BioTheRoS

Collaborative actions to bring novel **BIO**fuels **THE**rmochemical **RO**utes into industrial **S**cale

# Deliverable 7.1

## Identification and mapping of selected EU funded and international projects with potential synergies

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## Disclaimer

## Executive Summary

This document represents the Deliverable D7.1 Identification and mapping of selected EU funded and international projects with potential synergies, developed within WP7. The introduction includes a general description of the BioTheRoS project, the importance of international cooperation and network development, the objective of WP7, the scope of this report, a description of Mission Innovation countries and the used methodology.

Deliverable 7.1 lists and maps identified research projects in the field of pyrolysis and gasification. The report includes EU funded as well as international projects, with a focus on MI (Mission Innovation Countries). Based on the identified projects and existing networks, the respective research groups have been identified and listed. Synergies with those projects and research groups are planned via information exchange and collaboration for the planned network for knowledge sharing (Knowledge Hub).

The chapter Mapping of selected European projects gives an overview on relevant ongoing projects on EU level and potential synergies. The synergies are categorized into overall synergies (Process development and demonstration, scale-up, biomass value chains), technological synergies (Gasification, FT, pyrolysis, upgrade of biocrude), methodological synergies (Sustainability, BECCUS) and application-related synergies (SAF, marine fuels, biofuels). In addition, relevant completed projects on EU level are listed. The "sister projects" of BioTheRoS which were funded under the Programme HORIZON-CL5-2022-D3-03-02 - Best international practice for scaling up sustainable biofuels are ICARUS and SUSTEPS and the information exchange with those projects is pointed out

The mapping of selected international projects is done in the next chapter where the different international expert networks, including IEA Bioenergy Task 33, IEA Bioenergy Task 34, IEA Bioenergy Task 39, IEA Bioenergy Task 40, and IEA AMF and potential synergies are described. The following chapter maps selected research groups which are conducting research in the field of biomass gasification, pyrolysis or both. The research groups are divided into universities and research institutes. Besides projects and research groups, already existing initiatives and facilities working on thermochemical technologies (gasification or pyrolysis) are mentioned and the databases where they can be found are listed.

At the end of the deliverable the potential synergies with EU funded and international projects are elaborated and the planned BioTheRoS Knowledge hub is described.

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# Contents



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# List of abbreviations

| | |
|---|---|
| 1G, 2G | First generation, second generation |
| AI | Artificial Intelligence |
| AMF | Advanced Motor Fuels |
| BECCUS | Bioenergy with carbon capture and storage or utilisation |
| BMG | Biomass and waste gasification |
| CCU | Carbon Capture and Utilization |
| CFD | Computational Fluid Dynamics |
| CHP | Combined Heat and Power |
| ERDF | European Regional Development Fund |
| ETIP | European Technology and Innovation Platform |
| EU | European Union |
| EUBCE | European Biomass Conference |
| ExCo | Excecutive Committee |
| FT | Fischer Tropsch |
| H2020 | Horizon 2020 |
| HTL | Hydrothermal Liquefaction |
| IEA | International Energy Agency |
| LCA | Life Cycle Assessment |
| LCC | Life Cycle Costing |
| MI | Mission Innovation |
| NFRF | New Frontiers in Research Fund |
| P&P | Pulp and Paper |
| PEC | photoelectriccatalytic |
| RFCS | Research Fund for Coal and Steel |
| SAF | Sustainable Aviation Fuel |
| sLCA | Social Life Cycle Assessment |
| TCP | Technology Collaboration Programme |

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# Introduction

## The BioTheRoS project

BioTheRoS Project aims at developing a holistic methodology that will boost the scale-up of sustainable biofuels via thermochemical conversion technologies. These are pyrolysis upgrading through hydrodeoxygenation and Fischer-Tropsch synthesis from biomass gasification. The project will bring together key actors at both European and International level, such as technological and social experts, renewable energy-oriented associations along with industrial experts that will bring and exchange their knowledge in order to reach the project targets.

Within the project, several non-food biomass feedstocks will be analyzed and optimized across their entire value chain. Barriers linked with the selected feedstocks supply and pretreatment will be identified. Furthermore, AI-based predictive models will be developed, in order to be adapted to the scale-up cases. Then, the most promising biomass feedstock will be tested experimentally in the studied thermochemical reactors. At this point of the project, technical constraints and opportunities for the scale-up of the sustainable biofuels thermochemical processes will be identified. Possible synergies of blending pyrolysis oil and gasification based advanced biofuels will be investigated by a potential end-user (petroleum company). The selected data will be used as an input for advanced modelling tools, including process modelling, CFD tools and LCA/LCC/sLCA tools results of which will feed a multi-criteria analysis to derive generalized up-scaling rules and guidelines of the produced biofuels.

The engagement of several stakeholders in the planning of the scaling-up of sustainable biofuels production will be crucial at this point, since they will review the project results and assess if a biofuel production technology can be delivered from the lab/pilot to a larger-scale, by considering operational difficulties, plant cost and plant capacity limitations (technological barriers).

## International cooperation and network development

For the integration of stakeholders and experts the project has a work package on “International cooperation and network development”. Scaling up sustainable biofuels is a global challenge in terms of environmental, social, and economic sustainability, which can benefit from international collaboration and knowledge exchange. The objectives of the work package are to

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- map and use synergies with European and international research groups working on relevant research questions for scaling-up sustainable biofuels
- exchange information with European and international groups and networks on topics related to sustainable biofuels value chains
- develop a network for knowledge sharing and information exchange through international collaboration

International cooperation activities including active seeking for synergies with EU and international projects, cooperation with international networks and setting up a network for knowledge sharing to ensure that the project builds on and contributes to global knowledge building for sustainable scaling of advanced biofuels value chains.

## Scope of this report

Deliverable 7.1 shows results from Task 7.1 ”Potential synergies with EU funded and international projects”. Within this task EU funded and international projects doing research in pyrolysis and gasification were identified and selected projects are mapped in this report. The report includes EU funded as well as international projects, with a focus on MI (Mission Innovation Countries). From the projects and existing networks, the respective research groups have been identified and listed. Synergies with this projects and research groups will be used via information exchange and collaboration for the planned network for knowledge sharing (Task 7.3).

## Mission Innovation countries

Mission Innovation [1] is a global initiative launched in 2015 during the Paris Climate Conference (COP21) with the goal of accelerating public and private clean energy innovation. The initiative brings together 23 countries and the European Commission (on behalf of the European Union), all committed to significantly increasing their investments in clean energy research and development. The aim is to make clean energy widely affordable and accessible, thereby helping to combat climate change and achieve net-zero emissions. Member countries include major economies such as the United States, China, India, the United Kingdom, Germany, France, and Japan, among others, see Figure 1.

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*Figure 1. Mission Innovation Member Countries*

As BioTheRoS aspires to foster the knowledge exchange among international stakeholders to improve global knowledge on sustainable biofuels, it is of importance to include and cooperate with Mission Innovation countries. During the project, the consortium will be in contact with experts from MI countries, so that experts in these countries will be aware of BioTheRoS results and use them to cooperate and collaborate with governments, private investors and researchers, so that main outcomes reach global market penetration in transportation applications.

