CARBIOW

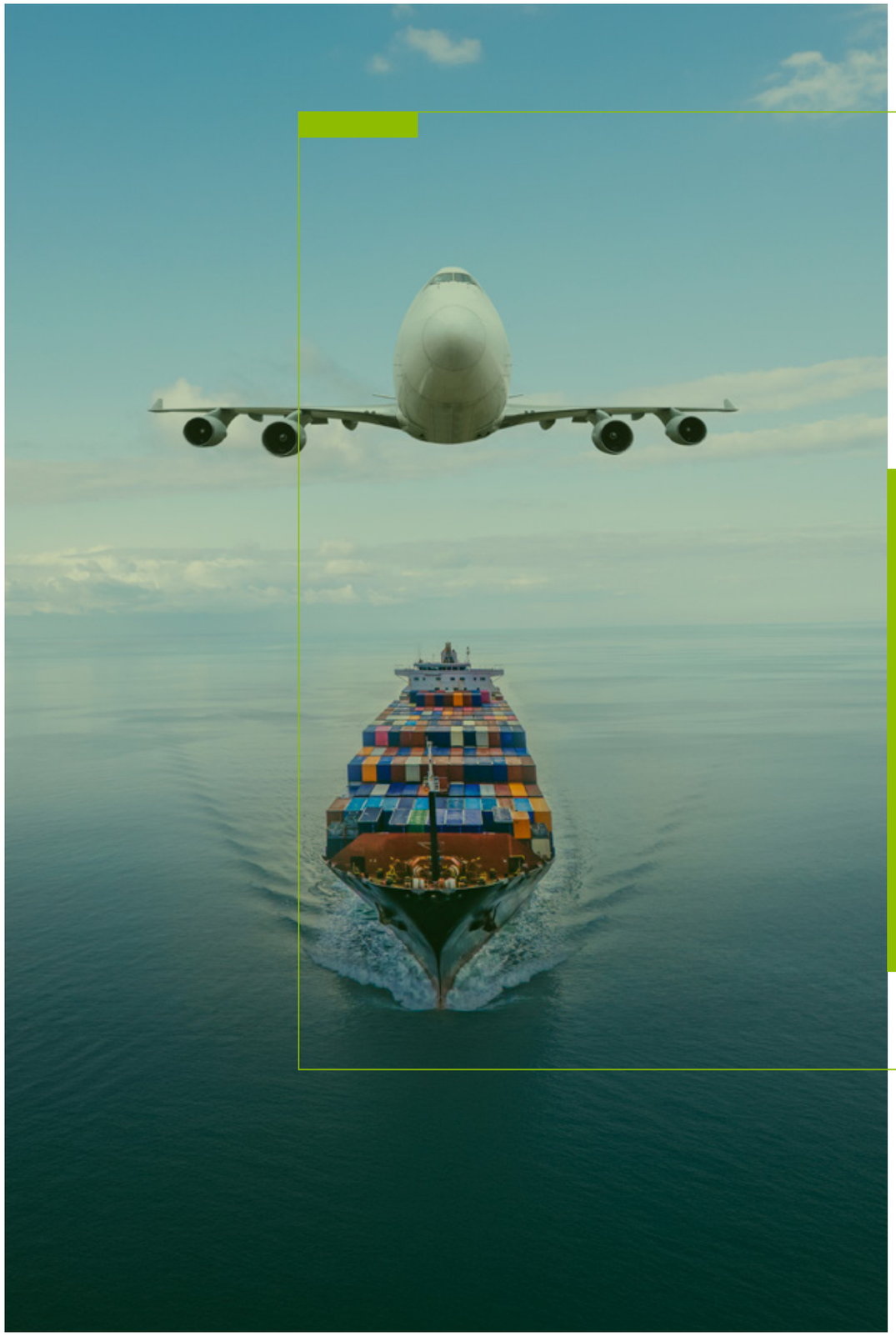
CARBIOW Project Results

FROM ORGANIC WASTE TO GREEN MARITIME AND AVIATION FUELS

Funded by the European Union

A Horizon Europe Research and Innovation Project

March 2026



FROM ORGANIC WASTE TO GREEN MARITIME AND AVIATION FUELS

CARBIOW Project Results

CARBIOW **demonstrates an integrated value chain that converts organic waste into sustainable aviation & maritime fuels and bio-based materials by combining thermochemical conversion, Fischer–Tropsch synthesis, and innovative carbon mineralisation approaches.**
The project contributes to the defossilisation of aviation, maritime transport, and other carbon-intensive industries.

