

Non-impact bus: Circular economy for sustainable transport

DD1.7 – Layman's report

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Full name: Non-IMpact BUS: Demonstration of a biological methanation plant for sustainable urban transport

Acronym: LIFE NIMBUS

Funding: LIFE programme, the funding instrument of the European Union for environment and climate action

Budget: €1,987,494 (EU contribution: €894,372)

Duration: 58 months (from September 2020 to June 2025)

Coordinator: Cetaqua Barcelona

Consortium: Aigües de Barcelona, Universitat Autònoma de Barcelona and Transports Metropolitans de Barcelona

Demonstration site: Baix Llobregat WWTP (Barcelona, Spain)

Website: <https://www.life-nimbus.eu/>



Renewable fuels for transport:

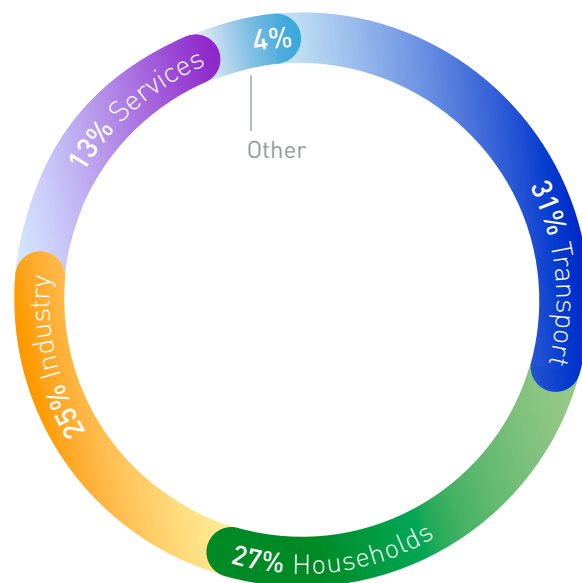
A bit of context

The transport sector demands above 30% of total energy consumption in Europe. However, despite an increasing diversification of energy sources, such as natural gas and electricity, more effort is needed to reduce its impact on the environment.

In this context, while the production and use of renewable electricity in the European Union (EU) continues to grow – accounting for 47% of electricity in 2024 – the prospects for wind and solar sources being added into the power mix are limited by the electricity grid's storage capacity, which often means that the renewable power plants are forced to decrease supply during low demand periods.



Image 1. Mobility in high-density environments.



31%
Transport



27%
Households



25%
Industry

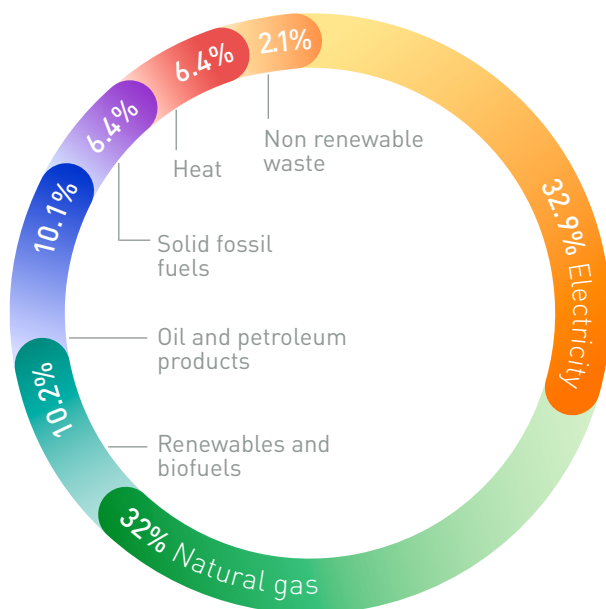


13%
Services



4%
Other

Figure 1. Final energy consumption by sector, EU, 2022. Source: Eurostat.



Moreover, **the increase in renewable electricity does not translate into a corresponding rise in renewable fuels**: in 2024, only around 10% of the fuels used for transport within the EU were of renewable origin.

In order to help meet the EU's goal of having 29% of energy consumption for transport come from renewable sources by 2030, **the production of biomethane through the combination of sludge digestion and surplus renewable energy – via a process known as power-to-gas – presents an interesting opportunity**, as this approach creates a bridge between renewable electricity generation and the decarbonisation of the transport sector.

Biomethane is a high-quality renewable biofuel that can be easily adopted as a transport fuel in place of natural gas, offering the potential to reduce CO₂ emissions by up to 88%, aligning with European regulations for CO₂ emissions reduction in transport (Regulation 2019/631). Several cities – such as Stockholm, Bergen, Lille and Bristol – have already adopted biomethane-powered buses, sourcing the fuel through various biogas upgrading technologies.

Wastewater treatment plants (WWTPs) have a huge potential for biomethane production, as they enable the use of sludge derived from wastewater while also offering space for implementing power-to-gas technologies and storing the biomethane generated.