Cooperation with Mission Innovation countries is ensured in several ways, firstly by feedstock assessment and selection where a global perspective is taken, focusing on feedstock available especially in MI countries. Secondly by cooperating with the four named IEA Bioenergy Tasks (33, 34, 39, and 40), IEA AMF and ETIP Bioenergy in which representatives of many Mission Innovation countries are taking part. Mission Innovation Countries from these networks outside Europe include Brazil, Canada, China, India, Japan, South Korea, United Kingdom and United States. The MI countries within those Tasks and the EU are Austria, Denmark, the European Union, France, Germany, Italy, Netherlands and Sweden. The lists of research groups indicate if these are located in a Mission Innovation country.

## Methodology

In order to map selected European and international research groups and projects, various sources were considered. First, the CORDIS database [2] of the EU was scrutinized using dedicated keywords, which resulted in a list of past and ongoing Horizon projects with potential synergies to the BioTheRoS project. Ongoing projects were categorized and potential synergies are described below. The list of European projects was extended by nationally funded projects with involvement of consortium members of the BioTheRoS project. This results in a total of 28 completed and 25 ongoing projects. For mapping international projects, websites of relevant IEA Tasks have been consulted, namely IEA Bioenergy Task 33: Gasification of biomass and waste [3], Task 34: Direct thermal liquefaction [4], Task 39: Biofuels to

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decarbonize transport [5], Task 40: Deployment of biobased value chains [6] and the IEA Advanced Motor Fuels TCP [7].

The list of selected research groups (universities and research institutes) consists of consortium members of completed and ongoing projects and IEA Task members. This list has been extended using conference proceedings from the EUBCE [8], publications of IEA TCPs [9, 10, 11, 12], leaflets and workshop invitations as well as additions from the BioTheRoS consortium. It should be noted that the screening of the above-mentioned sources does not allow for a complete list of international research groups with potential synergies.

## Mapping of selected European projects

The cooperation on European level is important for accelerating the scale-up and commercialization of biofuels. The project team is closely linked to several Tasks of IEA Bioenergy, IEA AMF and the European Technology and Innovation Platform ETIP Bioenergy, and will facilitate information exchange with these networks and the member countries.

### Relevant ongoing projects on EU level and potential synergies

This chapter lists ongoing projects with potential synergies to the BioTheRoS project on EU level, which aims for developing a holistic methodology boosting the scale-up of sustainable biofuels via thermochemical conversion technologies, namely gasification (FT) and pyrolysis. All projects are dealing with related topics along the supply chain.

BioTheRoS foster the knowledge exchange among international stakeholders to improve global knowledge on sustainable biofuels. Synergies with the listed projects will be mainly used via information exchange and collaboration for the planned network for knowledge sharing (Task 7.3). Experts around the globe will be aware of BioTheRoS results and use them to cooperate and collaborate with governments, private investors and researchers, so that main outcomes reach global market penetration in transportation applications.

Table 1 lists ongoing projects dealing with biofuels from thermochemical conversion routes and related topics. Besides title, lead institute, funding program and project duration, a brief description of the topic covered is given and the projects are categorized according to their potential synergies. The synergy categories are described below the table.

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*Table 1: Ongoing projects dealing with biofuels from thermochemical conversion routes and related topics*

| Acronym | Title | Lead institute | Funding | Topic | Date | Synergy categories |
|---|---|---|---|---|---|---|
| BIOCTANE | Organic waste gives wings to sustainable aviation | Fundacion IMDEA Energia | H2020 | Combining biotechnology and hydrothermal gasification | 2022-2026 | Process development, scale-up, SAF |
| BUTTERFLY | Flexible and efficient coproduction of clean fuels for hard-to-decarbonize sectors | TNO | H2020 | Integration of indirect gasification, sorption-enhanced DME synthesis and methanation | 2023-2026 | Process demonstration, scale-up, gasification |
| CARBIOW | Carbon Negative Biofuels from Organic Waste | Tecnalia | H2020 | Oxygen-blown gasification, FT | 2022-2028 | Process development, SAF, marine fuels |
| CIRCULAIR | Develop and demonstrate a cost-effective pathway to biofuel production from abundant feedstock | Bauhaus Luftfahrt | H2020 | HTL | 2023-2027 | Scale-up, upgrade of biocrude, SAF |
| CORALIS | Creation Of new value chain Relations through novel Approaches facilitating Long-term Industrial Symbiosis | CIRCE | H2020 | Demonstrate and deployment of industrial symbiosis solutions | 2020-2025 | Scale-up, Biomass value chain |
| CRONUS | Capture and Reuse Of biogenic gases for Negative-emission - sustainable biofUelS | NTUA | H2020 | Technological solutions for biogenic gases utilisation within the biofuels value chain | 2022-2026 | Process demonstration, scale-up, BECCUS |
| DECADE | Distribution chemicals and fuels production from $CO_2$ in photoelectrocatalytic devices | European Research Institute of Catalysis | H2020 | PEC technology using alcohols and waste $CO_2$ as feed to produce fuel boosters | 2020-2025 | Biofuels, BECCUS |
| EBIO | Novel electrochemical processes for upgrading of industrial bio liquids | Sintef | H2020 | Electrochemical technologies for upgrading Kraft lignin and fast pyrolysis liquids | 2020-2024 | Upgrade of biocrude, sustainability |

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|---|---|---|---|---|---|---|
| EHLCATHOL | Chemical transformation of enzymatic hydrolysis lignin (EHL) with catalytic solvolysis to fuel commodities under mild conditions | Aalto University | H2020 | Direct catalytic solvolysis | 2020-2024 | Process demonstration, biofuels |
| ETIP Bioenergy SABS 2 | Increase excellence of EU biofuels and bioenergy research | BEST | H2020 | Bioenergy technologies | 2022-2025 | Biofuels |
| EUCANwin! | Increase viability of forest biomass supply chains | RISE | H2020 | Heat and power technology with negative carbon emissions in international cooperation between EU and Canada | 2021-2025 | Scale-up, BECCUS |
| Fuel up | Powering a greener future for aviation and marine transport | Sintef | H2020 | Hydroprocessed pyrolysis oil (co-processing) | 2024-2027 | Process demonstration, pyrolysis, SAF, marine fuels |
| FUELPHORIA | Accelerating the sustainable production of advanced biofuels and RFNBOs - from feedstock to end-use | CERTH | Horizon Europe | Sustainable, competitive, and secure value chains for advanced biofuels and renewable fuels of non-biological origin | 2023-2027 | Biofuels, Biomass value chains |
| GLAMOUR | GLycerol to Aviation and Marine prOducts with sUstainable Recycling | University of Man-chester | H2020 | Chemical-looping gasification from waste bio-based feedstock into aviation and marine fuels | 2020-2024 | Process demonstration, scale-up, gasification, SAF, marine fuels |
| GOLD | Growing energy crops on contaminated land for biofuels and soil remediation | CRES | H2020 | Producing biofuels with no risk of indirect land use change | 2021-2025 | Sustainability, biofuels |