TEAM

CARBIOW AT A GLANCE

PROJECT TITLE

CARBIOW
|
Carbon Negative Biofuels from Organic Waste

PROGRAMME

Horizon Europe
|
Research and Innovation Programme

DURATION

October **2022**
|
March **2026**

COORDINATOR

TECNALIA
Research and Innovation

CONSORTIUM

12
partners
|
8
countries

COUNTRIES

Spain,
Germany,
Belgium,
Netherlands,
Norway,
Slovenia,
Finland,
Sweden

TARGET SECTORS

Aviation
Maritime
Transport
Cement industry

WEBSITE

carbiow.eu

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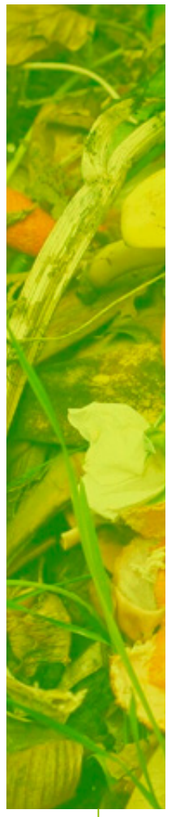
CARBIOW (Carbon Negative Biofuels from Organic Waste) is a research and innovation project funded by the Horizon Europe programme addressing the green transition, the biocircular economy and the biowaste valorisation through the development of novel and groundbreaking technologies.

These innovative and efficient technologies enable the conversion of organic waste into **advanced biofuels for the aviation and maritime sectors**, helping to replace conventional fossil-based fuels with sustainable, potentially carbon-negative alternatives.



In addition, CARBIOW integrates **innovative carbon capture and storage (CCS) approaches** to improve carbon management within the zero–waste process. By capturing CO_2 in gasification residues and transforming it into cement-based materials, the project also contributes to reducing emissions in one of the most carbon-intensive sectors: the cement industry.

CARBIOW represents a valuable opportunity to address environmental challenges across several carbon-intensive sectors. Through its circular and sustainable approach, the project contributes to **industrial decarbonisation, resource efficiency, and the European Union's technological leadership in sustainable fuels and bioeconomy solutions**, while also supporting job creation and the development of new skills linked to the growth of a sustainable bioeconomy.

THE CARBIOW PROJECT GOAL AND KEY TARGETS

The goal of CARBIOW is to establish an efficient and scalable zero-waste process capable of converting the Organic Fraction of Municipal Solid Waste (OFMSW) and other hard-to-utilise organic residues into sustainable biofuels **through an integrated thermochemical conversion pathway based on torrefaction, gasification and Fischer–Tropsch fuel synthesis**.

KEY TARGETS

The process developed within CARBIOW follows four main steps:

CARBIOW starts with torrefaction and pre-treatment of organic waste, followed by oxygenblown gasification of the torrefied material to produce clean syngas. Aviation and maritime fuels are then produced through the Fischer–Tropsch process. Finally, gasification ashes are used to capture CO_2 and synthesise cement-based materials, contributing to negative carbon emissions.

KEY TECHNOLOGICAL ADVANCES IN CARBIOW

During the project, CARBIOW has achieved important technological progress across the entire value chain, from feedstock pre-treatment to fuel production and carbon utilisation. These developments have enabled the definition of an integrated process capable of converting around 10,000 kg/h of organic waste (primarily OFMSW) into approximately 491 kg/h of liquid biofuels. The resulting product stream mainly consists of Fischer–Tropsch-derived hydrocarbons in the aviation fuel range together with lighter alcohol fractions that can be used as maritime fuel components. The overall carbon conversion efficiency reaches around 29 % based on the life-cycle assessment conducted within the project.