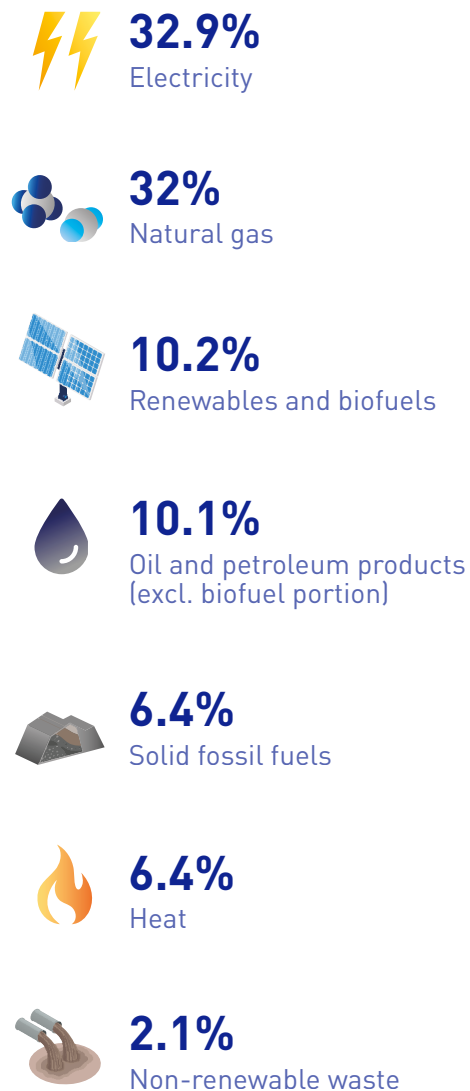


Figure 2. Final energy consumption by energy product, EU, 2020. *Source: Eurostat.*

This promotes a circular economy model and helps to reduce urban environmental impacts.

It is with this vision that the LIFE NIMBUS project was launched, becoming the first case of biomethane production for public urban road transport in Barcelona.

LIFE NIMBUS: Production of biomethane for sustainable urban transport

LIFE NIMBUS, a project co-financed by the LIFE programme of the European Commission, aims to **produce biomethane as a sustainable fuel for Barcelona's public road transport system**. It achieves this by developing an innovative system that integrates sewage sludge treatment with power-to-gas technologies at a WWTP.

Led by Cetaqua-Water Technology Centre, and carried out in collaboration with Aigües de Barcelona, the Universitat Autònoma de Barcelona (UAB) and Transports Metropolitans de Barcelona (TMB), LIFE NIMBUS seeks to transform WWTPs into ecofactories – facilities that recover valuable resources from waste materials (in this case, sewage sludge) and from otherwise unexploited resources (such as surplus renewable energy).

To achieve this goal, biogas from the anaerobic digestion of sewage sludge is upgraded to **biomethane through biological methanation**, using hydrogen produced with surplus renewable electricity and reclaimed water or wastewater.

The renewable biomethane produced through this process can then be used to fuel buses at a dedicated biomethane refuelling station.

The LIFE NIMBUS pilot, **located at the Baix Llobregat WWTP** in El Prat de Llobregat (Barcelona) and operated by Cetaqua, has successfully demonstrated the technical feasibility of producing biomethane from sewage sludge using power-to-gas technologies.

This biomethane has been used to fuel NIMBUS, a pilot bus operated by TMB that has covered several lines over two years, confirming that this solution can be applied in a real-world urban setting and marking a significant milestone in the city's efforts towards sustainable urban transport. The pilot also serves as a **springboard for exploring large-scale biomethane production at WWTPs and shows strong potential for other sectors such as freight transport**.



Image 2. General view of the LIFE NIMBUS pilot site.

The renewable biomethane produced through this process can then be used to fuel buses at a dedicated biomethane refuelling station

Main objectives of the LIFE NIMBUS project



Demonstrate the biological biogas methanation process to produce biomethane at an urban WWTP, ensuring sufficient quality for use as a biofuel.



Contribute to more sustainable mobility by using biomethane as a biofuel, reducing the carbon footprint of the NIMBUS bus.



Promote the power-to-gas concept within urban environments by leveraging the potential of renewable energies, while disseminating the benefits of the solution to maximise its societal and environmental impact.



Foster a circular economy between the WWTP and the city, raising awareness among stakeholders and key decision-makers about the great potential of creating energy from waste, moving towards eco-cities.



Contribute to the implementation of the revised European Renewable Energy Directive (RED III), which sets the target that renewable energy sources account for 29% of EU energy in the transport sector by 2030.



Increase social awareness among Barcelona's citizens about the city's circular economy initiatives and its progress toward becoming a circular city.



Assess the replicability of the demonstration project at other sites across Europe.



Image 3. NIMBUS bus being refuelled at the project's pilot site.

