Newsletter
Direct Thermochemical Liquefaction

When the wind of change blows, some build protective walls, others build windmills. (Chinese quote)
Security describes a relative state of freedom from danger. Absolute security does not exist. Nor is it quantifiable; what seems safe to one person is frightening to another.

In times of serious demographic and sociocultural changes, security is a market of the future.

It is the fear that calls for something to be done, but this leads to irrational actions, ideologies and desires.

Inside this Issue:

One could even say that the evergrowing desire for security slows down and hinders progress, innovation, development and research.
New things can only emerge if people feel the courage to take risks and the desire for freedom within themselves.

Now that you have read this text, I ask you to replace the word safety with the word innovation in your mind.
And if you think about it, it makes also sense. Too much forced innovation is just as damaging as too much security because it does not lead to real innovation.

Innovation also means saying "no" to a thousand things.
On the one hand, this can mean that you let go of old ways, but also that you don't go down new paths that don't seem to make sense at second glance, even if it is the current trend.

Yes, innovation has never been more urgently needed than at this moment. But the attemp to force innovation, however, usually misses the mark. That's why science, also must find a way to combine the old and the new, the conservative and the modern in a meaningful way. The solution lies in the mixture of both. It also takes courage to stand still and let things mature. And only with this courage we can move forward.

I have learned that the path of progress is neither short nor easy, as Marie Curie already recognized.

Let us continue to bravely explore new horizons without forgetting the traditional or even demonizing it.

For exactly these reasons, I am happy to be able to work with such smart, courageous and forward-thinking scientists who have internalized exactly that. I also have to say thank you to our community for this spirit.

You are now looking at the brandnew Pyrolysis Newsletter.
Read more about the Renewell project, a joint project between BTG, Eindhoven University and Goodfuels. The specific goal of the project was to develop a process to produce a sustainable 2G drop-in marine fuel (page 3).

Scion is also dedicated to this topic and you can find an article about optimizing the production of marine drop-in biofuels (page 8).

Increasing concerns about climate change and global warming have led to a push to decarbonize the long-haul transportation sector (e.g., aviation, trucking, and shipping), which is difficult to fully decarbonize through electrification or the use of hydrogen as a fuel. In this regard, biomass offers a ready-to-use solution to produce sustainable and defossilized liquid fuels
Find out news from Aalborg University, which adresses to this on page 12.

And last but not least, there is news from VTT/ Finland on the utilization of eucalyptus, giant reed Arundo, fibrous millet and sugarcane bagasse by fast pyrolysis and subsequent bio-oil gasification. Read more on page 15.

Finally, it remains to us to thank you for your interest in our work and your loyalty and support.

All the members of IEA Bioenergy Task 34 wish you a Merry Christmas and an excellent start in 2023!

Yours sincerely,
Alexandra Böhm, Task Assistant

Hydrotreated pyrolysis oil for marine application: fuel production and combustion performance

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A consortium consisting of BTG Biomass Technology Group BV, the Eindhoven University of Technology (TU/e) and Goodfuels Marine BV cooperated in a Dutch project called "Renewell" on the production and use of hydrotreated pyrolysis oil (HPO) as drop-in marine fuel.

The specific goal of the project was to develop a process for the production of a sustainable, 2G drop-in marine fuel suitable to blend at least 5wt% in conventional marine fuel (MGO) with the ambition to achieve 30 wt% replacement. The "Renewell pathway" is a multistage process based on fast pyrolysis. First, the biomass is converted into a mineral free fast pyrolysis bio-oil (FPBO). Subsequently the FPBO is hydrotreated at elevated temperature and pressure over different catalysts to obtain a Hydrotreated Pyrolysis Oil (HPO). FPBO from different biomass resources have been tested, but for the majority of the work FPBO from a commercial production plant was used.

Process

The FPBO upgrading process is shown schematically in Fig. 1. In the first step, FPBO is stabilized at relative low temperature and high pressure in a hydrogen atmosphere and using a proprietary BTG-catalyst (Picula™). The purpose of the stabilization is to convert the highly reactive functional groups in FPBO such as carbonyls (aldehydes, carbohydrates, ketones) into e.g. alcohols. The product from the stabilization process is called SPO (Stabilized Pyrolysis Oil) and is further processed using commercial hydrotreating catalysts. This second step will result in the drop-in biofuel called HPO (Hydrotreated Pyrolysis Oil), and the specific properties depend on the severity of the treatment and the catalyst applied.

