NEXTGEN roadfuels

Newsletter Issue 3, March 2021

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EU RESEARCH & INNOVATION FOR RENEWABLE ENERGY CARRIERS

With the **Green Deal** in motion, the European Union is aiming to become the **first climate-neutral continent** by 2050 while at the same time pursuing three other objectives: protect human life, animals, and plants by cutting pollution; support companies to become world leaders in clean products and technologies; ensuring a just and inclusive transition.

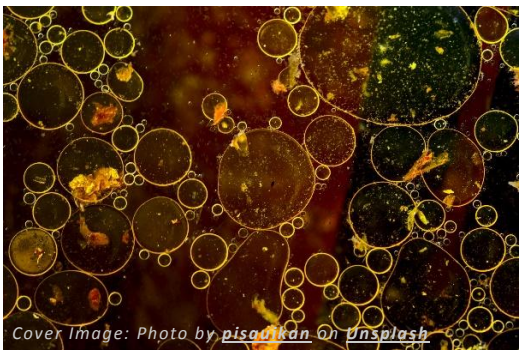
Ultimately, the European Green Deal will improve the well-being and health of the citizens and future generations.
Within this context, the role of **Research & Innovation (R&I)** is pivotal to fulfil the target for at least **55% GHG reduction in 2030** and to stimulate EU competitiveness in EU's ambitious new industrial strategy. Moreover, **R&I aims at leading international collaboration** for cutting global emissions and **to reduce the carbon footprintin transport**; focus on which renewable fuels has been allocated with great attention.

Under the umbrella of the European Green Deal the main policies and strategies that affect the area of bioenergy and renewable fuels:
- **The EU Strategy for Energy System Integration COM (2020) 299 final** which explicitly mentions the objective to: unlock the potential of sustainable biomass and biofuels, green hydrogen, and synthetic fuels.
- **The Hydrogen strategy for a climate-neutral Europe COM (2020) 301 final**: this is about creating an industrial chain, boost demand in industry and mobility and promote R&I in clean hydrogen.

SEQUENTIAL HYDROTHERMAL PROCESSING OF SEWAGE SLUDGE TO PRODUCE LOW NITROGEN BIOCRUDE:

The problem that surrounds the reutilization of sewage sludge is caused by its water content. The valorization of **wet sewage sludge** to useful products has the potential to augment energy production and tackle disposal issues. However, due to high water content, they are not particularly well suited for several thermochemical conversion processes, (e.g., incineration, fast pyrolysis, and gasification) requiring a dry feedstock.

On the other side, a technology that tolerates and even needs high water content is **hydrothermal liquefaction (HTL)**. The viscous oil-like biocrude product is comparable with the vacuum gas oil cut of a heavy petroleum crude oil, but it is **richer in heteroatoms**. Especially nitrogen heterocycles, originating from proteins are unwanted in final products and need extensive upgrading processes.



Cover Image: Photo by pisauikan on Unsplash

A new approach to **lower nitrogen content** and thus to increase biocrude quality is to investigate an upstream mild hydrothermal pre-treatment, improving the HTL feedstock.

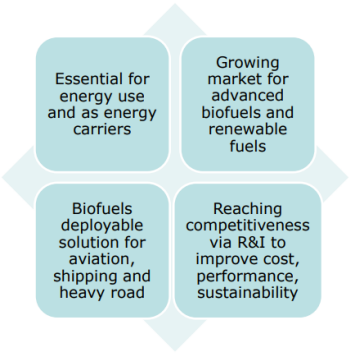
- **The EU Biodiversity Strategy for 200 COM (2020) 380 final**: restoring forests, soils and wetlands and creating green spaces in cities, this is very relevant for the production and supply of sustainable biomass from forests and agriculture.
- **The Sustainable and Smart Mobility Strategy– putting European transport on track for the future COM (2020) 789 final**: this strategy aims for at least 30 million zero-emission vehicles in operation by 2030, carbon neutral collective travel of under 500 km, automated mobility deployed at large scale, zero-emission vessels ready for market. Also, by 2035 zero-emission large aircraft are to be ready for market.

