated carbon, (iii) removing remaining impurities (e.g. siloxanes) using virgin activated carbon. The conversion of biogenic CO₂ within the biogas is then carried out via 3-step thermo-catalytic methanation. This involves reacting the CO₂ with renewable H₂ using nickel-based catalysts to produce high purity biomethane (>95%).



Timeline

The technology is expected to progress from TRL 5 to TRL7 by the end of the project.



Facts: Design and Implementation

1/4

What are the most important influencing process parameters, and how are they investigated in the lab tests?

The process's success depends on the catalyst composition and the reaction temperature. These parameters greatly influence the efficiency and outcomes of the methanation. Laboratory tests verified the catalyst's quality. The appropriate catalyst composition is essential for catalysing the intended transformations, while an optimal temperature promotes ideal reaction kinetics. Reactor dimensions are determined by analysing the mass and flow balances of input gases, based on experiments conducted with lab-scale equipment. The overall pressure of the gases introduced into the reactor is regulated by mass flow controllers. This method guarantees that the reactor's size and configuration precisely meet process requirements, enhancing efficiency and operational success, and producing pipeline-quality biomethane (96–98 vol-% CH₄).

2/4

What are the main technical or operational challenges faced during the implementation process?

In transitioning from pilot to full scale biomethane plant, strategic measures are required to address the main challenges. In-depth studies on catalyst composition and optimal conditions help prevent the deterioration and contamination of the catalyst and ensure sustained catalyst performance and overall system efficiency. The implementation of requisite safety protocols is essential in H-related activities, including storage, distribution, and replenishment. Process automation, monitored through a controller unit, ensures real-time adjustments for critical parameters (e.g. temperature, pressure, and biogas composition). Continuous evaluation of the operation is vital to identify issues such as reduced biomethane yield or suboptimal catalyst conditions, enabling timely intervention and adjustments for optimal performance.

3/4

Are there specific safety aspects to be considered and how are they being addressed?

Hydrogen poses risks such as flammability and pressure-related hazards, demanding stringent safety measures during transportation and use. Compliance with legislation involves labeling, documentation and adherence to design standards for containers. Safety protocols include loading and unloading procedures. At the biogas facilities, hydrogen storage and usage involve leak detection systems, and constant monitoring of temperature and pressure. Site infrastructure undergoes safety and compatibility assessments, ensuring material resistance to hydrogen and adherence to safety standards. This multifaceted approach ensures safe hydrogen handling from transport to its use in biomethane production.

4/4

How much can this innovation increase the biomethane output and reduce production costs?

Catalytic methanation for biogas upgrading significantly increases biomethane output while reducing production costs. By converting all the CO₂ in the biogas to biomethane, the productivity increases by about 66%, with the output biomethane flow increasing by 2.4 Nm³/h. The process elevates the CH₄ content from 60% in the input biogas flow to over 95% in the output stream. Notably, this method eliminates the need for biogas separation before the catalytic process and the use of product recycling compressors, which are costly in terms of operation and maintenance. Consequently, this innovation is expected to lead to a reduction of production costs by approximately 20% relative to conventional biogas-to-biomethane upgrading technologies.

Cost without BIOMETHAVERSE innovation	Cost with BIOMETHAVERSE innovation	Methane cost reduction	Methane production increase
57 EUR/MWh	39 EUR/MWh	32%	66%

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Ex-Situ Biological Methanation (EBM) in Italy

CAP Holding Wastewater Treatment Plant Bresso-Niguarda (Italy)

Gruppo CAP is one of the main Italian providers of integrated water services, operating 40 wastewater treatment plants (WWTP) of different sizes and capacities in the Lombardy region, serving a population of approximately 2.5 million people. Gruppo CAP's WWTP site in Bresso-Niguarda has a water treatment capacity of 2,200 m³/h of in-flow from the sewer, corresponding to 320,000 PE. The clean water after biological oxidation flows into the Seveso River and is used for agricultural purposes while the sludge is valorised via AD to produce biogas. Installed in 2018, this is the first Italian biogas upgrading plant to produce biomethane from sewage. The plant currently produces about 600,000 m³/yr biomethane, which is injected into the SNAM grid.