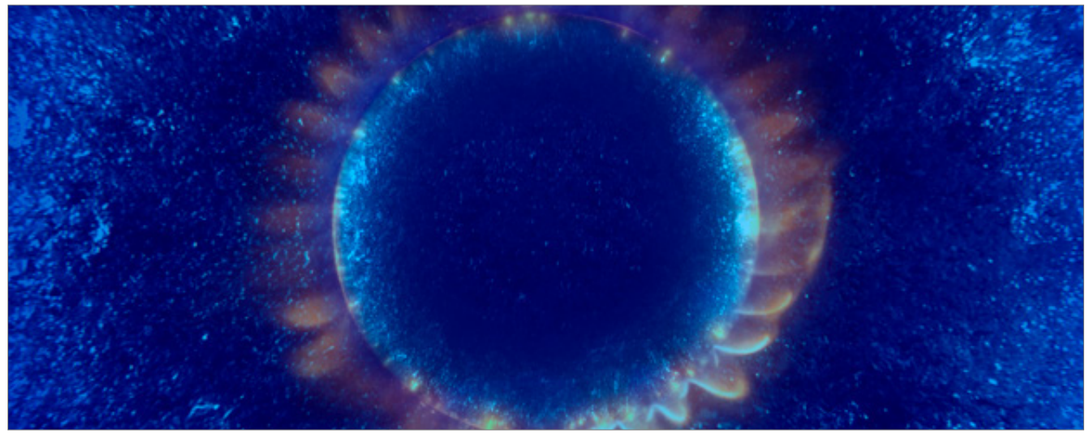
Converting around **10,000 kg/h of organic waste** (primarily OFMSW)

491 kg/h of liquid biofuels

84–96% lower GHG emissions compared with conventional fossil jet fuel

29% carbon conversion efficiency

1,500 kg/h of CO_2 captured



Optimised torrefaction of organic waste

Torrefaction processes were optimised for different types of organic waste, including OFMSW, wood cellulose pulp and other biogenic residues. Both dry and wet torrefaction approaches were tested under different operating conditions. Wet torrefaction with catalysts produced valuable liquid by-products containing light alcohols, thereby improving the quality of the resulting biochar.

Pilot-scale oxy-fired fluidised bed gasification

An innovative approach based on the use of an oxygen-carrier bed material in oxy-fired fluidised bed gasification was tested in lab-scale and pilot-scale experiments. The oxygen-carrier can transfer oxygen, thereby ensuring better oxygen distribution and exhibiting catalytic properties that increase the conversion rate. In lab-scale studies of various active bed materials, ilmenite and slag from the steel industry proved to be highly active in promoting the conversion. Additionally, multiple torrefied waste streams were tested to identify optimal operating conditions at pilot-scale.
Several tons of torrefied biogenic waste were successfully gasified while applying ilmenite as bed material for the first time in this process. The multi-day pilot-scale tests confirmed the high conversion efficiency and revealed further potential for optimising the conversion of these novel waste materials under industrially relevant conditions, marking an important milestone for future scale-up.

Advanced catalysts for sustainable fuel production

Innovative 3D-printed monolithic catalysts were developed and tested in the Fischer–Tropsch process. Advances in 3D printing have enabled printing at previously challenging resolutions and a careful optimisation has significantly improved cobalt reducibility in monoliths. The production of optimal monoliths could be scaled up to larger-scale production. Successful synthetic e-fuel production has been achieved using an advanced millichannel reactor combined with these monoliths, demonstrating the feasibility of producing aviation-range hydrocarbons and light alcohols from biogenic waste-derived syngas.

Carbon fixation through mineral carbonation

Gasification ashes and bed materials were evaluated for their CO_2 carbonation potential, enabling the production of stable carbonates for use in cement-based materials. This approach contributes to improving carbon management and supports solutions between the energy and construction sectors.