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| Hellenic Energy Competence Center | Strengthens the link between academic research and entrepreneurship through innovative projects | National Technical University of Athens (NTUA)[1] | National funding (Greece) | Centralised Power Generation in Post-Lignite Era; Renewable Energy Sources (RES) Projects including biomass; (Decentralized) energy production and saving; Smart Cities and Communities, Sustainable Development, Environment | 2021-ongoing | Biomass value chains, sustainability |
| HIGFLY | HIGee to Furanic-based jet Fuel technologY | TU/e | H2020 | Synthesis of furfural and biooxygenates | 2021-2024 | Process demonstration, SAF |
| ICARUS | Expedite the global expansion of sustainable aviation biofuels production | CRES | H2020 | Biocrude oils, isobutanol, FT | 2023-2026 | Sustainability, SAF |
| NET-Fuels | Increasing biomass conversion efficiency to carbon-negative sustainable biofuels | University of Bologna | Horizon Europe | Combination of thermal and bio-electrochemical processes | 2022-2026 | Process demonstration, pyrolysis |
| Phy2Climate | Improved phytoremediation coupled with advanced liquid biofuel production | ITS Förder-beratung | H2020 | Drop-in biofuels for road and shipping | 2021-2025 | Process demonstration, sustainability, marine fuels |
| Purejet | Process development for SAF | BTG | National Funding (Netherlands) | SAF from REDII feedstocks | 2022-2025 | Process development, SAF |
| PYRAGRAF | Decentralized pyrolytic conversion of wastes towards local circular value chains and sustainability | Politécnico de Portalegre | H2020 | Solar-assisted gasifier burner and | 2023-2027 | Process demonstration, sustainability, |

[1] Institute of Communication and Computer Systems (ICCS)

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| | | | | an integrated pyrolysis reactor | | gasification, pyrolysis |
| REF4FU | Renewable fuels from green refineries of the future | KIT | National Funding (Germany) | Methanol, Fischer-Tropsch hydrocarbons, pyrolysis oil | 2022-2025 | Process development, FT, pyrolysis |
| Refolution | Unlocking the potential of biofuels for aviation and marine | Sintef | Horizon Europe Innovation Action | Co-processing of pyrolysis oil, hydroprocessing | 2023-2027 | Process demonstration, scale-up, SAF, marine fuels |
| SUSTEPS | Sustainable, secure and competitive energy through scaling up advanced biofuel generation | Tübitak | Horizon Europe | Bio-refinery concept producing biofuels from microalgae | 2023-2027 | Scale-up, sustainability |

The categorized synergies can be summarized into the following fields: overall synergies, technological synergies, methodological synergies and application related synergies. The interaction with the listed ongoing projects is made according to the synergy category and topics that fit together. Information exchange with the projects and the respective work package of BioTheRoS (according to the topic and synergy category) is carried out. Feedback on project results is requested and discussions on technological issues are foreseen. The projects can also contribute to the planned database for information exchange (BioTheRoS Knowledge Hub). The BioTheRoS consortium will try to build the potential links with the listed projects according to their synergy categories.

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### Overall synergies

*Process development and demonstration, scale-up, biomass value chains*

The projects listed are working on relevant research questions for scaling-up the production of sustainable biofuels. This includes improvements and optimization in terms of efficiency increase and cost reduction. Process development is the category for projects dealing with those improvements and optimization of the technological processes. Process demonstration is the category for projects dealing with this topic and having a demonstration plant or facility where the process development takes place. In addition, the projects dealing with biomass value chains are also part of the overall synergies. Exchanging information and discussing on technical constraints and opportunities for the scale-up of the sustainable biofuels thermochemical processes and the biomass value chain, which will be identified during the BioTheRoS project, is expected to be beneficial both for BioTheRoS as well as for the synergetic projects. The information exchange with those projects is of importance for the technological work packages of BioTheRoS, as well as for the biomass value chain work package and the overall project goal of scale-up.

### Technological synergies

*Gasification, FT, pyrolysis, upgrade of biocrude*

Technological synergies are seen with projects dealing with one of the thermochemical routes focused in the BioTheRoS project, as well as upgrading issues. The work packages on gasification and pyrolysis are the contact points for those synergies and will benefit from information exchange with the respective projects. Technical Expert Workshops organized by the BioTheRoS consortium are a good opportunity to discuss and to elaborate on technological details, such as the possible synergies of blending pyrolysis oil and gasification based advanced biofuels. Another important potential for exchange is the upgrading of biocrude, such as pyrolysis oil to SAF.

### Methodological synergies

*Sustainability, BECCUS*

Scaling up sustainable biofuels is a global challenge in terms of environmental, social, and economic sustainability, which can benefit from international collaboration and knowledge exchange. The holistic methodology of BioTheRos includes a sustainability assessment as well as the integration of carbon capture to feed a multi-criteria analysis to derive generalized up-scaling rules and guidelines of the produced biofuels. Many projects are dealing with sustainability issues and offer good synergy and exchange potentials on that topic. The projects dealing with carbon capture will be of interest for the BioTheRoS task

dealing with hydrogen and CCU. Information can be exchanged via the planned Technical Expert Workshops.

### Application-related synergies

*SAF, marine fuels, biofuels*

Most of the selected projects are researching on the production of biofuels and many of them are focusing on SAF or marine fuels. The BioTheRoS project is researching the scale-up of thermochemical production routes for biofuels used in the aviation or maritime transport sector. Potential information exchange includes supply and demand, legal aspects as certification or fuel specifications.

## Relevant completed projects on EU level

As part of the EU funding program, numerous projects have been funded in recent years that deal with the production and application of biofuels, thermochemical conversion technologies and their scale-up. The BioTheRoS project team was also involved in or led some of these projects. Prior knowledge could be generated within these projects and the points of contact with project partners and other research groups were given. The consortium wants to ensure that the project builds on and contributes to global knowledge building for sustainable upscaling of advanced biofuels value chains. The most important of these projects are listed in the following table.

*Table 2: Past Projects dealing with biofuels from thermochemical conversion routes and related topics*[2]

| Acronym | Title | Lead institute | Funding | Topic | Date |
|---|---|---|---|---|---|
| 4REFINERY | Co-processing of pyrolysis oil and HTL biocrude | Sintef | H2020 | Co-Processing | 2020-2023 |
| AgroFossil Free | Strategies and technologies to achieve EU fossil-energy free agriculture | CERTH | H2020 | Evaluate and promote available fossil-energy-free strategies and technologies | 2020-2024 |
| AXIA | Innovative technologies for the capture and utilization of industrial $CO_2$ streams for the production of biofuels and bioactive compounds with microalgae – AXIA | Motor Oil Hellas | Attica Regional Programme | Biofuels from microalgae | 2022-2024 |

[2] Own research with the following sources: Participations in projects, Cordis database, ETIP Cluster Event, IEA networks, EUBCE

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| BECOOL | Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels | University of Bologna | H2020 | Thermochemical and biochemical technologies | 2017-2022 |
| Be-Rural | Bio-based strategies and roadmaps for enhanced rural and regional development in the EU | Ecologic Institut | H2020 | Connection between economy, society and environment | 2019-2022 |
| Bio4Products | 4x4, demonstrating a flexible value chain to utilize biomass functionalities in the processing industry | BTG | H2020 | Pyrolysis | 2016-2021 |
| BIOFIT | Bioenergy retrofits for Europe's Industry | BTG | H2020 | P&P, 1G biofuels, fossil refineries, CHPs and power only | 2018-2022 |
| BioSFerA | Gasification of biogenic residues and wastes | CERTH | H2020 | Gasification | 2020-2024 |
| BL2F | Black Liquor to Fuel by Efficient HydroThermal Application integrated to Pulp Mill | Tampere University | H2020 | HTL | 2020-2024 |
| BPD | Scale-up of a slurry reactor | BEST | COMET (Austrian National Funding) | FT | 2015-2019 |
| CERESiS | ContaminatEd land Remediation through Energy crops for Soil improvement to liquid biofuel Strategies | National Technical University of Athens | H2020 | Supercritical Water Gasification & Fast Pyrolysis integrated with novel contaminant separation technologies | 2020-2024 |
| CLARA | Chemical looping gasification | CERTH | H2020 | Gasification | 2018-2023 |
| CoCCUS | Cost-effective $CO_2$ capture and utilization | CERTH | European Regional Development Fund (ERDF) | $CO_2$ capture | 2021-2023 |
| Eucalyptus for large-scale jet fuel production | Feasibility study | BTG | Private client | Fast pyrolysis and upgrading | 2019-2022 |
| FLEXI-GREEN FUELS | Flexible and resilient integrated biofuel processes for competitive production of green renewable jet and shipping fuels | Hochschule Bremerhaven | H2020 | Fungal fermentation, algae dark fermentation | 2021-2023 |