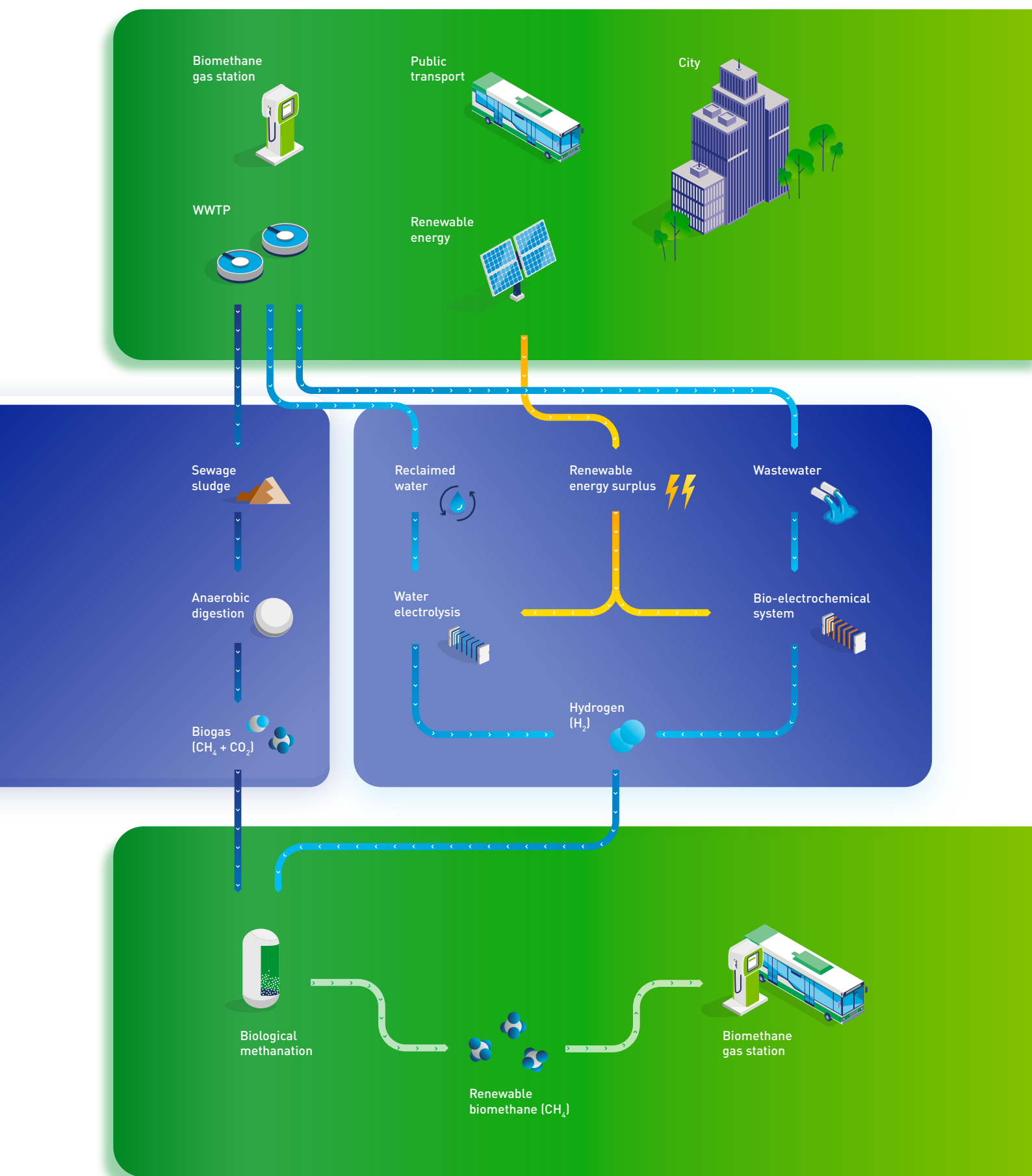


Figure 3. LIFE NIMBUS process. *Source: own production.*

Technological solution

At the Baix Llobregat WWTP, sludge from wastewater undergoes **anaerobic digestion** to stabilise it and reduce methane emissions, which would otherwise contribute significantly to global warming. This process produces **biogas**, primarily composed of **methane (64%)** and **carbon dioxide (36%)**, along with trace gases like hydrogen sulphide.

At the Baix Llobregat WWTP, the **biogas is used on-site** to generate **heat and power**, improving energy efficiency.

Biogas upgrading can be achieved using various separation technologies. In the LIFE NIMBUS project, a promising and innovative alternative is being further developed: biological methanation.

The LIFE NIMBUS project focuses on an advanced biogas upgrading method known as **biological methanation**, where carbon dioxide (CO_2) from biogas reacts

with green hydrogen (H_2) to produce biomethane (CH_4) through the **Sabatier reaction**. The LIFE NIMBUS pilot plant is designed to demonstrate this technology with a maximum capacity of $7.4 \text{ Nm}^3/\text{h}$.