Other important pieces of legislations that are relevant for the European Commission compiled **a 2030 climate target plan implementation for policy measures** are summarized in the figure below (EC).

Revision of the **EU Emissions Trading System** (ETS), including maritime, aviation and CORSIA
Carbon Border Adjustment Mechanism (CBAM)
Effort Sharing Regulation (ESR)
Amendment to the **Renewable Energy Directive** to implement the ambition of the new 2030 climate target
Amendment of the **Energy Efficiency Directive** to implement the ambition of the new 2030 climate target
Revision of the Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry (**LULUCF**)
Reducing **methane emissions** in the energy sector
Revision of the **Energy Tax Directive**
Revision of the **Directive** on deployment of **alternative fuels infrastructure**
Revision of the Regulation setting **CO2 emission performance standards** for new passenger cars and for new light commercial vehicles
Revision of the energy performance of **Buildings Directive**
Revision of the **Third Energy Package for gas** to regulate competitive decarbonised gas markets

All these policies will shape the framework for the development of biofuels and intermediate bioenergy carriers, including those obtained from HTL. With the EU allocating more than **500 billion Euro for climate and environment in its Multiannual Financial Framework**, the plan can become a reality and R&I is crucial for bringing in new and innovative solutions.

The Horizon Europe Programme for Research and Innovation has allocated 95.5 billion Euro, 15.218 of which are allocated to Cluster 5 – Climate, Energy and Mobility where a sustainable, secure, and competitive energy supply is the core goal. Under Cluster 5 of Horizon Europe, **bioenergy, biofuels, and renewable fuels** are considered as essential not only for energy use but also as energy carriers largely expected to ramp up replacing fossil fuels as deployable solution especially in aviation, shipping and long-haul transport.



To achieve this, the R&I priorities of Horizon Europe will focus on the challenges that bioenergy sector still faces to reach competitiveness through reducing the costs and increasing the efficiency and sustainability of technologies and processes.
In order to develop a solid technological base ground, the R&I policy focus is built around five thematic areas:

-**Technology improvement & diversification**
-Feedstock diversification
-Drop in renewable fuel
-**Market uptake** and addressment of particular transport needs
-Breakthrough research and **market-creating innovation**
-**Coordinated R&I funding** / risk-funding needed for market uptake
-**International cooperation** to tackle global societal challenges.

In addition to these factors, **a seamless integration of bioenergy**

The pre-treatment step **was performed at 150 °C** with the addition of three different agents, namely deionized water, sulfuric acid and citric acid. The aim was to solubilize nitrogen-containing compounds into the aqueous supernatant. Downstream, the residual solid material was liquefied with the addition of sodium carbonate via **hydrothermal liquefaction at 350 °C**.

All pre-treatments transferred primarily nitrogen into the aqueous supernatant, while most of the carbon was recovered in the solid. Organic compounds in the form of lipids retained in the sewage sludge solid, which increased the favored biocrude yield significantly. Furthermore, the quality evaluating value, the H/Ceff ratio was increased and the characterization of the biocrude composition showed a lower concentration of N-heterocycles, while long-chain aliphatics derivates are increased.

Read the full paper here.

Author: Joscha Zimmermann.

PRESSURE-DRIVEN FILTRATION AND AMMONIA RECOVERY OF THE LIQUID BYPRODUCT OBTAINED FROM HYDROTHERMAL LIQUEFACTION (HTL) OF SEWAGE SLUDGE

Hydrothermal liquefaction (HTL) of sewage sludge produces an aqueous phase (AP) byproduct, which contains oil-in water-emulsions, suspended solids (SS) as well high concentrations of dissolved solids (DS). Among these constituents, some are of **high value for HTL process itself such as the organic carbon**. **Recirculation** of the organic carbon is an option to increase the yield of HTL. Others can be purified and used in other fields such as the use of ammonium salts as **fertilizers in agriculture**. In addition, the AP contains high concentrations of toxic compounds such as phenols and needs a special treatment before being released in a municipal wastewater treatment plant or being discharged into water bodies.

and biofuels into existing infrastructure can facilitate and speed up their adoption through the use of technologies of four types:
-**Thermochemical** (pyrolysis, gasification, HTL, combustion)
-Biochemical
-Electrochemical
-Photochemical.