Finally, to obtain the drop-in marine fuel a simple distillation step is required to remove the light components. This last step is required to achieve a minimum flashpoint of 60 °C as required for marine fuels. The composition of
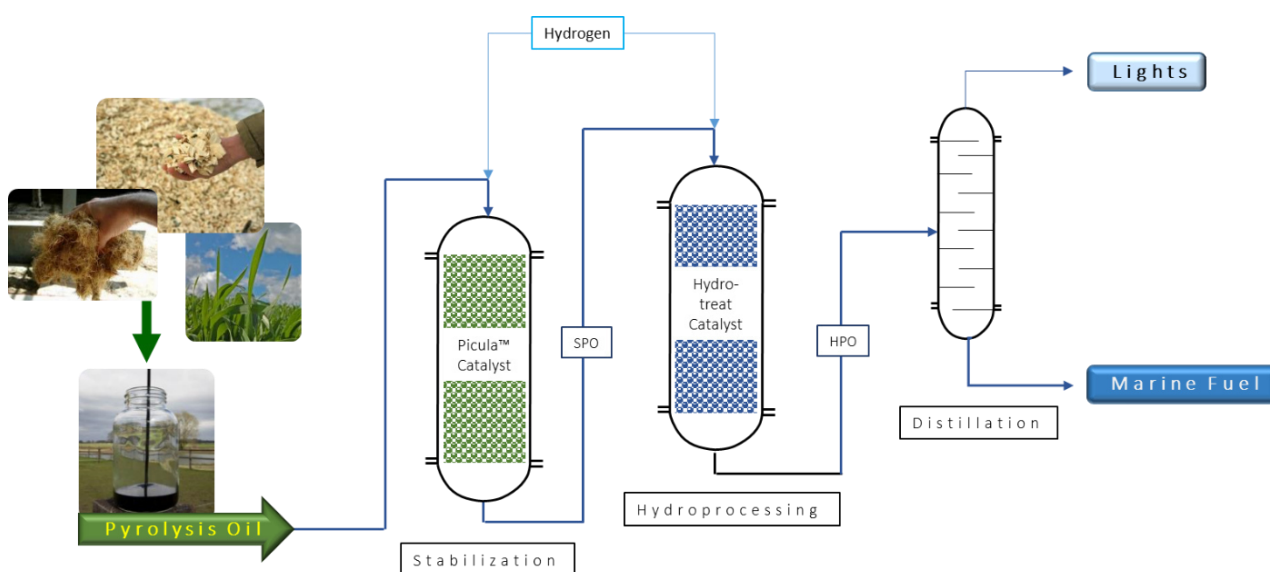

Fig. 1: Schematic drawing of the FPBO upgrading process

Table 1: Properties of some selected Renewell HPO samples

BTG Sample Code	Elemental composition			LHV [MJ/kg]	Density [kg/L]	MCRT [wt%]	TAN [mg KOH/g]	Viscosity [cSt]	FlashPoint [°C]	Ox. Stability [min]	
	C [wt%]	H [wt%]	N [wt%]								
1755 (FPBO)	44.4	7.1	0.2	16.3	1,203	17.1	73	40.5	-	-	
1804	86.1	10.8	0.1	40.9	0.934	0.1	0.1	16.3	66	47	
1806	88.9	11.6	0.1	42.9	0.894	0.1	0.1	4.6	78	56	
1805	89.0	11.6	0.1	42.9	0.890	0.1	0.1	4.4	77	222	
2337	86.0	11.9	0.0	42.2	0.906	0.02	0.02	2.6	63	190	
2336	86.0	11.5	0.0	41.7	0.921	0.02	0.02	3.3	73	159	

the lights has been discussed in Pyne Newsletter 48.

Products

Several HPO samples were produced, and chemical /physical properties have been determined. Variations are a result of differences in severity of processing (e.g. residence time, pressure and temperature) as well as the application of different catalysts in the hydrotreating step. Some properties of selected samples are shown in Table 1.