Hydrogen is supplied from two sources. One is a **bio-electrochemical system (BES)**, and the second source is an **alkaline electrolyser** powered by surplus renewable electricity and fed with water reclaimed from the WWTP's tertiary treatment process.

The clean biomethane is then **compressed to 250 barg**, odorised, and stored on-site. It is used to refuel buses via a dedicated **compressed gas station**, demonstrating the viability of this system as a renewable fuel solution.

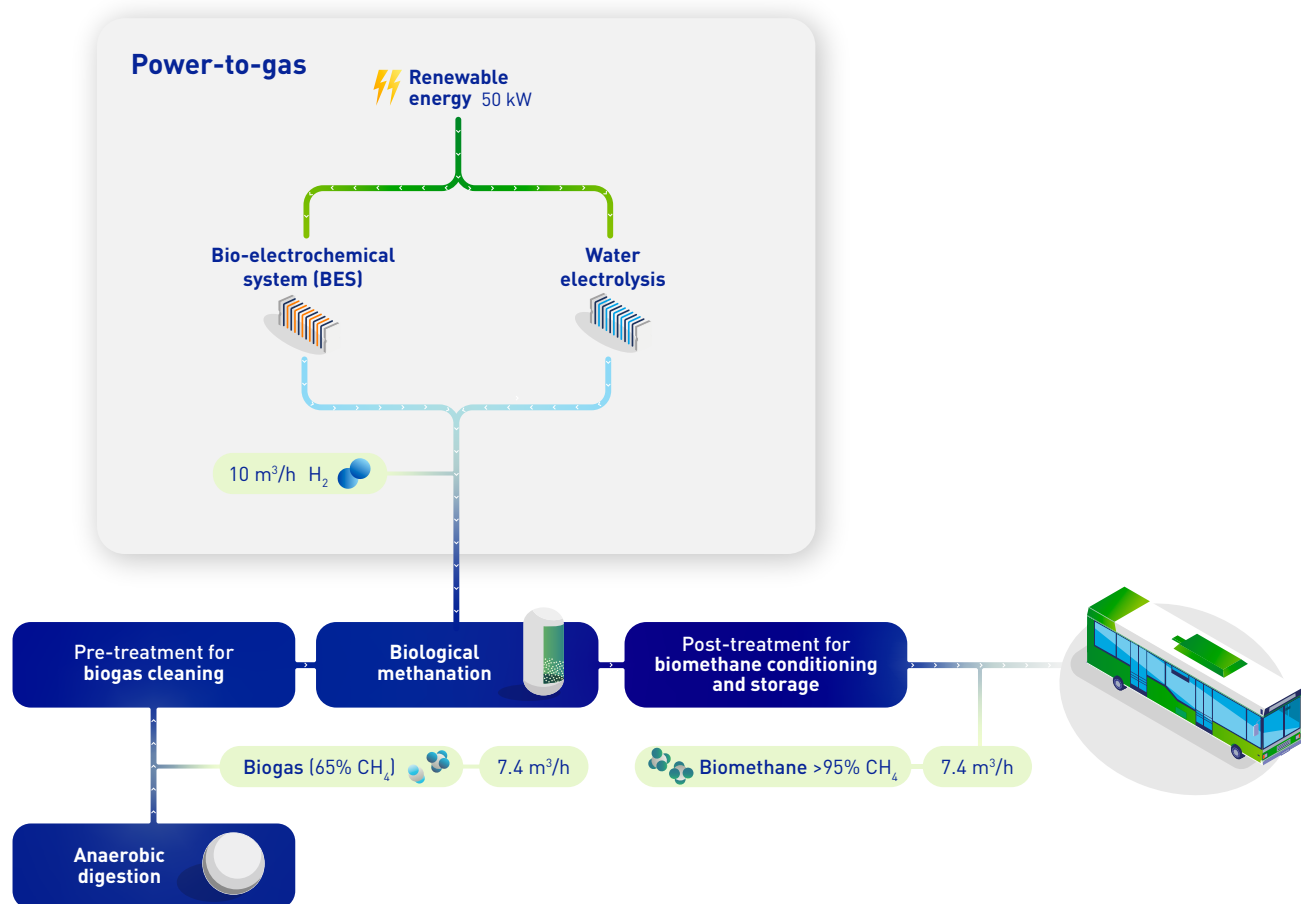


Figure 4. LIFE NIMBUS Power-to-gas technology. *Source: own production.*

Hydrogen production process:

A significant innovation from the LIFE NIMBUS project

The production of H_2 in power-to-gas systems is typically carried out through water electrolysis, a well-established technology that uses electricity to split water molecules into hydrogen and oxygen gases. However, its energy demand is very high, around 5 kWh/m³ of H_2 . An alternative to reducing the energy consumption of H_2 production is the bio-electrochemical approach, which can significantly lower energy demand.