Something to keep an eye on is the next generation technologies such as algal fuels, novel catalysis, artificial photosynthesis, etc. and on bioenergy solutions for **a circular economy in a value chain approach**. Moreover, the coupling of renewable electricity and /or renewable hydrogen production and /or CCS in bioenergy conversion systems with biofuel & renewable fuel production can lead to an efficient production with negative carbon emissions.

Watch the full presentation by Maria Georgiadou (Senior Expert at European Commission, DG Research & Innovation) **here.**

GLOBAL POLICY MARKET SCENARIO RELEVANT FOR HTL IN THE ENERGY TRANSITION

Cover photo by Dominik Lückmann on Unsplash

With the **HTL technology** as the focal technology, it may result legit asking which are **the factors** that are influencing its development and what will be its role in the **energy transition**. When considering the production of advanced biofuels from solid waste, five elements are necessary to be considered:
- **Legislation, Certification, GHG emission reduction**
- **Feedstock** availability and quality
- **Solid to liquid** technology
- **Upgradeability** of biocrude to produce fuels
- **CAPEX /OPEX**.

With these elements in mind, the production of biofuels is expected to increase significantly from 1.9 Million Barrels per day in 2018 to around **7.7 Million Barrels per day** in 2040 according to **IEA** – Sustainable Development (2019). There are three types of feedstocks distinguished by "**generation**". The **first generation** includes virgin oils, whether the **second generation** is about waste oils and fats. The **third generation**, for which there is quite some space for improvement in terms of quantity of biofuel production, consists in solid waste such as sewage sludge, forestry residue, organic fraction of MSW and mixed plastic waste.

The largest and most interesting market worldwide for biofuels and HTL technology is, on top of road transport, the one tackling the **marine and aviation sector**. In fact, two initiatives at EU level are being launched in 2021 over these topics: **FuelEU Maritime** and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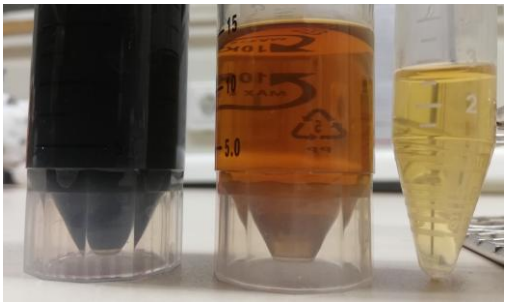
In the next generation road fuels project, the partners from **the Engler-Bunte-Institut (EBI) at Karlsruhe Institute of Technology** have been working on this topic focusing on membrane technologies.

In December 2020, first results were presented by **MSc Ali Sayegh** in a poster at the International Congress on Membranes and Membrane technologies (**ICOM**). In his Poster, Mr. Sayegh showed his investigations on filtering the HTL-AP with a **variety of nanofiltration** (NF) and **low-pressure reverse osmosis** (LPRO) membranes, which were able to retain up to 80% of the dissolved organic carbon and clarify the liquid color to a high extent. Main drawback of using polymeric membranes for HTL-AP treatment was fouling formation and the corresponding flux decline.

In order to achieve a stable membrane performance a pretreatment of the liquid is needed.



In February 2021, further results regarding HTL-AP-pretreatment were presented in the **Annual meeting of the ProcessNet specialist groups Extraction and Membrane Technology** (**ProcessNet**).

In this Conference, Mr. Sayegh gave an oral presentation on a hybrid system consisting of **submerged membrane ultrafiltration** (UF) and an **ammonia recovery** in an acid solution. In continuous experiments lasting up to 10 days, he showed that an UF membrane with a molecular weight cutoff (MWCO) of 100 kDa can retain all particles, suspended solids and micellular oil-in-water emulsions. He also provided the required conditions of the UF process, for an optimized membrane filtration including critical water flux determination and cleaning procedures.