Basic facts:

- **Location** (city and country): Bresso-Niguarda, Italy
- **Feedstocks used**: WWTP sewage sludge – AD inlet flow 190,000 m³/yr (1.6% dry matter)
- **Plant production capacity** (m³/h biogas): 90
- **Digester volume** (m³): 6,000
- **Operational start date**: 2018
- **Upgrading technology**: physical scrubbing

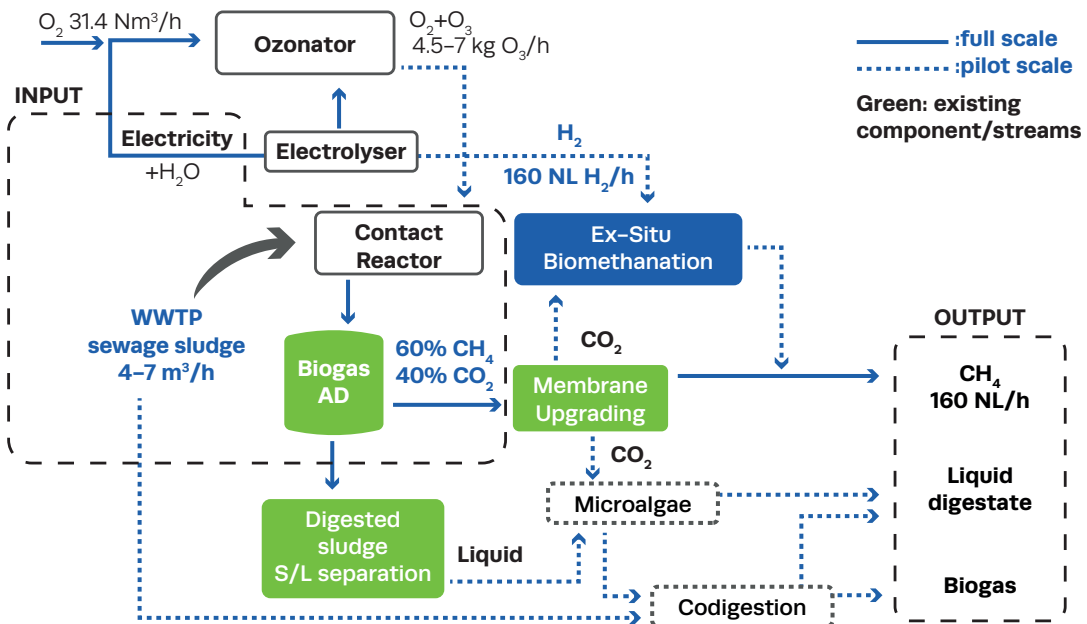


The project will be set up in a demonstrative pilot plant with 4 interlinked technologies. The pilot is composed of 2 main units:

- I. Pretreatment via ozonolysis increases the digestibility of sewage sludge and thereby increases biogas yield and maximises the conversion into biomethane.
- II. Hydrogen assisted biological biogas upgrading (i.e. ex-situ biological methanation, or EBM), in which specific microorganisms convert CO_2 into CH_4 , increases the overall biomethane yields while minimising C emissions for a sustainable energy transition.

2 auxiliary units complement the process by further valorising the CO_2 and waste biomass from the previous stages:

- III. A reactor for the growth of microalgae biomass, fed with the unconverted CO_2 and the liquid fraction of the digestate, reduces CO_2 emissions from the AD process; it absorbs nutrients from the digestate, while regenerating the biomass ready for use for biomethane production in the co-digester (IV).
- IV. A unit for the co-digestion of sludge and microalgae biomass to produce additional biomethane.



Timeline

The demonstrative pilot comprises 4 units, each of which has undergone rigorous laboratory-scale testing and brief experimental campaigns in previous projects, advancing them to TRL 3–4. Within the project framework, thanks to new experimental laboratory tests, technology and design enhancements, and real-world implementation in continuous operation, the objective is to progress to TRL 7.



Facts: Design and Implementation

1/4

What are the most important influencing process parameters, and how are they investigated in the lab tests?

The determining factors in the process are different in each of the 4 technological steps, as indicated in the table below. In the laboratory tests, a range of international standard tools and procedures has been employed to investigate these parameters. Certified laboratory instruments and standardised testing protocols have been used to ensure accuracy and reliability in data collection and analysis.

Ozonolysis	EBM process	Microalgae cultivation	Co-digestion operation
• Biogas flow • O₃ transfer rate • O₃ dosage • Sludge flow rate • Total volume of sludge and volatile solids component	• H₂ input • H₂ transfer efficiency • CO₂ input • % v/v of H₂/CO₂ input • Temperature • Operation pressure • Reactor volume • VFA/Alk • pH	• CO₂ input • pH • Temperature • Nutrient concentration of influent (digestate) and effluent (algal suspension) • Removal efficiency • Biomass productivity	• Mix ratio of input materials (microalgae, sludges, food wastes) and their corresponding biochemical methane potential • Pressure • Temperature • Hydraulic Retention Time

2/4

What are the main technical or operational challenges faced during the implementation process?