Generally, the hydrotreating leads to a strong increase in heating value and a significant reduction in acidity, carbon residue and viscosity. The density of the samples in Table 1 are above specifications for marine distillate fuel, but it was found that it can be easily lowered by extending the residence time in the hydrotreater. Turbiscan experiments performed at TU/e showed very good miscibility with fossil derived MGO.

HPO-MGO blends (10, 30 and 50 wt% HPO) have been prepared for engine testing using sample 2337 (Table 1). Samples of these blends as well as the pure HPO were sent to an external laboratory to perform C-14 biogenic carbon analysis (LSC). The blending ratio was exactly known for the different samples.

The biogenic carbon content can be calculated and compared to the results from the LSC analysis, see Fig. 2. The pure HPO contains 88% of carbon, and the LSC method confirms that all carbon is from biogenic origin. At lower blend ratio's the measured biocarbon content is lower then calculated, but the deviations are within the 3% absolute error. However, it should be noted that carbon tracking after blending could underestimate the actual biogenic carbon content.
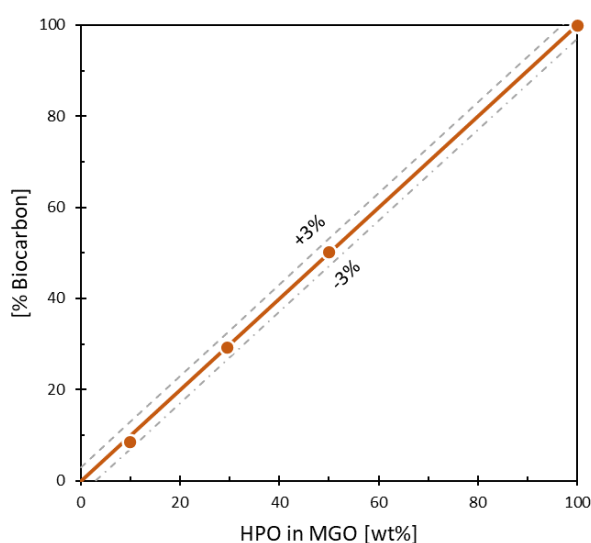

Fig. 2: Biogenic carbon in MGO-HPO blends

Combustion testing

The combustion research was conducted at TU/e, and initial work was performed on a so-called Combustion Research Unit (CRU) [1]. HPO is blended with MGO from 10-30 wt% and named 10HPO, 20HPO, and 30HPO respectively. The experimental investigation starts with the combustion properties tests in the CRU, set to reproduce the cylinder ambient condition after compression stroke at CRU as close as possible. Therefore, the chamber wall temperature is swept from 575oC up to 750oC in steps of 25oC, and the chamber pressure is fixed at 50 bar without application of EGR (Exhaust Gas Recirculation). A single injection is applied with an injection pressure of 1500 bar and a duration of 1.0 ms. The test settings are identical for all measurements (10HPO, 20HPO, 30HPO, Diesel).

Figure 3 illustrates the combustion characteristics of HPO/MGO at various wall temperatures. Though the ID differences among the tested fuel are quite small under CRU conditions, the addition of HPO does increase the ID. It can be seen that the ID becomes longer at a higher blend ratio. Yet, keep in mind that this is wall temperature, and the ambient air temperature in the centre of CRU is expected to be around 50oC lower than the set wall temperature. Since the real

bulk gas temperature in an engine would be higher than that in the CRU, the ID differences are also expected to be even smaller. The burn duration (BD) of tested fuels is presented on the right of Fig. 3. It is seen that the BD decreases as the blend ratio increases in general. This is related to the fact that the longer the ID the large the dominance of the premixed combustion phase in these experiments (due to short injection duration compared to the ID).

The HPO/MGO blends showed similar behavior as diesel with increasing ignition delay with increasing HPO content. Interestingly, a blend of 75% HPO and 25% HVO (Hydrotreated Vegetable Oil) – a 100% renewable fuel- showed the same combustion performance as EN590 diesel. Apparently, the somewhat lower Cetane number of the HPO is compensated by the higher Cetane number of HVO.