ReFuelEU Aviation. The first one aims at accelerating the uptake of sustainable alternative fuels & power in operation and at berth in EU, whereas the second initiative aims at boosting supply and demand for sustainable fuels (advanced biofuels and electro-fuels) in the aviation sector of the EU.

An additional interesting driver for **thermochemical technologies** is the **chemical recycling of waste**. More in particular, in the EU, legislation is heavily supporting **plastic recycling** given the goal of 50% of plastic packaging waste to be recycled by 2050 and an 800 Euro/ton tax on non-recycled plastic packaging waste from 2021. This is translated in investments and commitments from the **PetChem industry** in chemical recycling by adopting technologies such as HTL, which is very flexible on the typology of feedstock resource. In general, it became evident that dedicated legislation is already in place in the EU and in the UK, and potentially specific legislation is expected in North America in 2021.

This article is based on the presentation of Sylvain Verdier, Haldor Topsoe A/S, given at the NGRF conference "HTL in Green Energy transition".

Have a look at the slides here.

BUSINESS OPPORTUNITIES AND A CHANGE MANAGEMENT PROCESS FOR ADVANCED BIOFUELS

Cover photo by Cameron Venti on Unsplash

In order to deploy the **Hydrothermal Liquefaction** (HTL) technology at scale there is a need to fully understand the value network and comprehend what is its **road to commercialization**. There are several stakeholders along the **value chain** and each of them may have concerns which need to be appreciated so to identify the key questions and the related challenges. By showcasing the technology's potential, the willingness to invest can increase and through **demonstrations plants** a reduction in technical concerns occurs. In turn, the demonstration of the viability of the entire value chain from feedstock to finished fuel, will reduce financial risk. An additional advantage arises from demonstrating the transfer from an existing value chain to a new value chain which can mitigate the personal and organizational concerns the industry may face in a transition phase. The **industrial pathway** is to achieve efficient production of biocrude in terms of full characterization for woody biomass and to reach a **full characterization for urban waste streams**. At the same time the industrial pathway aims at tackling the downstream handling with a demonstrated roadmap for

Furthermore, he showed that the aeration applied in submerged membranes led to a **faster striping of more than 90% of the dissolved ammonia-Nitrogen**. Stripped ammonia was then recovered in a sulfuric acid solution in the form of ammonium sulfate, which is a typical fertilizer used in agriculture and can hence **improve the economic value of the HTL process in total**. At the moment, after fixing the pretreatment method, EBI is **investigating Membrane Distillation** (MD) as an alternative for further treatment of HTL-AP. MD is a thermal driven filtration, which can benefit from the high temperature of the HTL-AP and decrease the operating costs of the HTL-water treatment.

Author MSc Ali Sayegh.

HTL DEVELOPERS' PERSPECTIVE: MAIN DEMOS IN EU AND WORLDWIDE

Cover photo by Mauro Tandoi on Unsplash

One of the main challenges for the **Hydrothermal Liquefaction** (HTL) technology is to prove that it can perform and compete with already established technologies such as **Anaerobic Digestion** (AD). The valorization of urban biogenic waste is one of the potential early uses of HTL technology.

In this sector, AD is the dominant technology, widely adopted for its reliability and technological maturity, while HTL still ranks at a lower technology readiness level and therefore needs to demonstrate its competitiveness. This quest is a long process as HTL is a recent technology which is still in its innovation funnel phase. More in particular, several **demonstration facilities** are being installed across Europe and in multiple locations around the world.

As the technology develops, is becoming clear that it can feature an additional value by being able to deliver a **useful byproduct**

standalone upgradingor co-refining with fossil counterpart.

To fully take advantage of the business opportunities, the HTL product has to become competitive and able to consistently provide a **petroleum-equivalent advanced biocrude**. As a first market segment, targeting the **heavy transport sector** – that is incompatible with electrification or low energy density fuels – seems to be the niche to pave the way for the technology's deployment. A crucial value proposition that the HTL products wants to deliver is its **compatibility** with the already existing petroleum infrastructure and refineries (co-processing) in order to reach a **seamless integration with the system**. Finally, the product needs to be **flexibly upgradable**, according to the sector desired, to diesel, marine and jet fuels. The goal is to upgrade biocrude to the American Society for Testing and Materials (ASTM) Standard Advanced Renewable Fuels such as Sustainable Aviation Fuel (SAF).