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| | | | | and lipid rich larva production | |
| FlexSNG | Flexible Production of Synthetic Natural Gas and Biochar via Gasification of Biomass and Waste Feedstocks | VTT | H2020 and NFRF (Canada) | Gasification | 2021-2024 |
| FT4Industry | Further improvement of product upgrading of a FT demo system | BEST | COMET (Austrian National Funding) | Gasification FT | 2019-2023 |
| GreenDeal CO2 | Green Deployment of E-Fuels And Liquids based on $CO_2$ for closed and end-of-life coal-related assets | UNIVERSITY OF STUTTGART | Research Fund for Coal & Steel | sustainable e-fuels production through Fischer-Tropsch, e-methanation, and e-methanol production. | 2021-2024 |
| IDEALFUEL | Lignin as a feedstock for renewable marine fuels | TU Eindhoven | Horizon | Convert lignin to bio heavy fuel oil | 2020-2024 |
| MUSIC | Market Uptake Support for Intermediate Bioenergy Carriers | BTG | H2020 | Market uptake of pyrolysis oil, torrefied biomass and microbial oil | 2019-2023 |
| Retrofeed | Retrofitting and implementation of advanced monitoring | CIRCE | H2020 | Retrofitting | 2019-2023 |
| Set4Bio | Implement SET plan | CIRCE | H2020 | Bioenergy and renewable fuels for sustainable transport | 2020-2023 |
| Simple | Sustainable integrated method to produce lignocellulosic ethanol | Motor Oil Hellas | Cooperation, Regional operational Programmes[3] | 2G Ethanol | 2013-2015 |
| Tender CINEA/2022/OP/0004 | Outlook for the necessary means to build industrial capacity for drop-in advanced biofuels | BTG | CINEA | Bioenergy technologies | 2023 |
| TwinPeaks | Twinning for promotion to develop advanced gasification solutions | Lithuanian Energy Institute | H2020 | Gasification | 2020-2023 |

[3] Partnerships between industry and research organisations in focused research and technology areas - Operational Programme "Competitiveness and Entrepreneurship" (ΕΠΑΝ-ΙΙ), Priority Axis 1 "Creation and Exploitation of Innovation Supported by Research and Technological Development" and Regional Operational Programmes (ROP).

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| Waste2Grid | Converting WASTE to offer flexible GRID balancing Services with highly-integrated, efficient solid-oxide plants | Ecole Polytechnique federale de Lausanne | H2020 | Gasification | 2019-2020 |
| Waste2Road | Optimization of waste recycling logistics | SINTEF | H2020 | Fast pyrolysis, hydrothermal liquefaction | 2018-2022 |
| Waste2Value | Planning, erection and operation of a 1MW pilot gasifier | BEST | COMET (Austrian National Funding) | Gasification | 2019-2023 |

## Programme HORIZON-CL5-2022-D3-03-02 - Best international practice for scaling up sustainable biofuels

The project BioTheRoS is funded under the program HORIZON-CL5-2022-D3-03-02 - Best international practice for scaling up sustainable biofuels [13]. The projects under this program are fostering international cooperation to develop best practices and concepts along the entire value chain for accelerating the scale-up of sustainable biofuels worldwide. Within this program three projects were funded:

*Table 3: Projects funded under HORIZON-CL5-2022-D3-03-02*

| Akronym | Title | Website |
|---|---|---|
| BioTheRoS | Collaborative Actions to Bring Novel Biofuels Thermochemical Routes into Industrial Scale | https://www.biotheros.eu/ |
| ICARUS | International cooperation for sustainable aviation biofuels | https://www.icarus-biojet.eu/ |
| SUSTEPS | Sustainable, secure and competitive energy through scaling up advanced biofuel generation | https://susteps.eu/ |

The ICARUS project aims to expedite the global expansion of sustainable aviation biofuels production. The value chains considered here are three pathways to SAF: Bio-oils to SAF, Isobutanol to SAF and Syngas to SAF. Other important aspects are the biofuels markets and to enhance the sustainability of aviation fuels. There are many synergies and points of overlap with the ICARUS project. Exchange of information is sought and there is an intensive dialogue between the consortia. Reciprocal invitations as speaker at events or participants in panel discussions are issued.

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The SUSTEPS project focuses on advancing the sustainable production of biofuels from microalgae. It addresses as the BioTheRoS project the scale-up and the entire value chain of a process. As thermochemical conversion route SUSTEPS uses hydrothermal liquefaction. Therefore, the technology used is not a point of contact with BioTheRoS (which uses pyrolysis and gasification), but the general process development, the scale-up issues and also the carbon capture and utilization tasks offer the opportunity for using synergies and exchanging information and experiences.

## Mapping of selected international projects

For the scaling-up and commercialization of biofuels it is of importance to cooperate also on an international level, as a lot of projects and information on specific research topics are available. Several networks for information exchange already exist, like the Technology Collaboration Programmes (TCPs) within the International Energy Agency (IEA). The project team is closely linked to several Tasks of IEA Bioenergy and will facilitate information exchange with these networks:

- IEA Bioenergy Task 33 gasification of biomass and waste
- IEA Bioenergy Task 34 direct thermochemical liquefaction
- IEA Bioenergy Task 39 biofuels to decarbonize transport
- IEA Bioenergy Task 40 deployment of bio-based value chains
- IEA AMF Technology Cooperation Programme on Advanced Motor Fuels

### IEA Bioenergy Task 33 Gasification of Biomass and Waste

Task 33: Gasification of Biomass and Waste monitors the current status of the critical unit operations and unit processes that constitute biomass and waste gasification (BMG) process, and identifies hurdles to advance further development, operational reliability, and reducing the capital cost of BMG systems. The Task meetings provide a forum to discuss the technological advances and issues critical to scale-up, system integration, and commercial implementation of BMG processes [3].

IEA Bioenergy Task 33 comprises following countries: The Netherlands, Austria, Belgium, Canada, China, France, Germany, UK, India, Italy, Sweden and USA. The synergies with the BioTheRoS project are the work on gasification technology and fuel synthesis with different projects conducted within the frame of the Task network.

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## IEA Bioenergy Task 34 Direct Thermochemical Liquefaction

Task 34 'Direct Thermochemical Liquefaction' has as its main emphasis overcoming barriers to commercialization of DTL of biomass for liquid fuel production. The overall objective of the Task is to improve the implementation and success of direct thermochemical liquefaction of biomass for fuels and chemicals. This objective is achieved through monitoring, reviewing, and contributing to the resolution of issues that will permit more successful and more rapid implementation of pyrolysis technology, including identification of emerging opportunities to provide a substantial contribution to bioenergy [4].

The Direct Thermochemical Liquefaction Task is running in parallel with the other tasks in IEA Bioenergy, as approved by the IEA Bioenergy Executive Committee (ExCo) with membership including Canada, Denmark, Finland, Germany, India, Netherlands, New Zealand, and the USA. The synergies with the BioTheRoS project are the work on pyrolysis technology and pathways to transportation fuels from pyrolysis bio-oil in different projects conducted within the frame of the Task network. Task 34 wants to facilitate information exchange with stakeholders via workshops and webinars.

## IEA Bioenergy Task 39 Biofuels to Decarbonize Transport

IEA Bioenergy TCP Task 39: Biofuels to Decarbonize Transport, is a group of international experts working to increase use of and to commercialize sustainable transportation biofuels. Bioenergy and biofuels are important components within a country's green energy portfolio. While there are numerous renewable energy options for heat and electricity generation, biofuels are currently the only means of displacing liquid fossil fuels such as gasoline, diesel, and aviation fuels [5].

The goal of Task 39 is to provide participants with comprehensive information to assist with the development and deployment of transportation biofuels. For this they want to provide platforms for international collaboration and information exchange in bioenergy research, development, demonstration, and policy analysis. Participating countries in IEA Bioenergy Task 39 are Austria, Belgium, Brazil, Canada, China, Denmark, European Commission, Germany, Ireland, Japan, New Zealand, South Korea, Sweden, The Netherlands and USA. Synergies with the BioTheRoS project are in particular the markets for sustainable biofuels and the policies in the respective countries.

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## IEA Bioenergy Task 40 Deployment of biobased value chains

IEA Bioenergy Task 40: Deployment of biobased value chains (in the triennium 2016-2018 known as 'Sustainable biomass markets and international bioenergy trade to support the biobased economy'), commonly abbreviated Task 40, was established under the International Energy Agency (IEA) Bioenergy Implementing Agreement in December 2003 with the aim of focusing on international bioenergy technology potential, barriers, and trade as well as its wider implications [6].

The core objective of the Task is to support the deployment of viable, efficient, and profitable biobased value chains and their respective system services and value created in the context of sustainable, regional, national and international markets, including trade issues; reflecting on policy developments and economic aspects, e.g., carbon markets and financing; long-term climate and sustainability requirements. Synergies with Task 40 are on the areas of market developments, BECCUS and carbon markets and deployment strategies. Task 40 includes active and dedicated members with the aims to investigate and study sustainable biomass markets for a stable global commodity market in biomass energy and biobased economy including the following countries: Germany, Austria, Denmark, Sweden, the Netherlands, USA.

## IEA AMF Technology Cooperation Programme on Advanced Motor Fuels

IEA AMF is a Technology Cooperation Programme in the frame of the International Energy Agency dealing with Advanced Motor Fuels. AMF TCP is helping the transport sector to increase sustainability by reducing the impacts of the sector on the environment. AMF brings stakeholders from different continents together for pooling and leveraging of knowledge and research capabilities in the field of advanced and sustainable transport fuels. [7]

The objective is to advance the understanding and appreciation of the potential of advanced motor fuels towards transport sustainability. AMF provides sound scientific information and technology assessments facilitating informed and science-based decisions regarding advanced motor fuels on all levels of decision-making. Contracting parties are organizations from the following countries: Austria, Brazil, Canada, China, Denmark, Finland, Germany, India, Japan, Republic of Korea, Spain, Sweden, Switzerland and USA. Synergies with AMF are mainly on the application side, as this network has projects on aviation fuels and maritime fuels.

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## Mapping of selected research groups

Using the methodology described above, a total of 147 research groups (82 universities and 65 research institutes) have been listed. These research groups are conducting research in the field of biomass gasification, pyrolysis or both. All of these research groups are either part of the consortium of projects with potential synergies or part of dedicated international networks.

### Universities

The majority of universities identified are located in the EU (54) and North America (10), as can be seen in Figure 2 and Figure 3. 69 universities are located in Mission Innovation Countries (marked in italics).

- *Aalborg University*
- *Aalto University*
- *Aarhus University*
- *Adelaide University*
- *Aston University Birmingham*
- Bogazici University
- *BOKU University*
- *Brunel University*
- Brussels Engineering School (ECAM)
- *Chalmers University of Technology*
- *Christopher Newport University (CNU)*
- *Complutense University of Madrid*
- École Polytechnique Fédérale de Lausanne (EPFL)
- *Federal University of Goiás*
- *Friedrich-Alexander University (FAU)*
- Hasselt University
- *Hochschule Bremerhaven*
- *Hochschule Zittau/Görlitz*
- *Imperial College London*
- *Iowa State University*
- *Johannes Gutenberg University Mainz*
- *Königliche Technische Hochschule (KTH)*
- *Luleå University of Technology*
- *McGill University*
- National Technical University of Athens
- *Norwegian University of Science and Technology (NTNU)*
- NOVA School of Science and Technology
- *OTH Amberg-Weiden*
- *Politecnico di Milano*
- *Politecnico di Torino*
- *Polytechnique Montréal*
- Portalegre Polytechnic University
- *RWTH Aachen University*
- Silesian Uni of Technology
- *Tampere University*
- *Technical University of Darmstadt*
- *Technical University of Dresden*
- *Technical University of Eindhoven*
- *Technical University of Freiberg*
- *Technical University of Hamburg*
- *Technical University of Lappeenranta (LUT)*
- *Technical University of Munich*
- *Technical University of Denmark (DTU)*
- *Technical University of Vienna*
- *Tianjin University*
- *Tsinghua University*
- *Universidad Rey Juan Carlos*
- *Universidade Federal de Itajubá (UNIFEI)*
- *Universidade Federal de Uberlandia*
- *Università degli Studi di Napoli Federico II*
- *Universitat Autònoma de Barcelona*
- *Université de Lorraine*
- *Université de Sherbrooke*
- *Université du Quebec a Trois-rivieres*
- *Université Laval*

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- University Évora
- University Lublin
- University of Ankara
- University of Aveiro
- *University of Barcelona*
- *University of Bologna (UNIBO)*
- *University of Bozen-Bolzano*
- *University of British Columbia*
- *University of Calgary*
- *University of Copenhagen (UCPH)*
- *University of Groningen (RUG)*
- *University of Hohenheim*
- *University of Jharkhand*
- *University of Manchester*
- *University of New Brunswick*
- *University of Padova*
- *University of Rostock*
- University of Santander (UdeS)
- *University of Southern Denmark (SDU)*
- *University of Strathclyde*
- *University of the Basque Country (UPV/EHU)*
- *University of Toronto*
- *University of Twente*
- *University of Utrecht*
- *University Stuttgart (IFK)*
- *University Tuscia*
- *Wageningen University & Research (WUR)*

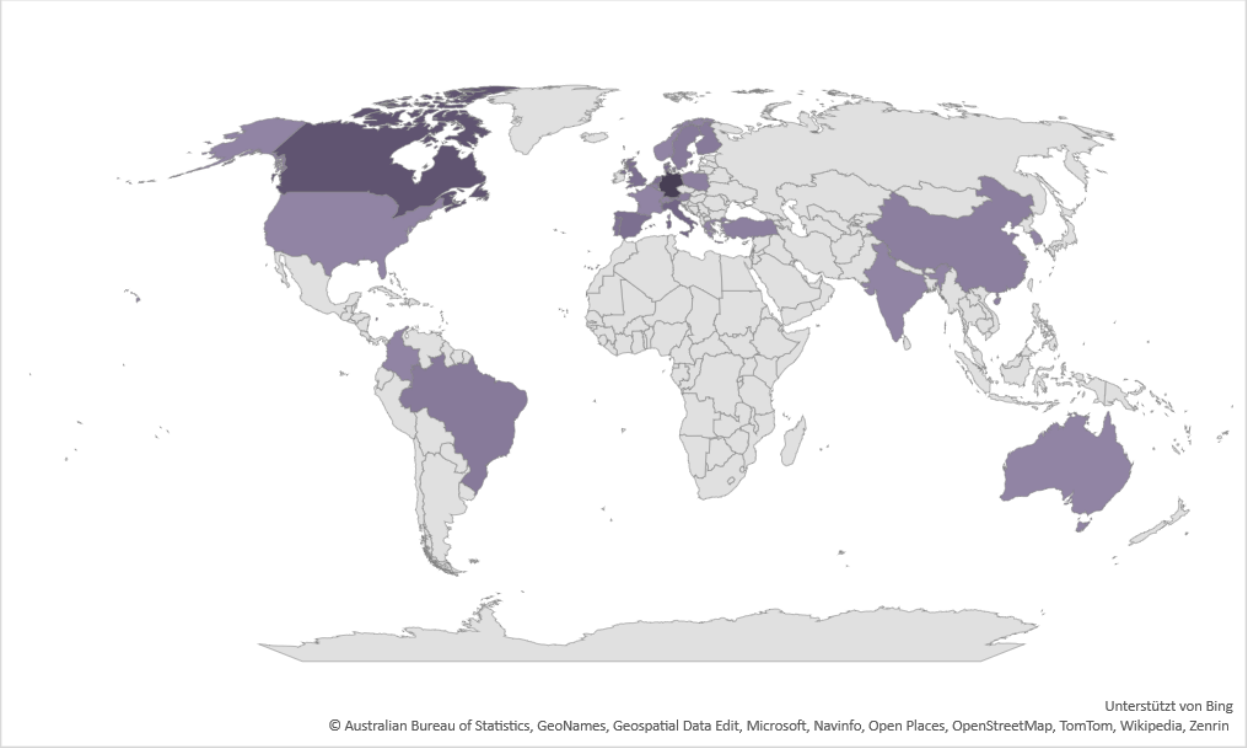


*Figure 2: Selected universities with potential synergies*

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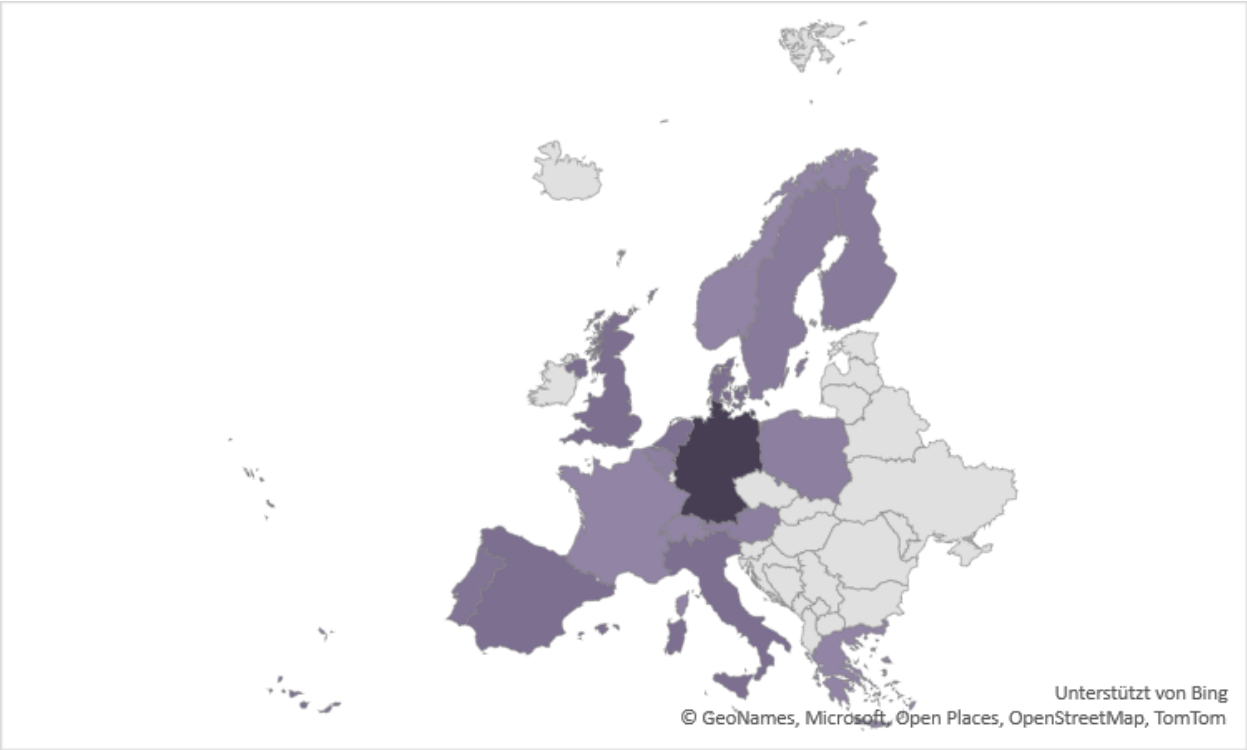


*Figure 3: Selected European universities with potential synergies*

## Research institutes

Most research institutes identified are located in the EU (47), as can be seen in Figure 4 and Figure 5. Of the listed ones 54 research institutes are located in Mission Innovation Countries (marked in italics).

- *AEE Intec*
- AlgEn
- *Argonne National Laboratory*
- Avecom
- *BEST*
- *BIOEN FAPESP*
- *BTG*
- *CanmetENERGY*
- *CARTIF*
- *CATARC (China Automotive Technology and Research Center)*
- *CEA*
- *CEPSA*
- CERTH
- *CIEMAT*
- *CIRAD*
- *CIRCE*
- *CNRS*
- *Consiglio Nazionale delle Ricerche*
- *CREA*
- CRES
- *CSIC (Consejo Superior de Investigaciones)*

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- *CSIR (Council of Scientific and Industrial research*
- *CUTEC*
- *Danish Technological Institute*
- *DBFZ*
- *DEEP Laboratory - INSA Lyon*
- *DLR*
- *Enea Research Center*
- *Etaflorence*
- *FNR*
- *Forschungszentrum Jülich*
- *Frauenhofer Institut IFF*
- *Fraunhofer Umsicht*
- Geonardo Environmental Technologies
- *GTI Gas Technology Institute*
- *ICFAR (Institute for Chemicals and Fuels from Alternative)*
- *IFEU*
- *IFP Energies nouvelles*
- *IINAS*
- *INRAE*
- *IRESEN*
- *JRC (Joint Research Center)*
- *KICT (Korea Institute of Civil Engineering and Building Technology)*
- *KIER*
- *KIT (Karlsruhe Institute of Technology)*
- *LEC - Large Engines Competence Center*
- *Leibniz-Institut für Katalyse*
- LIST
- LNEG
- *Natural Resources Institute Finland*
- *NEDO*
- NHRF (National Hellenic Research Foundation)
- *NREL*
- *OWI Science for Fuels*
- Paul Scherrer Institut
- *PNNL (Pacific Northwest National Laboratory)*
- *QIBEBT*
- Ranido
- *RISE*
- *RTI International*
- *Sintef*
- *Tec4Fuels*
- TÜBİTAK
- *VTT*
- *WIP Renewable Energies*

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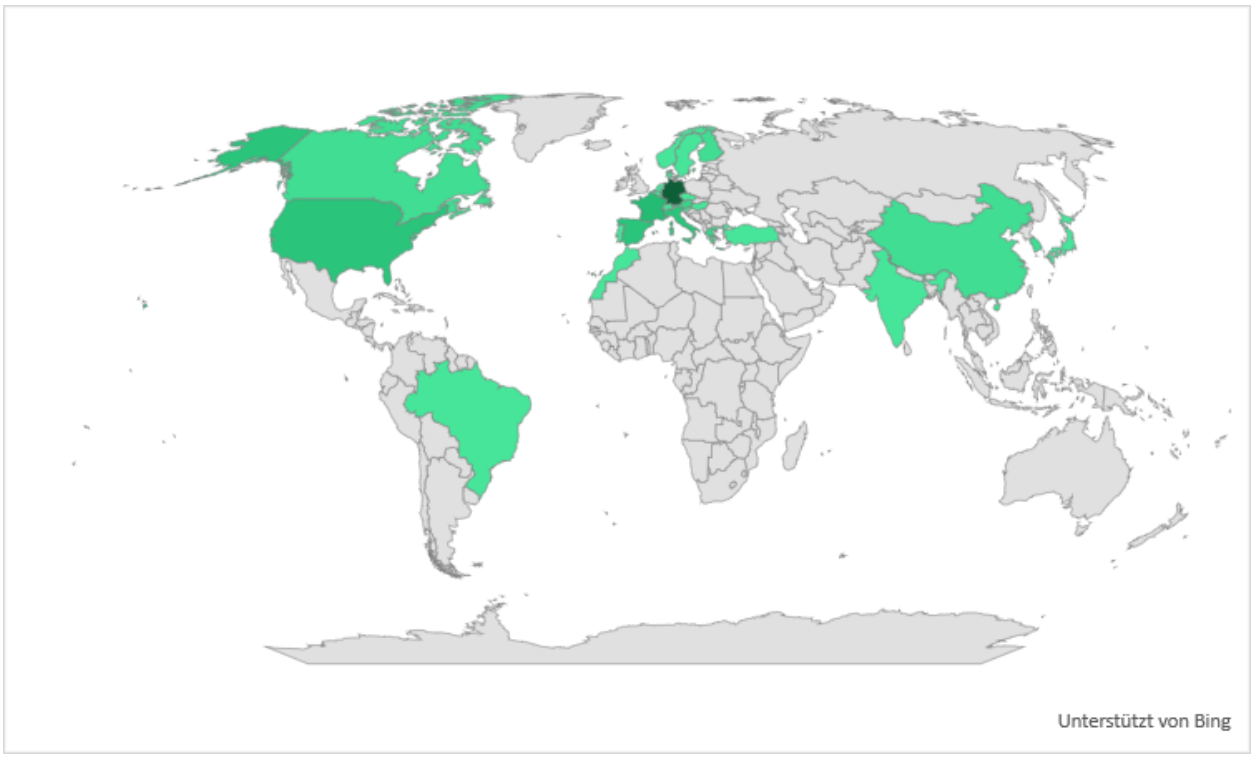


*Figure 4: Selected research institutes with potential synergies*

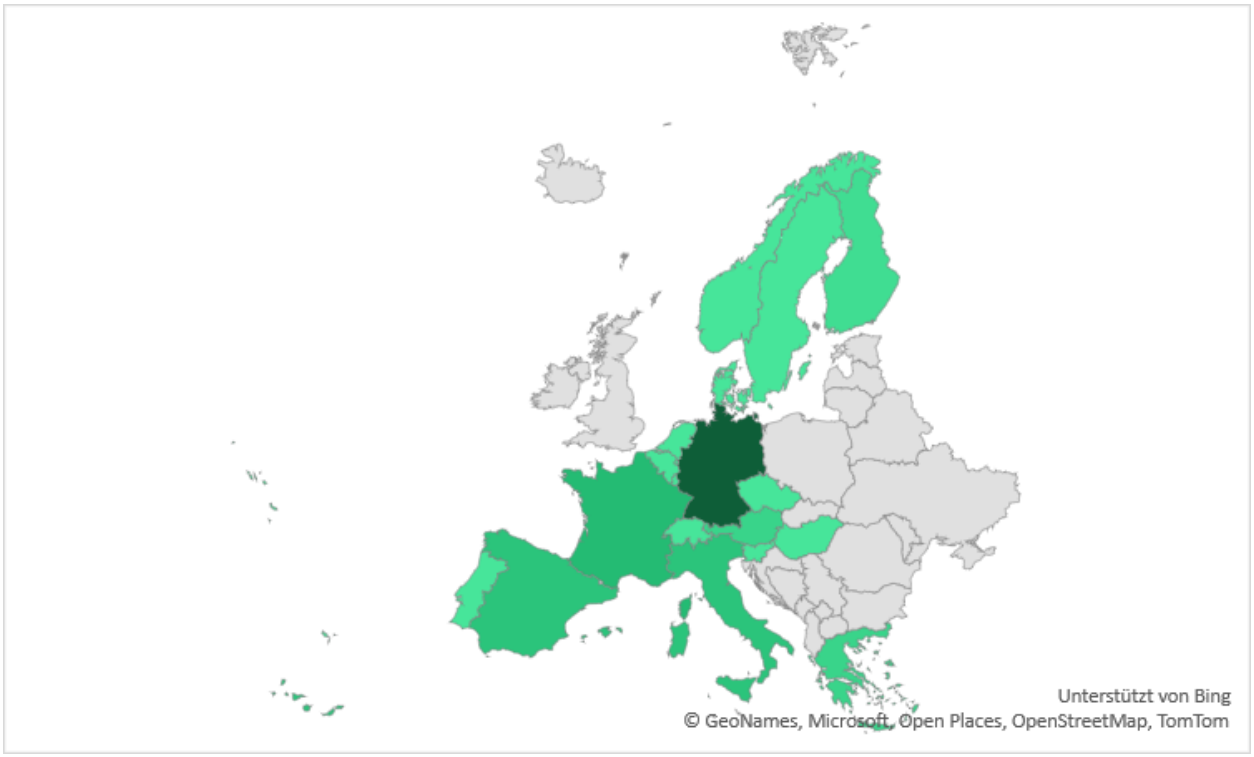


*Figure 5: Selected European research institutes with potential synergies*

## Initiatives and demonstration plants

Besides projects and research groups there are also initiatives and facilities working on thermochemical technologies such as gasification or pyrolysis. However, most of those facilities are not specifically dedicated for the production of biofuels, which is the focus of the BioTheRoS project. In Deliverable 6.1 Report on mapping of policy frameworks [14] chapter 8 provides information on operation and planned liquid transport biofuels production initiatives. The focus here lies on the aviation and maritime sector.