The investigation continued with engine performance and emission tests at various load/speed combinations. These tests were performed on an HD diesel engine test rig, which is a modified DAF 6-cylinder engine (MX13). Only the first cylinder functions as the test cylinder while the other five are disabled. To begin with, HPO fuel blends are benchmarked with B7 diesel in accordance with the European stationary test cycle.
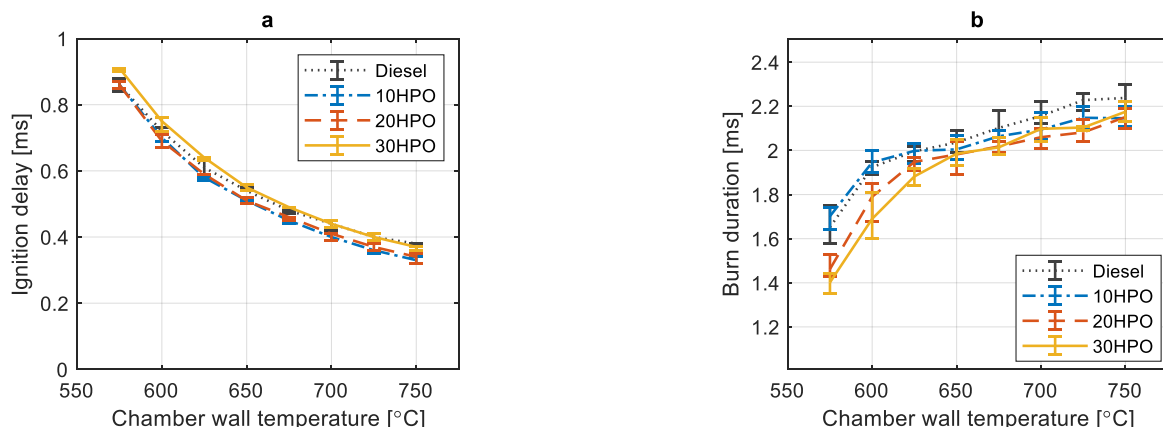

Fig. 3: ID (a) and BD (b) of HPO/MGO blends from CRU (10HPO means 10wt% HPO in diesel, etc)

Three regular truck cruise speeds (A, B, C) were selected from low to high load (30%, 50%, 70% of max load), leading to 8 measure points in total. Then, injection-related parameters such as the start of actuation timing (SOA) and injection pressure are varied at A30 for all four fuels to investigate the controllability and response of these HPO drop-in fuels.

Figure 4 compares the cylinder pressure and ROHR (Rate of Heat Release) plots among diesel and HPO at various load combinations. HPO/MGO blends show an identical combustion process as diesel for the same operating conditions. Specifically, both cylinder pressure and ROHR profiles of different blend ratio show a similar shape as well as peak values. The minor differences in the cylinder pressure curves before the combustion at the same load are due to the variances of inlet boosting pressures. Typical diesel heat release patterns are noticed for all

tested fuels, both premixed and mixing-controlled combustion peak are observed. The HPO/diesel fuel blends yield a slightly higher premixed peak than diesel. All these observations indicate that the application of HPO as a drop-in fuel is viable since no further recalibration is necessary to achieve comparable engine performance and emission values. Furthermore, recent engine tests have shown that even 50:50 HPO/MGO blends can be used without any problem.

Overall, the Renewell project showed the viability of fueling the engine with second-generation, FPBO derived, drop-in biofuel. The engine can be operated safely and smoothly with its original calibration up to at least 50 wt% HPO addition without a major influence on combustion and emission characteristics. Moreover, the combustion properties of HPO can be further improved (e.g. increasing Cetane number) by optimizing the hydrotreating step.
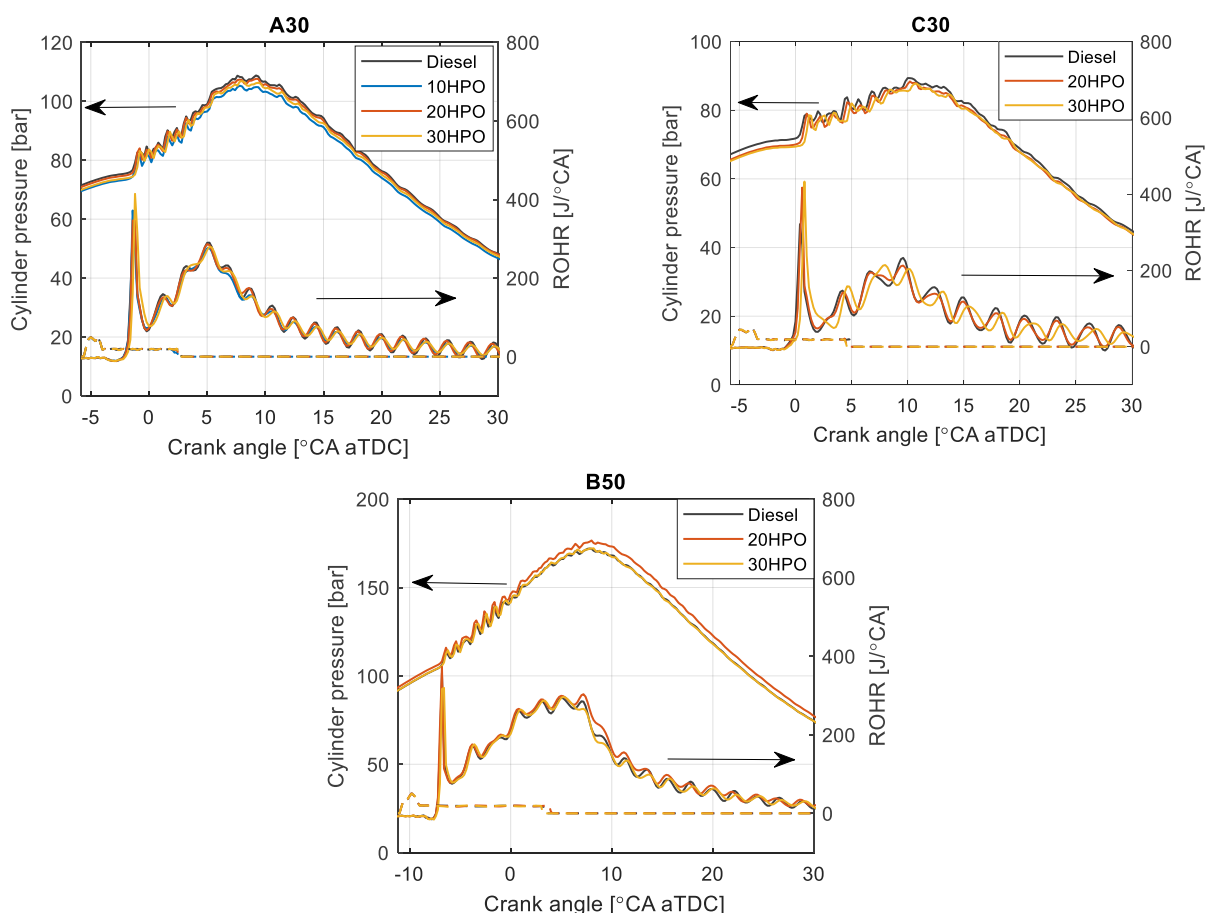

Fig. 4: Cylinder pressure and ROHR at different loads (A30 = speed A at 30% load etc)

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Optimising catalytic fast pyrolysis of wood for the production of drop-in marine biofuels

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Biofuel policies

In New Zealand, the Government is introducing a Sustainable Biofuels Obligation aiming at reducing greenhouse gas emissions in the transport sector. Fuel wholesalers will be required to deploy biofuels as a part of their fuel supply. From 2024, the target percentage of biofuels will increase on a yearly basis and could reach up to 9% by 2035. Failing to meet such an obligation will result in penalties based on the amount of excessive emissions (CO_2 equivalent). It is expected that New Zealand will rely, at least initially, on imports to meet the mandate. Only biofuels that are sustainable and offer credible GHG emissions reductions will be allowed. The inclusion of international aviation and marine emissions in New Zealand's emission budgets is under consideration and could happen from 2024.