In the operation of the ozonolysis reactor, the prevention of ineffective transfer yields is ensured by design and by maintaining the optimal configuration of the contact reactor. Regular maintenance and cleaning procedures avoid clogging and related malfunctions. Optimal sludge dewaterability and polyelectrolytes dosage are crucial for overall reactor performance. To maximise H₂ utilisation in the EBM reactor it is necessary to investigate mass transfer into the medium, bacterial growth factors, and selection criteria that govern the presence and activity of the bacteria. Systematically adjusting and optimising input parameters (e.g. pH, temperature, pressure and hydraulic retention time) fosters the desired biological processes and supports the efficiency of the EBM.

3/4

Are there specific safety aspects to be considered and how are they being addressed?

There are specific safety issues concerning the storage or handling of explosive gases such as hydrogen or oxidising agents like oxygen. ATEX assessments and fire authorisation procedures have been carried out, resulting in the issuance of Fire Prevention Certification (CPI) and ATEX permits.

4/4

How much can this innovation increase the biomethane output and reduce production costs?

The project aims to enhance biomethane productivity by up to 66% through the conversion of CO₂ into biomethane, thanks to the EBM process. In addition, the ozonisation of sewage sludge is projected to boost biogas productivity by about 20% and to reduce the quantity of sludge to be disposed of by 10–15%. It is estimated that this model could reduce biomethane production costs by 44% while ensuring the production of biomethane of gas grid quality.

Cost without BIOMETHAVERSE innovation	Cost with BIOMETHAVERSE innovation	Methane cost reduction	Methane production increase
44.2 EUR/MWh	23.9 EUR/MWh	44%	78%

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Ex-Situ Syngas Biological Methanation (ESB) in Sweden

Cortus Energy plant Höganäs, Götaland region (Sweden)

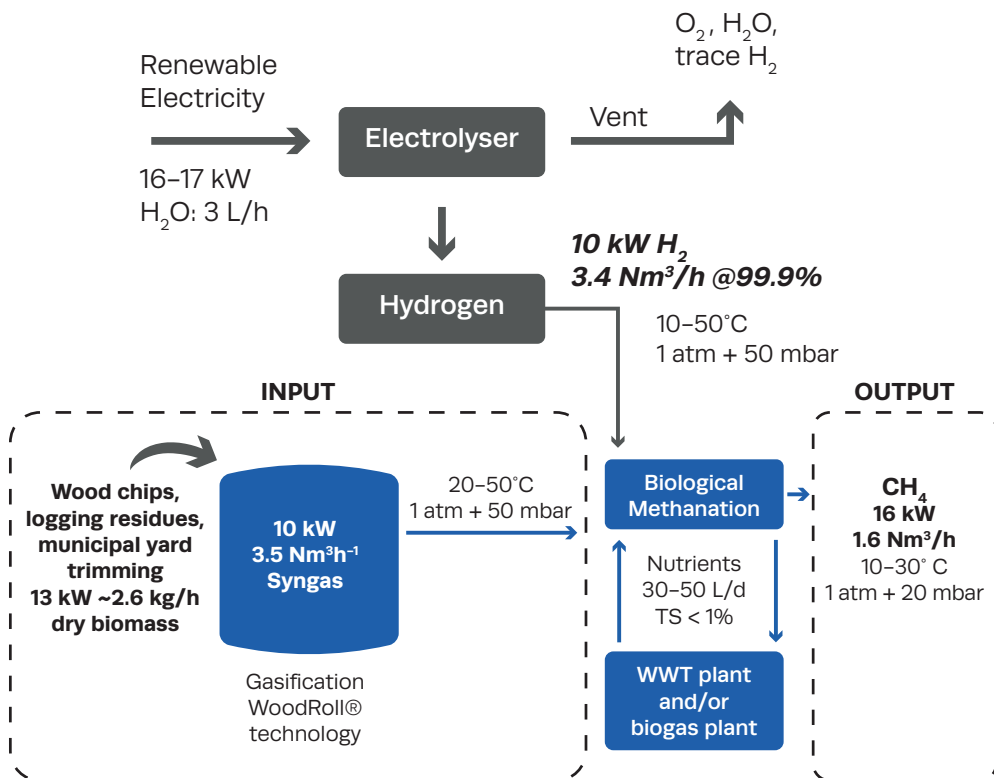
The demonstration site is an existing 6 MW gasification plant owned by the company Cortus. The plant is situated in Höganäs, in the Götaland region. The gasification technology employed is referred to as the WoodRoll® process. This involves drying, pyrolysis and gasification stages to convert raw biomass into synthesis gas, a mixture of carbon monoxide (CO) and hydrogen (H₂) in a ratio of approximately 1:2 CO:H₂. Additionally, the gas contains CO₂ (13–14%) and CH₄ (1–2%). The current feedstock is wood chips with a 40% moisture content. However, the plant could run on fuel with up to 45% moisture without pre-drying, meaning the conversion of woody waste products such as logging residues or municipal yard-trimmings is possible. The syngas produced is used as a green energy input for steel powder manufacture by a neighbouring industry.