The international research networks identified maintain databases on demonstration plants or facilities with focus either on biofuels, gasification, direct thermochemical liquefaction or European facilities. These databases share the same structure. Operational, planned or closed facilities are displayed, with references to TRL, technology, output and other information. In all the databases it is possible to filter according to the various categories.

*Table 4: Databases on demonstration plants for pyrolysis, gasification and biofuels*

| Network | Title | Focus | Link |
|---|---|---|---|
| IEA Bioenergy Task 33 | Database Gasification of Biomass and Waste | Gasification | https://task33.ieabioenergy.com/database/ |
| IEA Bioenergy Task 34 | Pyrolysis Demoplant Database | Pyrolysis | https://demoplants21.best-research.eu/projects/displaymap/twhWVt |
| IEA Bioenergy Task 39 | Database on facilities for the production of advanced liquid and gaseous biofuels for transport | Advanced Biofuels | https://demoplants.best-research.eu/ |
| ETIP Bioenergy | Production Facilities | European Facilities | https://www.etipbioenergy.eu/databases/production-facilities |

Figure 6 shows an example for filtering on one of the databases [15]. In this case results for Gasification plants which produce either FT Liquids, methanol or SAF with TRL 6-8 are listed. With the filtering options all varieties can be searched and found and more information on the single facilities is available.

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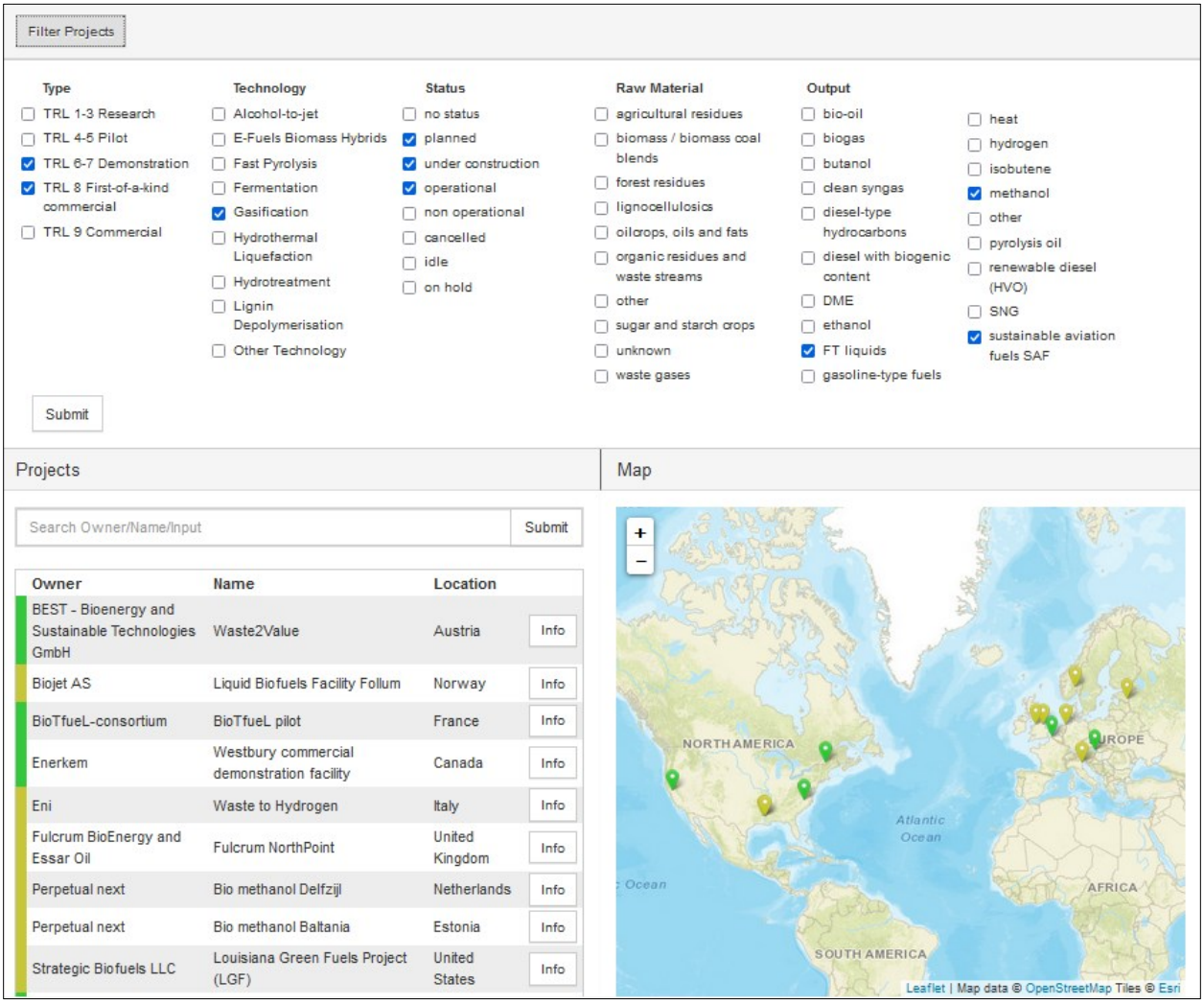


*Figure 6: Example for filtering and results on the IEA Bioenergy Task 39 database [15]*

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## Potential synergies with EU funded and international projects

Scaling up sustainable biofuels is a global challenge in terms of environmental, social, and economic sustainability, which can benefit from international collaboration and knowledge exchange. Potential synergies with EU-funded and international projects are crucial for advancing sustainable biofuel innovations. BioTheRoS is committed to establish close collaboration links with well-known entities, research groups and projects in the field of gasification and pyrolysis for biofuel production. By partnering with projects like ICARUS and other similar initiatives, BioTheRoS aims to promote Sustainable Aviation Fuel (SAF) innovations.

Potential synergies with the listed projects and research groups exist on several levels – projects can deal with same technologies (pyrolysis or gasification, upgrading), same methods (implementing digital tools and AI, BECCUS), same expected products (SAF or maritime fuels) or in general with scale-up issues and biomass value chains. In particular the technological synergies are important links to the technological work packages in BioTheRoS (WP3 Pyrolysis, WP4 Gasification). Collaboration on developing and optimizing those biofuel conversion technologies can enhance efficiency and reduce costs and subsequently this leads to an acceleration of the scale-up.

The BioTheRoS project team will exchange data and results with the international networks of IEA Bioenergy (Task 33, 34, 39, 40), IEA AMF and ETIP Bioenergy, as well as with the “sister projects” funded under the HORIZON-CL5-2022-D3-03-02 programme and other relevant European and International research groups. The information exchange with those networks will build on workshops and online meetings, discussion of results, linked with the respective technical work packages within the BioTheRoS project, and attendance of webinars and joint events (see also deliverables of WP8).

In an upcoming Task of WP 7 – Task 7.3 the development of a network for knowledge sharing is created through gathering information from existing projects and a platform for this collected information on the BioTheRoS website is established. This database (Knowledge Hub) contains and lists relevant information, which includes a list of research groups and stakeholders (Research Network), as well as a list with technical reports and links to important scientific publications (Publication Database). The synergies identified in this task will be used and the research groups are provided with collected and edited information. Research groups which are not listed in this publication and would like to be involved in the BioTheRoS network for knowledge sharing are invited to contact andrea.sonnleitner@best-research.eu.

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