Switching side of the table, being the end-user and the municipality's green goals and targets, new regulations and community concerns are requiring novel solutions to deal with bio-organic wastes. Two factors can drive the uptake of HTL by the **urban biogenic waste management market segment**. First, the disposal costs and fees for waste enable the deployment of the technology at a smaller scale given the economic support. Secondly, multiple forestry demonstrations plants of equivalent scale to a commercial sewage plant are being tested – thus, it is possible to leverage learning from forestry demos directly to urban commercial solution.

Check out the full workshop on the HTL technology here!

HTL END USER'S PERSPECTIVE: WASTEWATER TREATMENT PLANTS AND SEWAGE SLUDGE

The **Paris agreement** made the goal of limiting global warming to well below 2, preferably to 1.5, degrees Celsius calling for action in GHG emission reductions.

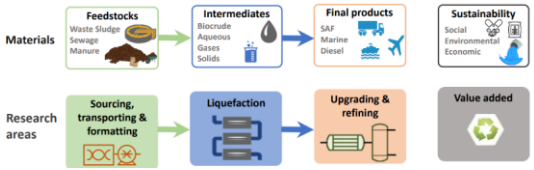
Cover photo by **John Cameron** on **Unsplash**

The **EU Green Deal** has set the goal of a carbon neutral environment clear with the achievement of the **decarbonization of fuels and chemicals.**

via the **recovery of phosphorous** in the process. Next, a list of main demos around EU and the rest of the world:

- HTL Demonstration at **Annacis Facility**: MatroVancouver points out the need for water management, understanding opportunity cost
- **Steeper Energy Norway** (wood) and Calgary (sewage sludge) point to H2 use and links to refining
- **Northern and Southern oil refineries** (Australia), note capital and operating cost both need to come down
- **Licella catalytic HTL** (Australia, UK, and North America) noted the importance of collaboration: end-of-life plastics in the UK with Mura and post-consumer biomass in North America with Arbios
- **Reliance** (India) points at the need to demonstrate robustness at scale to reduce risk
- **RE-CORD** (PoliTo) notes the for co-liquefaction as well as co-refining
- **HyFlexFuel** note, among other things the need for understanding feedstock supply chain and valorization
- **PNNL** notes the importance of blends (urban and rural), as well as increasing catalyst life in upgrading

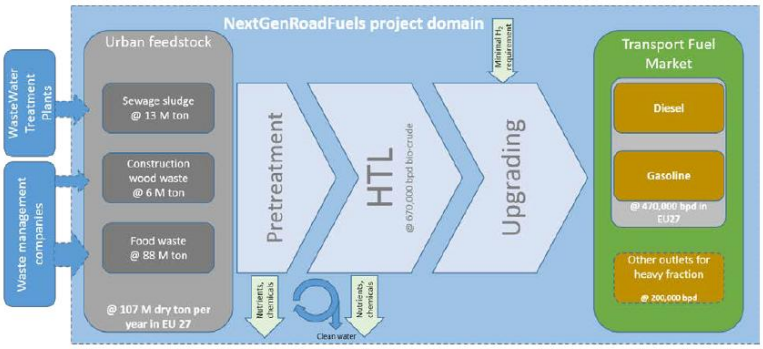
More details and specifics of these demo plants can be found in the **presentation** given by **John Holladay**, Energy and Environment Director, Pacific Northwest National Lab.



In order for HTL to become a mature technology several efforts are still to be undertaken in the form of Research & Development (R&D). As shown in the figure above (**NGRF – PNNL**) the **value chain** is summarized. In the leftmost column, the major **R&D gaps** are enclosing feedstock availability, feedstock blending, water management and large-scale pumping. For what regards **Intermediates and Liquefaction**, the focus is on the time on stream, heat exchanges, scale/ modularization, and higher liquid yields. The column concerning final products and the **upgrading & refining** block has its effort on N and O removal, Fe and mineral removal, catalyst life, and ASTM specification. Finally, the right most column is being researched for improvements on nutrient recovery, water cleanup, avoidance of landfills, and elimination of pathogens.