An opportunity for marine biofuels

The global consumption of fossil fuel oil by the shipping sector, estimated at 350 Mt/year, contributes to 2-3% of the global CO_2 emissions. In 2018, more than 90% of ships in operation and on order were based on the conventional diesel engine, which means that liquid fuels will be needed for many years to come. Drop-in biofuels, compatible with current infrastructure, appear as the most credible fuel alternative for short-term decarbonisation of the marine sector. According to the New Zealand Biofuels Roadmap [1], a technical report assessing the potential of biofuels deployment, large scale biofuel production from lignocellulosic feedstock is feasible within New Zealand and would be a significant part of the solution for reducing New Zealand's emissions, while improving energy security. The use of biofuels from lignocellulosic origin produced in a sustainable way can result in a > 70% reduction in CO_2 emissions, compared to fossil fuel [2].

Based on the flexibility of marine engines and the wide specification ranges of the fuels used in the marine sector, the local production of marine biofuels in the short term appears achievable. Direct thermochemical liquefaction (DTL) has been identified as one of the most economical ways to produce a liquid fuel from lignocellulose. Scion is investigating the opportunity of producing marine biofuels via catalytic fast pyrolysis of wood, as part of the research program on Transport biofuels (Integrated Bioenergy portfolio).
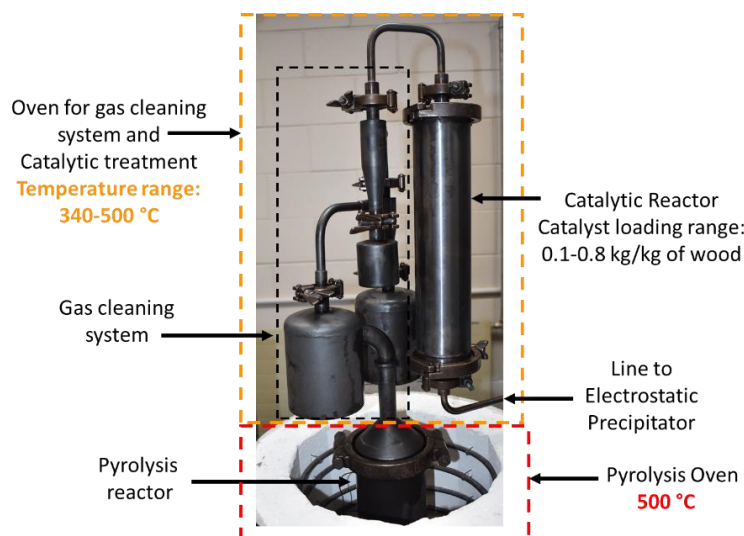

Fig. 1: Experimental set-up for ex-situ catalytic treatment

Table 1: Maximum yield (as predicted from a Central Composite Design model) and required conditions as a function of the Higher Heating Value (HHV) of the fuel product

HHV (MJ/kg)	Maximum Yield* (wt.%)	Catalyst Temperature (°C)	Catalyst loading (kg / kg of wood)	Oxygen content* (wt.%)
29	20.0	441	0.159	25.2
30	18.0	423	0.253	22.8
31	16.2	410	0.351	20.9
32	15.1	339	0.588	22.5

* Yield and oxygen content of the organic phase are reported on dry basis

Research

An optimisation study was conducted to determine the amount of fuel that can be produced as a function of the targeted Higher Heating Value (HHV) [3]. Volatiles generated from fast pyrolysis in a fluidised bed reactor (0.54 kg of wood/h) were upgraded in an ex-situ catalytic reactor (see Figure 1) using a commercial H-ZSM-5 zeolite. The variables were the temperature of the catalytic treatment and the catalyst loading. The liquid product collected in the condensation system was composed of an organic phase, which is the fuel product of interest, and an aqueous phase. The maximum fuel yields that could be achieved for fuel products with different HHVs are detailed in Table 1.

Without catalyst, the yield and oxygen content of organic volatiles produced by fast pyrolysis were 44 wt.% of dry feedstock and 38 wt.% (dry basis), respectively. During catalytic treatment, volatiles are deoxygenated through reactions releasing compounds such as H_2O, CO and CO_2, inevitably resulting in a decrease of the fuel yield. The coke formation on the catalyst surface, the cracking of aliphatic groups into gaseous hydrocarbons and the presence of organic compounds in the aqueous phase also negatively affect the yield. In this study, mild upgrading was targeted to avoid the low yields (< 10 wt.%), typically reported when oxygen content is reduced to values lower than 10 wt.%.