The LIFE NIMBUS project introduces a **major innovation in biohydrogen production** through the scale-up of **microbial electrolysis cell (MEC)** technology, a type of **bio-electrochemical system (BES)**. This system uses microorganisms to oxidise organic matter in wastewater at the anode, while producing hydrogen at the cathode with a minimal external voltage input – significantly lower than that of conventional electrolysis.

The pilot plant, the largest of its kind to date, treats real wastewater on-site and produces hydrogen of high-grade purity (>90%), which is then intermittently fed to the biomethanation unit. The modular design supports future scalability, and the project will provide the first performance data for coupling MEC-derived hydrogen with biological methanation in a WWTP context.



Image 4. Bio-electrochemical system that produces hydrogen for the biomethanation pilot plant within the LIFE NIMBUS site.

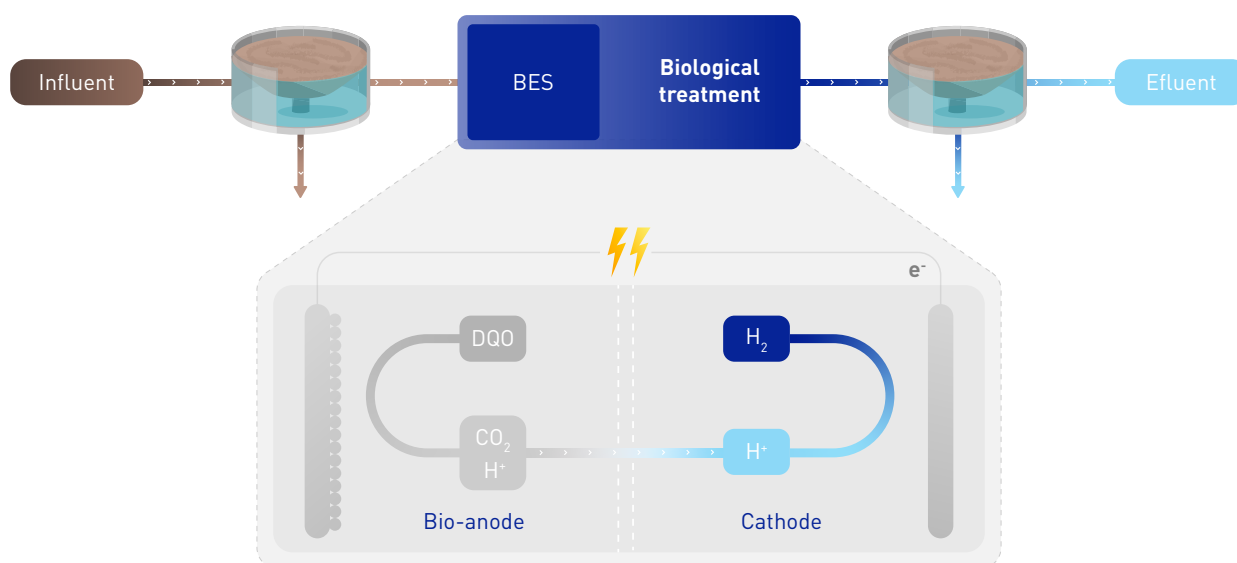


Figure 5. LIFE NIMBUS hydrogen production process. *Source: own production.*

What are the key differences between conventional biogas upgrading processes and biological methanation?

Conventional separation technologies remove CO_2 by using physical or chemical processes to obtain a gas with a higher methane content. In contrast, **biological methanation does not remove the CO_2 – it chemically transforms it into CH_4** by using a specific bacteria called **archaea** and hydrogen produced from renewable electricity. This not only increases the total methane yield and energy content of the gas, but also makes the process more energy efficient, as it stores renewable electricity in the form of methane, effectively enabling a **power-to-gas** approach that allows to transform electrical energy into chemical energy.

Biological methanation does not remove the CO_2 – it chemically transforms it into CH_4



Image 5. LIFE NIMBUS pilot biomethanation tower.



Want to discover the plant first-hand? Take the LIFE NIMBUS virtual tour

If you want to visit the LIFE NIMBUS site from home, scan this QR code for an interactive virtual tour that is not to be missed.

What has LIFE NIMBUS achieved?



Demonstration and validation of the biological biogas methanation process as a feasible solution for producing high-quality biomethane in an urban WWTP.



Promotion of biomethane as a sustainable fuel for urban transport available to government authorities, transportation professionals, technologists, and the citizens of Barcelona.



Production of 10,500 m³ of biomethane suitable for fuelling a bus.



Development of a replication plan that includes 4 case studies.