Check out the full presentation here!

In the future scenarios, the presence of waste is drastically reduced as the majority of its streams enters a **circular economy paradigm** in which waste becomes a valuable resource. These residues are of various kinds as of dry and wet and some in between like **wastewater sludge, digestate from biogas plants, slaughterhouse wastes, side streams form organic factories** and so on. All these are containing large amounts of carbon, nutrients and some even hazardous chemicals and plastic residues. Particularly, **organic carbon reuse** might be essential with a growing population as the demands for food will surge and the availability of land and water will become scarce. In this context, the **wastewater sector** is particularly relevant as it is an interesting source for carbon and nutrients. The recovery of **carbon and nutrients** throughout the entire production value chain is the main driver for the circular bioeconomy. Thanks to its process design, **Hydrothermal Liquefaction (HTL)**, which can be fed with all sort of wet streams, is promising high potential in the coming decade by **being one of the enablers** that will contribute to the shift from a linear to a circular economy.



The image above shows the variety of urban biogenic feedstock that can feed the HTL process and the end products that can be obtained. The potential total feedstock amounts to about **107 M dry ton per year only in the EU**. Specifically, sewage sludge equal to 13 Mton, construction wood waste 6 Mton, and food waste to 88 Mton. In the EU 27, sewage sludge is produced at the **rate of 24.3 kg/pe/year**, where pe is the population equivalent served by WWTP.

According to the harmonized definition by Eurostat and the OECD, **urban areas** —defined as cities, towns, and suburbs — **provide a home to 72%** of the EU-27's population; 41% live in cities and 31% in towns and suburbs, with the urban population in continuing growth over the past 50 years. OECD statistical data also indicate that 30% of the EU population lives in **metropolitan areas** with population between 500,000 and 1.5 million inhabitants, corresponding to accumulated sludge in the **range 12,000-36,000 dry tons per year**. This feedstock availability is adequate for construction of **HTL plants close to wastewater treatment facilities** with capacity of approximately 33-100 dry tons/day (100-300 bpd bio-crude production).

A representative of the wastewater treatment plants, Erik C. Wormslev**,** NIRAS, Director -Innovation, Climate Change & Energy, was present at the NGRF virtual workshop.

Check out his presentation.

ABOUT NEXTGENROADFUELS PROJECT

NextGenRoadFuels is a Research and Innovation project funded by the Horizon 2020 programme to develop a cost-effective valorization pathway for **multiple urban waste streams** such as sewage sludge from treated wastewater, food waste and construction wood waste. These waste streams will be converted into **renewable fuels, fertilizers and proteins**, thus fostering the urban transition towards a circular economy.

Started in 2018 with a consortium of thirteen partners coordinated by the University of Aalborg, the 4-years project will prove the **Hydrothermal Liquefaction pathway (HTL)** as an efficient route to **produce high-volume, cost-competitive, drop-in synthetic gasoline and diesel fuels**, as well as **other hydrocarbon compounds**.

The project is fully aligned with the **SET Plan Key Action 8 on renewable fuels**, which calls for an acceleration of the development and deployment of low-carbon technologies in the transport sector. NextGenRoadFuels will also contribute to the renewable-energy-in-transport target, as well as to the GHG emissions reduction objectives, in line with the Renewable Energy Directive (RED II) and the European Energy Roadmap 2050.

The consortium, coordinated by Aalborg University (Denmark), counts on 11 beneficiaries from 7 countries: Steeper Energy ApS (Denmark), Chemical Process and Energy Resources Institute | CERTH (Germany), CENER (National Renewable Energy Centre of Spain)(Spain),Technical University of Munich (Germany), Karlsruhe Institute of Technology (Germany), SINTEF ENERGI (Norway), HaldorTopsoe A/S (Denmark),ENI S.p.A. (Italy), Goodfuels (The Netherlands), ETA-Florence Renewable Energies (Italy). **Further information: https://www.nextgenroadfuels.eu/**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 818413.

Follow the project on: