IMPACT

ENERGY CARRIERS FROM ORGANIC WASTE

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A brighter future with biofuels

Innovative research activities are focused on contributing to the important goal of bringing innovative biofuels from sustainable raw materials to the market

The European Commission's proposal for the Renewable Energy Directive for the period following the year 2020 introduces a gradual phase-out of conventional biofuels and sets a minimum target for advanced biofuels for transport. Therefore, there is a pressing need for research that will pave the way for innovative biofuels from sustainable raw materials to be brought to the market.

TO-SYN-FUEL is a Horizon 2020-funded project coordinated by Fraunhofer Institute for Environmental, Safety, and Energy Technology (Fraunhofer UMSICHT) in Germany, that is seeking to build-up, operate and demonstrate the production of synthetic fuels and green hydrogen from waste biomass. The project began in May 2017 and will run for a period of 48 months. As part of Horizon 2020's new research and innovation programme, it is assisting in the long-term goal of bringing innovative biofuels from sustainable raw materials to the market.

AN IMPACT DRIVEN CONSORTIUM

The project consortium comprises of key industrial stakeholders with the knowledge and expertise to develop and implement a full commercial scale technology. 'The key industrial partners consist of stakeholders with expertise ranging from across the whole value chain and include feedstock providers as Slibverwerking Noord-Brabant, engineering providers as Verfahrenstechnik Schwedt, Engie Services Netherlands, Susteen Technologies and HyGear Technology and Services, and fuel off takers as ENI', says Daschner. Academia is also heavily involved, with collaborators including the University of Bologna in Italy and the University of Birmingham in the UK. Specific tasks supporting the technology and knowledge transfer are in charge of LEITAT, ETA-Florence and WRG Europe, project partners with a valuable expertise in those fields.

Fraunhofer UMSICHT has developed a technology called thermo-catalytic reforming (TCR®), which it hopes will have a significant impact on addressing sustainable energy, economic, social and environmental needs. The technology produces renewable liquid fuels from waste biomass, converting residual biomass into three main products: H_2-rich synthesis gas, biochar and liquid bio-oil. Using high-pressure hydro-deoxygenation (HDO) in small-scale refining units that operate in multiple decentralised locations, the distillation creates a diesel or petrol equivalent that can then be used directly in internal combustion engines. The main goal of TO-SYN-FUEL is to demonstrate and validate the technical and economic viability of TCR® in combination with PSA and HDO, as well as its environmental and social sustainability.

To do this, the researchers are combining TCR®, HDO and pressure swing absorption (PSA) with respective environmental and social sustainability mapping in one plant. Project Coordinator Professor Andreas Hornung explains why this is beneficial: 'Considering the significant demand for processes that can produce sustainable synthetic fuels efficiently and cost competitively in smaller decentralised units, this integrated approach presents many advantages in terms of flexibility of scale and delocalisation at regional and local level, flexibility of feedstock, quality and reproducibility of products, and competitively low costs (capital and running)'. In addition, the project will deliver a comprehensive exploitation business plan that the team hopes will serve as an example for facilitating rapid commercial uptake. 'The business plan will capitalise on the key strengths of project partners towards facilitating in the successful commercial deployment of the technology,' observes Daschner.

A VERSATILE COMBINATION

In this particular project, the researchers are focusing on sewage sludge, but the technology combination is extremely versatile, which Daschner highlights. 'Within the TO-SYN-FUEL project, sewage sludge will be tested as feedstock, but the technology combination TCR®/HDO/PSA can convert a broad range of residual biomass like digestate from AD plant, biowaste and oil pomace.' The TCR®-oil has physical characteristics such as low molecular weight components and low oxygen content that enable it to be blended with existing fossil fuels through HDO without the need for large volumes of expensive catalyst that are typically required due to the low oxygen content. 'This results in a liquid that readily distils into "synthetic" fuel fractions (diesel and gasoline) that can be used directly by existing transport infrastructure,' points out Hornung. 'It is the final liquid product quality which makes the TCR®/PSA/HDO process most attractive over all other state of the art technologies today.'

The University of Bologna will perform a full life cycle analysis (LCA) of the process, mapping the environmental effect of diverting waste streams from alternative pathways by converting them into drop in fuels using the TCR®-HDO technology. 'As well as using data from the demonstration plants this LCA will also include alternative disposal and conversion routes, the environmental footprint of the TCR®-HDO process, the effect of drop in fuels on engine performance and lifespan, and the emissions from engines using these drop in fuels to ensure that all foreseeable environmental concerns are addressed,' says Hornung.

The role of the University of Birmingham will be to monitor properties of all plant inputs and outputs with a view to ensuring the consistency of feedback, and in order to obtain operational datasets of the intermediate and final product properties to validate the integrated technology. 'Feedstock will be characterised through a proximate and ultimate analysis including ash and heavy metal analysis and heating value,' Daschner reveals. 'Intermediate products will be analysed through physical and chemical property analysis (TCR®-oil, syngas and biochar). Composition of wastes (such as flue gases and process waters) will also be analysed in compliance with environmental legislation.'

GOING GREEN

According to the team, the TCR® process coupled with PSA and HDO enables the production of green transport fuels whilst generating an excess of hydrogen and energy. The integrated approach has been designed to be economical at a small scale as a result of the lower cost of the HDO step and the low cost of capital investment of a TCR® plant.

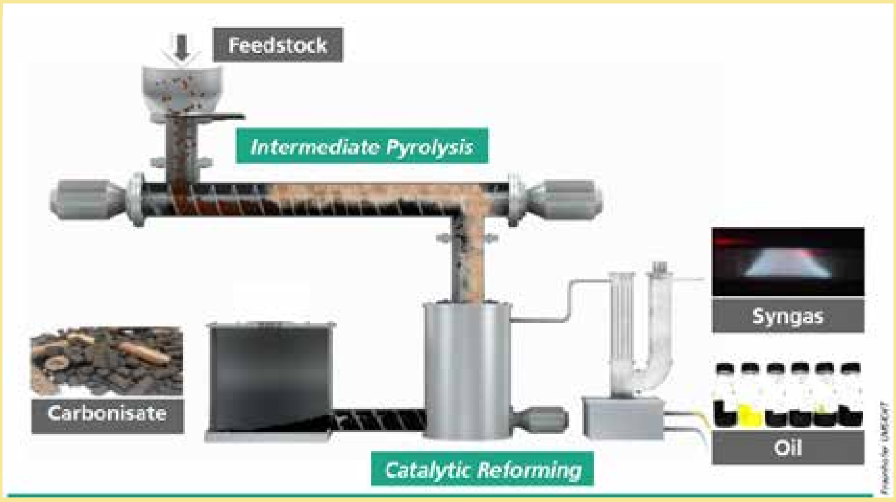
> *This integrated approach presents many advantages in terms of flexibility of scale and delocalisation at regional and local level, flexibility of feedstock, quality and reproducibility of products independent of feedstock, and competitively low cost*

The intention is for the demonstration site to be located near to a variety of organic waste producers and, potentially, petrochemical industries. This means that the concentration of potential end users of the integrated approach will be high. 'By locating the plant close to these feedstocks TO-SYN-FUEL will be able to engage with these waste generators and demonstrate to them the value of the approach thus facilitating their involvement in the next phase as feedstock providers to the commercial flagship plant,' says Hornung.

SUCCESS AHEAD

The consortium has already taken preliminary steps to identify other customers and have entered into discussions for further exploitation of the technology upon successful demonstration. Once the project has proven successful commercial contracts will be offered to potential customers. 'Consequently, work is ongoing to attract investors and to build confidence with respect to the products and the technology,' explains Daschner. 'In addition, registered stakeholders will be targeted through dedicated communication, interviews, meetings, and cross-promotional activities in order to extend the projects reach and attract greater industrial interest and investment.'

Although still in its early stages, and too early to assess measures of success, TO-SYN-FUEL's added value is the combination of the PSA, HDO and TCR® technologies, leading to a decentralised plant concept and the ultimate social, economic and environmental benefits this will yield.



Process flow diagram

Project Insights

FUNDING

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PARTNERS

• Alma Mater Studiorum – University of Bologna (Italy) • Engie Services Netherlands NV (The Netherlands) • ENI S.p.A. (Italy) • ETA–Florence Renewable Energies (Italy) • Fraunhofer UMSICHT (Germany) • HyGear Technology and Services BV (The Netherlands) • LEITAT (Spain) • Slibverwerking Noord-Brabant NV (The Netherlands) • Susteen Technologies GmbH (Germany) • University of Birmingham (UK) • Verfahrenstechnik Schwedt GmbH (Germany) • WRG Europe Ltd (UK)

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BIOS

Professor Andreas Hornung is Chair of the Management Board of TO-SYN-FUEL. He has been director of the Institute Branch Sulzbach-Rosenberg of Fraunhofer UMSICHT since January 2013. Since June 2015 he has been Professor in High Temperature Process Technologies at the Friedrich-Alexander-Universität Erlangen-Nürnberg and since April 2014 the Chair in Bioenergy at the University of Birmingham.

Dr Robert Daschner is Head of Department Renewable Energy at Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Sulzbach-Rosenberg, Germany. He completed his PhD at the TU Munich regarding the energetic optimisation of biomass conversion plants and is dealing with the development of new technologies for the utilisation of biogenic residues at the institute.

Impact Objectives

- Build-up, operate and demonstrate the production of Synthetic Fuels and Green Hydrogen from organic waste biomass
- Introduce a gradual phase-out of conventional biofuels and set a minimum target for advanced biofuels

Energy carriers from organic waste

***Professor Andreas Hornung** and **Dr.-Ing. Robert Daschner** from **Fraunhofer UMSICHT** are coordinating **TO-SYN-FUEL**, a project demonstrating a new integrated process for the production of synthetic fuels and green hydrogen from organic waste biomass*


Professor Andreas Hornung


Dr.-Ing. Robert Daschner

Can you describe the aims of the TO-SYN-FUEL project?

TO-SYN-FUEL will demonstrate a new integrated process combining thermo-catalytic reforming (TCR®), with hydrogen separation through pressure swing adsorption (PSA), and hydro-deoxygenation (HDO), to produce a fully equivalent gasoline and diesel substitute (compliant with EN228 and EN590 European standards) and green hydrogen for use in transport. The primary ambition of this project will be to demonstrate and validate the technical and economic viability of the integrated TCR®/PSA/HDO technology approach, together with their environmental and social sustainability, as well as the cost-competitiveness, at near-commercial scale through the construction of a demonstrator that will also serve as an exemplar to facilitate rapid commercial uptake.

What are some of the current barriers to bringing advanced biofuels from sustainable raw materials that you are hoping to address through this work?

Thermochemical processes such as gasification and pyrolysis are flexible with regard to feedstocks but require either expensive catalysts or considerable further upgrading steps of the products for the production of liquid fuels. As a result, they cannot be cost competitive unless carried out in large centralised facilities. This is itself not desirable as transporting the feedstocks to these centralised locations imposes a further economic and environmental cost, whereas an ideal solution would be modular, small-scale units that operate in multiple decentralised locations, thus minimising transport costs and tailpipe emissions from feedstock source to end user. There is a significant demand for a process that can produce sustainable synthetic fuels (biofuels with characteristics matching fossil fuels) efficiently and cost competitively in smaller decentralised units. This process, which will use industrial organic wastes (in the case of TO-SYN-FUEL, pre-conditioned sewage sludge) as feedstock, presents many advantages in terms of flexibility of scale and delocalisation at regional and local level, flexibility of feedstock, quality and reproducibility of products independent of feedstock, and competitively low costs (capital and operation).

What will the impact be from this work and who will benefit from the research?

To demonstrate and validate the technical and commercial viability of this integrated approach, this project will deliver a combined TCR®/PSA/HDO demonstrator, together with respective environmental and social sustainability mapping. This will validate a comprehensive exploitation business plan, building on already established end user interest – thus gaining an advantage to market with commercial exploitation of the technology as the next step of development. The scale up of such plants up to a capacity of three tonnes per hour and more for the installation throughout Europe would be the driver to produce thousands of tons of green fuel per year from organic wastes with greenhouse gas (GHG) savings of over 80 per cent.

How do you envisage the technology will be rolled out across Europe, and ultimately across the world?

By the end of the project the TCR®/PSA/HDO technology will have been validated at TRL-7 and the business plan and environmental/social sustainability analysis for the technology will be complete. This will open the way for a first commercial scale facility to be built in the following project. This will take the technology to TRL-9 and facilitate rapid uptake across Europe. The vision of the first commercial TCR®/PSA/HDO plant will vary dependant on the outputs from this project, and whilst the core enabling TCR® technology will not be changed, other variables have been identified. For instance, larger plants are usually more efficient due to economies of scale, but there is a trade off in the case of facilities using waste as this is typically low energy density material, so costs of transport are higher than for higher energy density fossil fuels. Therefore, the size of the commercial plant will be determined by economic data from the project, which will optimise the plant size versus waste collection radius. This means that the commercial scale facility could be a regional network of local small-scale TCR® reactors instead of a single large-scale unit. This flexibility is important for enabling the process to be adapted and integrated into a wide range of different scenarios.