Basic facts:

- **Location** (city and country): Höganäs, Götaland region, Sweden
- **Feedstocks used**: Wood chips, logging residues, municipal yard-trimmings (20,000 tonnes/yr)
- **Plant production capacity** (m³/h biogas): 2,000 (6 MW)
- **Digester volume** (m³): 30
- **Operational start date**: 2020
- **Upgrading technology**: not yet applicable



The conversion of syngas (CO , H_2 , CO_2 and CH_4) to biomethane via biological methanation is demonstrated in a Trickle Bed Reactor (TBR). The technology is containerised and mobile to allow processing at separate sites. The reactor is fed by syngas and a nutrient solution, in the form either of digestate from a co-located conventional biogas plant or of reject water from municipal wastewater sludge dewatering. The syngas meets a selectively adapted mixed-culture biofilm on carriers and a continuous flow of nutrient-rich solution. CO and H_2 are consequently converted to CH_4 and CO_2 . The TBR design allows for a high exchange rate between the gas and liquid phases. If it is also desirable to utilise the remaining CO_2 and produce a final gas mix with a very high CH_4 content, an additional source of H_2 from an electrolyser can be added to the input syngas.



Timeline

Design of demonstration pilot plant

Demonstration site completion (Cortus)

Demonstration pilot plant start-up at host site (Cortus)

Demonstration pilot plant run phase 1: syngas methanation

Demonstration pilot plant run phase 2: syngas methanation and H₂ boost

Operation including data collection

Process data evaluation

2023

2024

2025

2026

2027

TRL 3-4

TRL 6



Pilot construction



Pilot operation



End of pilot testing

Facts: Design and Implementation

1/4

What are the most important influencing process parameters, and how are they investigated in the lab tests?

The key parameter is the specific CH₄ production. Lab tests explored the concept of connecting 2 TBRs in series. In the first reactor the syngas was converted to CH₄ and CO₂ mixture, while in the second the remaining CO₂ was converted with added H₂. This created separate environments to optimise the conditions for CO and H₂ converting microorganisms separately. High CH₄ production despite high pH (intermittently > 8), along with high conversion of CO₂, were obtained without excessive surplus of H₂ in the output gas (intermittent periods of 2 vol% H₂, < 1 vol% CO₂). This indicates that maintaining pH control and implementing gas recirculation or other CO₂ polishing systems may not be crucial, potentially leading to lower capital and operational expenditures.

2/4

What are the main technical or operational challenges faced during the implementation process?

One of the primary challenges involves efficiently and safely detecting a gas leak and sealing the gas system, should a leak occur.

It is crucial to achieve sufficient power in the heating and cooling system to maintain a stable reactor temperature, independent of weather and operating mode, without resorting to an excessively high recirculation frequency, which would disturb the microbes.

Successfully pretreating the nutrient solution is vital, particularly the removal of enough suspended solids to prevent clogging of the trickling bed. The challenge lies both in the technical execution and in determining the necessary reduction of solids for optimal performance.

3/4

Are there specific safety aspects to be considered and how are they being addressed?

The CO contained in the syngas is toxic and this issue is addressed using risk analysis. Several measures have been taken to reduce the probability and consequences of a gas leak. Primarily, the plant has been designed with components with the greatest risk of gas leakage placed outside. Indoors, ventilation is maintained to avoid any leaked gas accumulating in the closed environment. Finally, both stationary and portable gas detectors with alarm function are used to ensure the safety of personnel.

4/4

How much can this innovation increase the biomethane output and reduce production costs?

The use of syngas for CH₄ production increases the biomethane potential as new carbon sources can be used as substrates. The external H₂ addition further increases CH₄ production as all carbon molecules are converted into CH₄. In the table below, catalytic syngas methanation without a hydrogen boost serves as the reference point *without BIOMETHAVERSE innovation*. *With BIOMETHAVERSE innovation*, ESB methanation with H₂ -boost, the cost is reduced by 23% and the methane production is increased by 100%.

Cost without BIOMETHAVERSE innovation	Cost with BIOMETHAVERSE innovation	Methane cost reduction	Methane production increase
135 EUR/MWh	103.5 EUR/MWh	23%	100%

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Visit Biomethaverse website:
www.biomethaverse.eu



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Innovations in bio-methanation technologies: demo-sites from the Biomethaverse project

The BIOMETHAVERSE project aims to diversify the technological basis for biomethane production in Europe. Five innovative biomethane production pathways are currently the subject of demonstration sites in France, Greece, Italy, Sweden, and Ukraine. On all the BIOMETHAVERSE demonstration sites, the CO₂ emissions from anaerobic digestion (AD) or gasification are combined with green hydrogen or renewable power to increase the overall biomethane yield. The project contributes to the cost-effectiveness of the different upgrading pathways, promotes sustainability by reducing GHG emissions, and ensures replicability and scalability for widespread market access.



In-Situ Biological Methanation (IBM) in Ukraine

MHP biogas

Ladyzhin Vynnytsia Region (Ukraine)

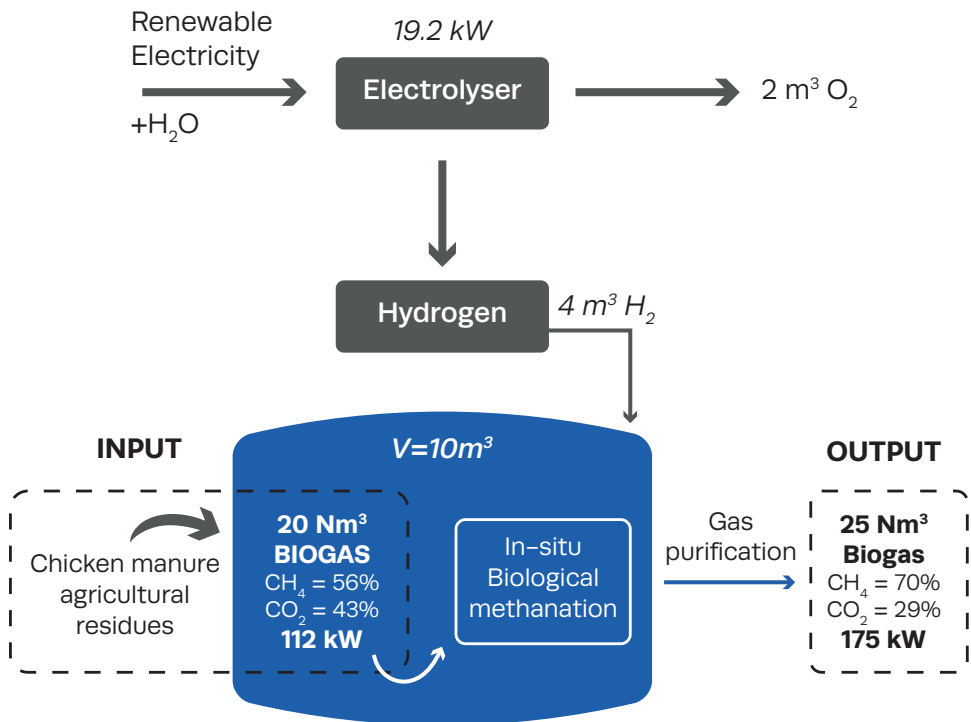
MHP Group's Vinnytsia Poultry Farm in Ladyzhin, in the Vinnytsia region of Ukraine, operates a biogas facility processing about 330 tonnes/day of chicken manure and other agricultural residues. The biogas plant is operated at the standard organic loading rate (OLR) of 3.5 ± 0.5 g volatile solids/L per day for anaerobic fermentation. The hydraulic retention time (HRT) is 45 days. The plant began operation in 2019 and is the biggest in Ukraine, with an installed electric capacity of 12 MWe. Its twelve reactors (9 main digesters and 3 post digesters), each with a volume of $7,500 \text{ m}^3$, produce a total of 85 GWh of electricity per year. The plant's own biogas pipeline transfers biogas to the cogeneration unit, located near the slaughter complex, in order to use heat to supply the slaughter complex with steam. 7–8% of the electricity generated is used by the biogas plant for its own needs. The fermenters are heated by a solid fuel boiler room.