Fuelling of NIMBUS, a bus owned by TMB that, at current capacity, is able to cover more than 14,000 kilometres per year using biomethane.



Creation of two alternative business models: a direct supply model and an intermediated model.



Reduction of 29 tonnes of annual CO₂ and an 85% decrease in the carbon footprint of the NIMBUS bus.



Dissemination of project results.



Production of over 67,000 kWh/year of renewable energy, which accounts for an increase of 68% at the Baix Llobregat WWTP.



Discover more about the LIFE NIMBUS results in this video

Do not miss LIFE NIMBUS's final video, featuring all its partners, to learn more about the project and its results in just a few minutes.

Replication plan

The LIFE NIMBUS project represents a strategic commitment to implementing advanced technologies for biomethane production and use, offering an innovative solution to current challenges in sustainability, energy security and the transition towards a circular economy – key objectives of the European Union’s roadmap.

To ensure the continuity of the technology proposed in LIFE NIMBUS, both a replication plan and a business plan have been developed. These plans outline the **strategic roadmap for introducing and positioning LIFE NIMBUS technology in the Spanish and broader European markets**. They also define the operational structure envisioned for its deployment and commercialisation, covering the entire value chain – from the supply, engineering and manufacturing of key equipment, to installation, commissioning, initial operation and technical support services.

Different WWTPs across Europe were identified as **promising candidates for replicating** the LIFE NIMBUS solution. Site selection was based on **technical feasibility, energy context and potential for integrating biomethane production into existing infrastructures**. Additionally, a potential replication opportunity is being investigated involving the application of the LIFE NIMBUS solution for CO₂ capture from an industrial facility. The captured CO₂ would be used in the production of biomethane.

An innovative solution to current challenges in sustainability, energy security and the transition towards a circular economy

Location	Case	Case interest
Ireland	WWTP + Sludge treatment facility	Biomethane production for heavy vehicle fuel , maintaining the full energy self-sufficiency of the facility .
Milan, Italy	WWTP	Biomethane production for public bus transport . Implementation of LIFE NIMBUS in a small WWTP .
Stuttgart, Germany	WWTP	Biomethane production for public bus transport and energy sufficiency . Implementation of LIFE NIMBUS in a medium-sized WWTP .
Sabadell, Spain	WWTP	Biomethane production for public bus transport . Implementation of LIFE NIMBUS in a large WWTP .
Italy	Cement factory	Biomethane production with CO ₂ capture for injection into the gas grid .

Table 1. Selected cases for the replication plant. *Source: own production.*

Business model

The LIFE NIMBUS business model presents a **comprehensive techno-economic assessment of biomethane commercialisation** pathways for the Baix Llobregat WWTP. The analysis explores **two alternative business models** that differ not only in infrastructure configuration, but also in commercial logic, stakeholder involvement and risk allocation.

1 A **direct supply model**, in which biomethane is produced, stored and supplied on-site to the municipal bus fleet via a dedicated refuelling station.

2 An **intermediated model**, in which biomethane is injected into the natural gas grid and distributed indirectly to end users such as industrial consumers or CNG stations.

The analysis also highlights critical risk factors – such as demand concentration, capital expenditure (CAPEX) uncertainty, and regulatory dependencies – as well as sensitivity variables like electricity sourcing and guarantees of origin (GoGs). These findings underline the importance of enabling frameworks, including public support schemes, green financing tools, and stable certification mechanisms, to enhance project bankability.

The direct supply model aligns closely with local decarbonisation goals by serving public transport directly, offering strong system control and public acceptance, but requires higher investment and depends on a single off-taker.

In contrast, **the intermediated grid injection model enables broader market reach and scalability through the gas network, though it introduces reliance on external actors and regulatory complexities.** Both models are technically and economically viable, with different strengths: local impact vs. systemic integration. The choice depends on local context, stakeholder capacity and policy support.

The outcomes of this study provide a strong foundation for informed investment decisions at the Baix Llobregat WWTP, while also offering a scalable and replicable model for other wastewater treatment plants and municipalities across Europe.

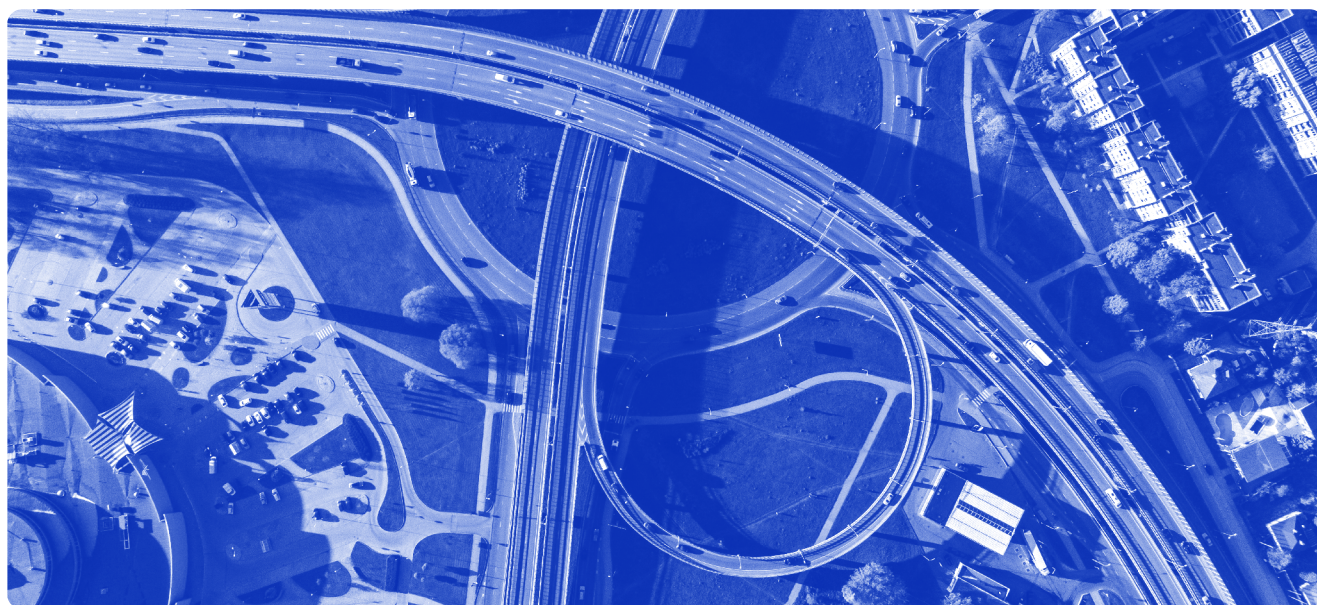


Image 6. Highway interchange in an urban setting.

Benefits and impacts of LIFE NIMBUS

The impacts of LIFE NIMBUS's technology have been assessed from environmental, economic and social perspectives using standardised methodologies such as life cycle assessment (LCA), life cycle costing (LCC), cost-benefit analysis (CBA) and social life cycle assessment (S-LCA).

The analysis compares three scenarios:

1 Conventional natural gas (NG) production and use (baseline)

2 The NIMBUS solution

3 Conventional biogas upgrading process based on membrane separation technology

Environmental assessment

From an environmental standpoint, **the NIMBUS solution shows net carbon savings**. This demonstrates that NIMBUS not only avoids emissions but potentially captures carbon or offsets more than it emits. The biogas upgrading scenario also results in improved environmental outcomes compared to conventional natural gas, although it does not reach the performance level of the NIMBUS solution.

NIMBUS technology consistently outperforms both conventional biogas upgrading and the baseline natural scenario across nearly all impact categories. Particularly notable are its **advantages in global warming mitigation, air pollutant reduction and resource efficiency**.



Image 7. Laboratory work on biomethane innovation.

Economic assessment

Economically, the baseline remains the least costly option in terms of both capital and operational expenditures. However, these cost advantages are offset by significantly higher environmental impacts. **The NIMBUS pathway entails higher capital investment yet offers long-term benefits** through reduced environmental externalities. The upgrading scenario, while showing moderate capital investment, is associated with the highest operational costs.

The baseline scenario emerges as the most cost-viable option for fuel procurement in urban transport, boasting the lowest construction and operational expenses. This outcome underscores the maturity and established nature of conventional natural gas production. In contrast, the higher CAPEX associated with the NIMBUS scenario reflects its status as a less advanced technology. However, as research progresses, these costs may decrease, akin to the trend observed in upgrading technology, which has advanced significantly over time.

Cost-benefit analysis

Considering both economic and environmental factors, **the NIMBUS process stands out as the most cost-effective and sustainable solution**. Although its economic costs are higher than those of the baseline, its significantly lower environmental impact – as demonstrated by the LCA – positions it as the preferred option for achieving long-term sustainability and resource efficiency.

Social assessment

Socially, the NIMBUS project has had a generally positive impact. Workers have reported improved capacities and overall well-being. Actors along the value chain expressed strong acceptance of the developed technology, reinforcing its perceived viability and potential for deployment. Nonetheless, community engagement was found to be limited and remains an area for improvement. Similarly, involvement from decision-makers and academic stakeholders was moderate, suggesting the need for enhanced institutional outreach in future implementations.

Considering both economic and environmental factors, the NIMBUS process stands out as the most cost-effective and sustainable solution



Image 8. Public transport in use.

Next steps: project continuation

Although the project concluded in June 2025, the plant will continue operating until September 2025, providing biomethane to fuel the NIMBUS bus.