Integrated sustainability assessment

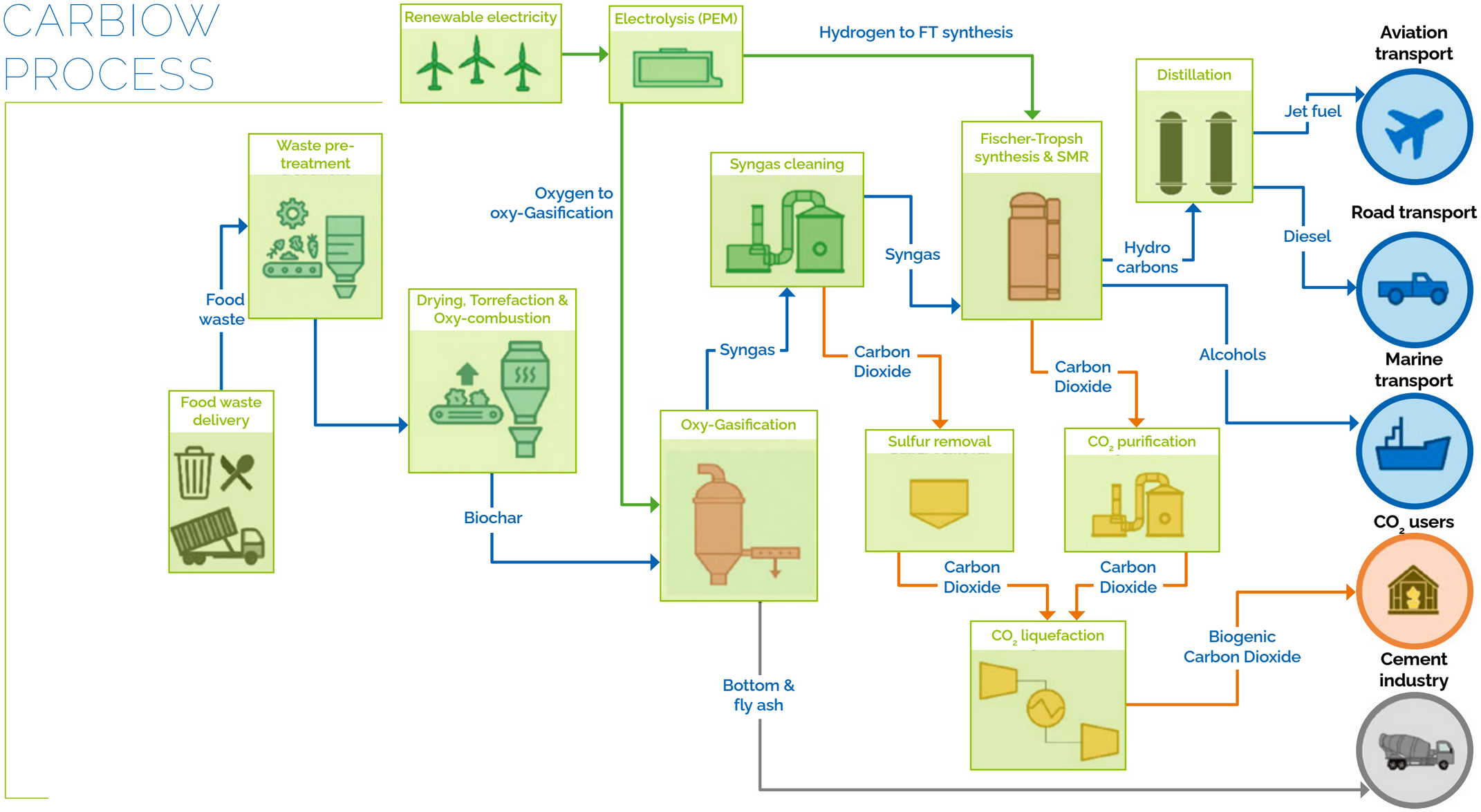
A comprehensive sustainability assessment was carried out to evaluate the environmental and economic performance of the CARBIOW value chain. The results show that converting food waste into aviation fuels can deliver substantial climate benefits.

At the product level, greenhouse gas emissions are reduced by approximately 84–96% compared to conventional fossil jet fuel. At the system level, diverting food waste to thermochemical conversion results in net emission reductions of around 145–245 kg CO_2-eq per tonne of waste treated.

The analysis also highlights environmental trade-offs, with higher impacts in categories such as human toxicity, eutrophication and ozone depletion, mainly driven by electricity use and waste logistics.

From an economic perspective, capital investment is identified as a key cost driver, with plant scale playing a critical role. The CARBIOW concept shows strong potential to support the transition towards circular and low-carbon fuel systems.

CARBIOW PROCESS



IMPACT & FUTURE PERSPECTIVES

The technologies developed in CARBIOW show how organic waste streams can be transformed into valuable resources for sustainable fuel production and circular materials.

The project has demonstrated the technical feasibility of an integrated waste-to-fuel pathway based on torrefaction, gasification and Fischer–Tropsch synthesis, complemented by innovative carbon mineralisation approaches for the utilisation of gasification residues.

CARBIOW contributes to improving the efficiency and sustainability of bioenergy systems, while demonstrating strong potential for greenhouse gas emissions reduction at both the product and system levels.

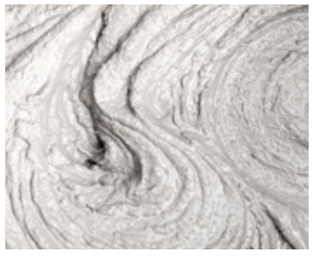
The integrated process developed within CARBIOW demonstrates the technical feasibility of converting organic waste into valuable fuel products at scale. Under the assessed conditions, the system is capable of processing around 10,000 kg/h of organic waste and producing approximately 491 kg/h of liquid biofuels, while converting around 29 % of the carbon contained in the feedstock into fuel products.

The project also analysed, via TEA and LCA models, the potential integration of renewable energy into such a complex process. CARBIOW addressed full utilization of electrolyzer system products (hydrogen, oxygen, and heat) in the process of conversion of biomass to biofuels: hydrogen was used in syngas conditioning and FT liquids upgrade, oxygen was used in oxy-gasification and oxy-combustion, and heat was integrated and used within the process. This is a credible and impactful result that can potentially improve the economic and technical aspects of integration of electrolyzers (and renewable electricity) in energy production processes of the future.

From an energy perspective, the process requires approximately 4.3 MW of electricity, with opportunities for heat integration and recovery contributing to improved overall efficiency. At the same time, the results highlight trade-offs associated with electricity demand and upstream material production for renewable electricity systems, underlining the importance of reducing electricity-intensive processes in future developments. In addition, around 1,500 kg/h of CO_2 can be captured and further utilised, particularly through mineral carbonation routes for the production of cement-based materials supporting the development of carbon management strategies.

CARBIOW addresses the decarbonisation of hard-to-abate sectors, particularly aviation and maritime transport, where electrification remains technically or economically challenging. By developing drop-in fuels such as alcohol blends for maritime applications and kerosene-range hydrocarbons for aviation, the project helps reduce emissions in these sectors.

The project has delivered key technological building blocks across the entire value chain, including optimised torrefaction processes, validated gasification conditions, advanced catalytic systems for fuel synthesis, and innovative approaches for CO_2 mineralisation into cement-based materials. These results provide a solid basis for the further development and integration of waste-to-fuel systems.



Looking ahead, several CARBIOW technologies show strong potential for further development towards industrial-scale applications. Future work will focus on process optimisation, system integration and validation under industrial conditions, as well as certification and standardisation steps where relevant.

From an economic perspective, capital investment has been identified as a key cost driver, with plant scale playing a critical role due to economies of scale. Future development will therefore require consideration of plant scale-up strategies, expansion of feedstock supply and integration of additional residue streams.

In addition, further technological improvements will be needed in key areas, such as feedstock pre-treatment, gasification optimisation and process integration to enhance overall system efficiency and sustainability.

In parallel, the project contributes to strengthening the knowledge base required to support the deployment of waste-to-biofuel systems, including sustainability assessment, system modelling and feasibility analysis. These elements are essential for enabling informed decision-making and supporting future investments in circular and low-carbon fuel pathways.

CARBIOW technologies have the potential to support the transition towards a climate-neutral and circular economy, while reinforcing Europe's position in the development of sustainable fuels and innovative bio-based solutions.

CARBIOW CONSORTIUM

CARBIOW's 12 partners compose a team of highly complementary partners spread around Europe:

TECNALIA - Fundación Tecnalia Research & Innovation (Spain)

TECNALIA is Spain's largest applied research and technological development centre and a member of the Basque Research and Technology Alliance. The organisation works across multiple fields, including energy transition, circular economy, smart manufacturing, sustainable mobility, and digital transformation.

IVL Swedish Environmental Research Institute (Sweden)

IVL is an independent research institute specialized in environmental and sustainability solutions. Its work covers areas such as waste management, industrial descarbonisation, energy systems and circular economy solutions.

TU Darmstadt - Technische Universität Darmstadt (Germany)

The Technical University of Darmstadt is a leading German public university. At the Institute of Energy Systems and Technology (EST), researchers develop innovative fluidised-bed processes for gasification and carbon capture, focusing on climate neutrality, environmental compatibility and secure energy supply.

VITO – Vlaamse Instelling voor Technologisch Onderzoek (Belgium)

VITO is a leading European research and technology organisation specialised in cleantech and sustainable development. Its Sustainable Materials Department (SuMAT) develops advanced materials and processes for chemical and energy applications, including shaping technologies such as droplet coagulation, coating and 3D printing.

SEAS - Svåheia Eiendom AS (Norway)

SEAS is a private company owned by three municipalities in south-west Norway and specialises in the development of commercial and industrial real estate. The Svåheia industrial area hosts waste management activities, renewable energy facilities and circular economy initiatives, supporting innovation and industrial symbiosis.

Vertoro B.V. (Netherlands)

Vertoro is a chemical biorefinery start-up developing bio-based alternatives to fossil resources. The company transforms sustainably sourced woody and agricultural residues into platform bio-oils that can be used to produce bio-based chemicals, materials and fuels.

CEMENTOS LA CRUZ (Spain)

CEMENTOS LA CRUZ is a cement manufacturer based in Murcia, Spain. The company produces cement, concrete and mortars, including low-carbon products under the CKLEEN brand. Its R&D strategy focuses on sustainability, circular economy solutions, digital transformation and innovative concrete technologies.

Feyecon Development & Implementation B.V. (Netherlands)

FeyeCon specialises in process and product development based on supercritical carbon dioxide technologies ($scCO_2$). The company has extensive experience in advanced separation processes and sustainable industrial technologies.

AMIBM – Aachen-Maastricht Institute for Biobased Materials/ Maastricht University (Netherlands)

Maastricht University is one of the most international universities in Europe. Through AMIBM, it focuses on the development of sustainable, advanced biobased materials, bridging fundamental research and market applications in technology and medicine, and covering the full value chain from raw materials to polymers, as well as sustainability assessment.

07. CARBIOW Consortium

NIC - National Institute of Chemistry | Kemijski Institut (Slovenia)

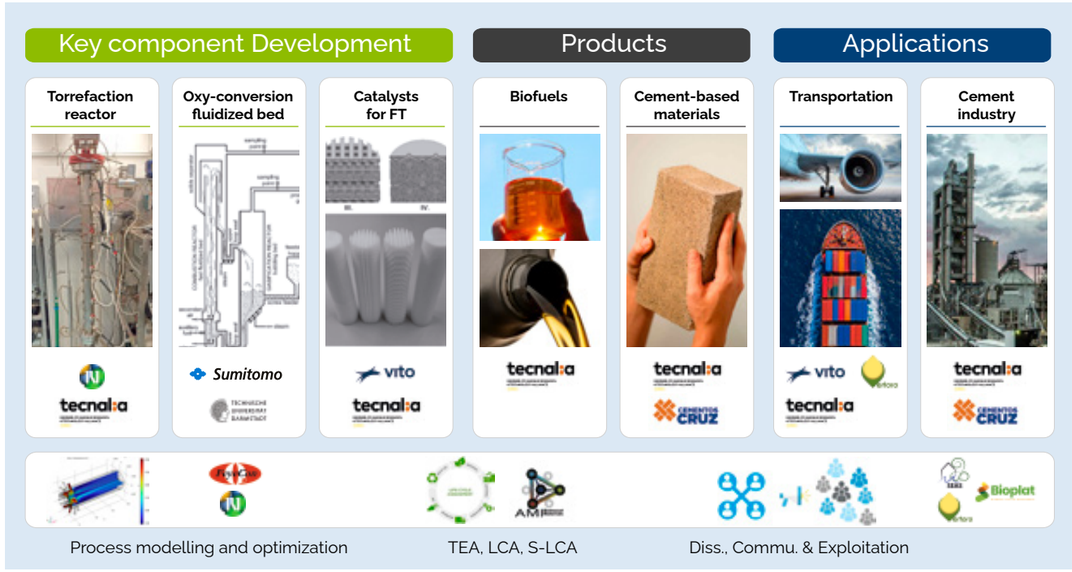
The National Institute of Chemistry (NIC) conducts research in fields including materials science, biotechnology, chemical engineering and environmental protection. Its work supports innovation in areas such as sustainable development, energy and climate change.

Sumitomo SHI FW (Finland)

Sumitomo SHI FW (SFW) is a global provider of technologies and services that support the decarbonisation of energy systems. Its solutions include biomass and waste-to-energy systems, carbon capture technologies, flue gas cleaning and sustainable fuel production.

Bioplat – Spanish Technology and Innovation Platform on Biocircularity (Spain)

Bioplat is a public-private, non-profit platform promoted by the Spanish Ministry of Science, Innovation and Universities that fosters research, innovation, and public-private collaboration in the field of biocircularity.



DELIVERING INNOVATIVE SOLUTIONS FOR SUSTAINABLE FUEL PRODUCTION AND CIRCULAR CARBON MANAGEMENT

KEY RESULTS FROM CARBIOW

CARBIOW demonstrates how biocircular approaches can transform organic waste streams into valuable resources for sustainable fuels and circular materials, contributing to the decarbonisation of hard-to-abate sectors while improving carbon management across industrial systems. Key outcomes of the project include:

- **A biocircular waste-to-fuel pathway**

Demonstration of an integrated process combining torrefaction, oxygen-blown gasification and Fischer–Tropsch synthesis to convert organic waste into advanced biofuels for aviation and maritime transport within a biocircular resource system.

- **Valorisation of municipal biowaste into advanced fuels**

The process design enables the conversion of around 10,000 kg/h of organic waste (OFMSW) into approximately 491 kg/h of liquid biofuels, including aviation-range hydrocarbons and alcohol blends for maritime applications.

- **Substantial climate benefits through circular carbon use**

Life-cycle assessment shows 84–96 % lower GHG emissions compared with conventional fossil jet fuel and net emission reductions of 145–245 kg CO_2-eq per tonne of waste treated, reflecting the benefits of diverting organic waste into productive biocircular pathways.

- **Circular carbon management through mineral carbonation**

Development of carbon mineralisation pathways enabling gasification residues to capture CO_2 and produce stable carbonates for use in cement-based materials, linking the bioenergy and construction sectors.

- **Full integration of renewable electricity and green hydrogen**

The project analysed the integration of renewable electricity and electrolyzer systems into the CARBIOW process. Hydrogen can be used in syngas conditioning and Fischer–Tropsch liquids upgrading, oxygen in oxy-gasification and oxy-combustion, and heat can be recovered and reused within the process, demonstrating the potential synergies between renewable electricity, green hydrogen and sustainable fuel production.

- **Development of a zero-waste process concept**

CARBIOW demonstrated at TRL 5 a zero-waste process concept in which by-products such as heat and CO_2, together with residues including ashes and bed materials, are further utilised within the system. This approach supports circular carbon management and addresses the needs of hard-to-abate sectors such as the cement industry.

- **Technological advances across the biocircular value chain**

The project delivered improvements in torrefaction optimisation, oxy-fired fluidised-bed gasification and Fischer–Tropsch catalysis, including the development of 3D-printed monolithic catalysts for sustainable fuel production.

- **Foundations for industrial biocircular fuel systems**

CARBIOW provides a technological and sustainability basis for the future scale-up of biocircular waste-to-fuel systems, supporting the deployment of sustainable aviation and maritime fuels in Europe.

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info@carbiow.eu

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