Basic facts:

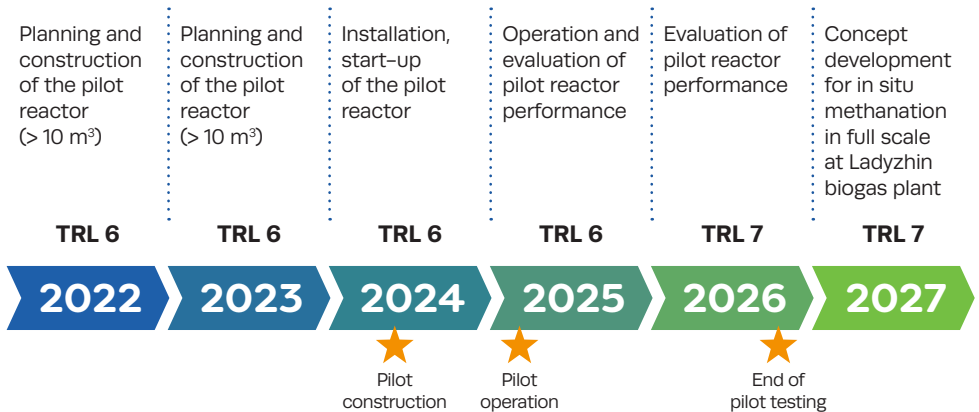
- **Location** (city and country): Ladyzhin, Vynnytsia Region, Ukraine
- **Feedstocks used**: chicken manure and agricultural residues ($120,450 \pm 18,250$ tonnes/yr)
- **Plant production capacity** (m^3/h biogas): 5,200
- **Digester volume** (m^3): $7,500 \times 12$
- **Operational start date**: 2019
- **Upgrading technology**: not yet applicable



By injecting H_2 directly into an AD reactor, the activity and the metabolic pathways of microbial consortia (i.e. hydrogenotrophic methane formers) are increased and the CO_2 in the biogas is reduced to CH_4 . This results both in an overall increase in the biomethane yield per given amount of feedstock, and in a higher CH_4 concentration (55–85 vol%) in the final biogas produced. The supply of additional green H_2 to the running AD reactor is provided using an existing gas circulation mixing system instead of conventional stirrers. Biogas from the headspace of the reactor is pumped to the bottom of the fermenters to achieve mixing of the substrate and a high conversion of H_2 and CO_2 into CH_4 .



Timeline



Facts: Design and Implementation

1/4

What are the most important influencing process parameters, and how are they investigated in the lab tests?

The critical influencing process parameters include the H_2 flow rate, reactor volume, temperature, hydraulic retention time, and organic loading rate. These parameters are investigated in the lab tests through systematic observation and experimentation. The H_2 flow rate is controlled using a calibrated device for hydrogen dosing. The reactor volume is monitored visually, through an inspection window. The temperature of the working environment is regulated by three independent temperature sensors. Gas composition is assessed daily using a portable gas analyser and periodically using gas chromatography. HRT and OLR are determined by analysing the input of raw material for dry organic matter content and daily loading volume, respectively.

2/4

What are the main technical or operational challenges faced during the implementation process?

The main technical challenges to the implementation process include optimising the H₂ flow rates, managing reactor volumes effectively, and addressing potential erosion of the gas mixing system. Operational challenges involve maintaining optimal process parameters, such as gas recirculation rates and temperature, for sustained efficiency. H₂ poses risks during transport and handling, and these require careful consideration.

3/4

Are there specific safety aspects to be considered and how are they being addressed?

Enhancing safety aspects is paramount and requires measures to mitigate potential risks and ensure a secure working environment. These measures entail the enforcement of stringent protocols for H₂ storage, transport, and usage, complemented by regular safety audits. Additionally, robust safety training for personnel handling hydrogen proactively prevents accidents and ensures a safe implementation process.

4/4

How much can this innovation increase the biomethane output and reduce production costs?

In-situ methanation is expected to significantly increase biomethane output at the Ladyzhin biogas plant. While specific figures may vary, the project aims to raise the methane concentration in the final biogas from 55% to 85% using H₂ injection, resulting in an overall increase in biomethane yield. The innovation may also help to reduce costs by improving carbon efficiency in the AD process.

Cost without BIOMETHAVERSE innovation	Cost with BIOMETHAVERSE innovation	Methane cost reduction	Methane production increase
31 EUR/MWh	27 EUR/MWh	13%	40%

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