Additionally, **efforts will focus on transferring the plant to other WWTPs and identifying new replication studies** in different geographic and operational contexts. Given the strong interest generated by the LIFE NIMBUS project, work will also continue on **developing a robust business plan and exploring alternative business models** in collaboration with stakeholders from various sectors and EU regions.

In addition, the Veolia group – of which Cetaqua and Aigües de Barcelona are part – is developing other European projects focused on large-scale biomethane

production, leveraging lessons learned from the LIFE NIMBUS project.

On another front, the scale-up of the bio-electro-chemical system for green hydrogen production from wastewater will continue, with the aim of improving its productivity and advancing its technology readiness level for future large-scale applications.



Image 9. The NIMBUS bus during a route in Barcelona.

Conclusions



Image 10. LIFE NIMBUS team at the pilot site.

The transport sector remains one of the largest energy consumers and sources of greenhouse gas emissions in Europe. Despite progress in renewable electricity generation, its direct impact on transport fuels is still limited. Biomethane emerges as a promising renewable alternative that directly contributes to the decarbonisation of urban mobility.

LIFE NIMBUS is a pioneering solution that combines waste management and energy innovation in a circular economy approach. By transforming wastewater treatment plants (WWTPs) into ecofactories, the project demonstrates how underutilised resources – such as sewage sludge and surplus renewable electricity – can be turned into clean, high-quality fuel for public transport.

The project's pilot at the Baix Llobregat WWTP has validated the technical feasibility of producing biomethane through biological biogas methanation. It successfully fuelled a TMB bus, confirming the applicability of this model in real-world urban

settings. Moreover, the replicable nature of the process offers **strong potential for broader deployment across Europe**, not only for urban mobility, but also for sectors such as freight transport.

By integrating renewable energy, wastewater reuse, and clean transport, **LIFE NIMBUS supports multiple EU policy objectives**, including the Renewable Energy Directive (RED III) and urban climate strategies. It contributes directly to the EU's 2030 target of over 29% renewable energy use in transport.

Beyond the technical achievements, **the project promotes public awareness and institutional engagement**, positioning the city of Barcelona as a benchmark for sustainable and circular innovation. It also encourages other urban areas to explore similar synergies between waste, water and energy sectors.

LIFE NIMBUS, a shared challenge among...

CETAQUA

WATER TECHNOLOGY CENTRE

Cetaqua Barcelona is a private non-profit foundation established in 2007 by Aigües de Barcelona, the Universitat Politècnica de Catalunya-BarcelonaTech (UPC) and the Spanish National Research Council (CSIC). It is a public-private collaboration model created to ensure the sustainability and efficiency of the complete water cycle while considering local needs.

Role in the project: Cetaqua coordinated the project's management and technical execution, providing the technical expertise needed to start up and operate the power-to-gas prototype for biomethane production and supply, interpret the data, and carry out technical, environmental and economic assessment, as well as replication studies.

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**Aigües de
Barcelona**

Aigües de Barcelona manages the complete water cycle: from catchment to drinking water treatment, transport and distribution, in addition to sewerage, wastewater treatment and reclamation, either for return to the natural environment or reuse. Committed to people and the planet, the company serves almost 3 million citizens from the municipalities of Barcelona metropolitan area and works with the clear aim of

improving the quality of life of people and making cities better places to live in.

Role in the project: Aigües de Barcelona participated in the construction and operation of the demo plant, placed at its facilities at the Baix Llobregat WWTP, and also collaborated in drawing up the business model for biomethane production.

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UAB

Universitat Autònoma
de Barcelona

The Universitat Autònoma de Barcelona (UAB) is a leading public university, globally recognised for its profound commitment to innovation in both teaching and cutting-edge research. At its core, UAB strives to be a catalyst for positive change, actively contributing to the creation of a better, more sustainable and fairer world through the relentless advancement of knowledge, scientific discovery and technical expertise.

Role in the project: GENOCOV, a UAB research group focused on biological treatment and liquid and gaseous effluent recovery, nutrient removal, odours and volatile organic compounds, was in charge of bio-electrochemical system (BES) design and construction and provided technical support for its operation.

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Transports Metropolitans de Barcelona (TMB) is the joint name of the companies Ferrocarril Metropolità de Barcelona, SA and Transports de Barcelona, SA, which manage the metro and bus network in the Barcelona metropolitan area. TMB also encompasses the companies Projectes i Serveis de Mobilitat, SA, which manages the Montjuïc cable car; Transports Metropolitans de Barcelona, SL, which manages fare products and other transport services, and the Fundació TMB, which looks after TMB's historical heritage and promotes public transport values through social and cultural activities.

Role in the project: TMB collaborated in the project by testing one bus fuelled by biomethane and assessing the impact of replacing natural gas with biomethane on the bus engine. TMB was also involved in the elaboration of the business model for biomethane trading and had an important role in dissemination actions.

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NIMBUS

More info at
www.life-nimbus.eu