For an HHV of 29 MJ/kg, the maximum yield was found to be 20.0 wt.% and the associated fuel had an oxygen content of 25.2 wt.%. An increase in HHV to 31 MJ/kg required more catalyst to decrease the oxygen content to 20.9 wt.%, which led to a fuel yield of 16.2 wt.%. Maximum fuel yield, associated to HHV in the range of 29-31 MJ/kg, required an upgrading temperature between 410-441 °C. For a targeted HHV of 32 MJ/kg, the maximum fuel yield of 15.1 wt.% was obtained for a treatment temperature of 339 °C (see Fig. 2). The interpretation explaining such temperature drop is based on catalyst selectivity.

At low catalyst loading, the selectivity towards deoxygenation is relatively high and catalytic reactions typically involve the most reactive oxygenated groups. Increasing the catalyst surface area helps converting some of the less reactive oxygenated groups. However, it appears that undesirable cracking of aliphatic groups is also promoted, especially at high temperature. For instance, the yields of gaseous hydrocarbons associated with the production of a fuel at 32 MJ/kg at 339 and 500 °C were 2.8 and 5.4 wt.%, respectively. GC/MS and NMR characterisations of the fuel product confirmed that decreasing the treatment temperature resulted in a less aromatic liquid fuel.

Perspectives

A negative implication of a low temperature treatment is the significant increase in coke formation on the catalyst surface, which affects the fuel yield and is likely to lead to faster catalyst deactivation. Coke yield at T ≤ 350 °C
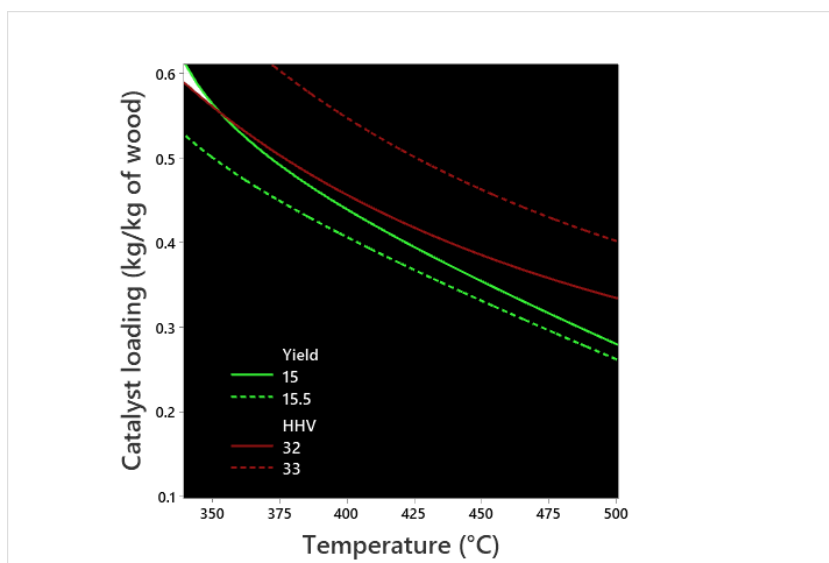
Fig. 2: Contour plots of HHV and yield of the organic phase showing the conditions required (white surface) to produce a fuel with HHV ≥ 32 MJ/kg at a yield ≥ 15.0 wt.%

was approximately twice as much as that at T ≥ 450 °C, and could reach up to 8 wt.%. These results highlight the need to better understand the influence of the catalyst properties on the upgrading mechanism, to develop specific catalysts more adapted to the treatment of the oxygenated compounds produced from biomass pyrolysis.

Acknowledging that theoretical yields are challenging to achieve due to the complex composition of the volatiles to be upgraded, it appears that significantly improving selectivity and decreasing coke formation could lead to the production of a fuel with an HHV of 32 MJ/kg at a yield as high as 20 wt.%.

The development of a more efficient catalyst could be a determinant step towards the production of biofuels at a competitive cost.

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Long-term continuous hydroprocessing of hydrothermal liquefaction biocrude

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Raising concerns regarding climate change and global warming have produced an urge to decarbonize the long-haul transportation sector (such as aviation, trucking, and shipping), which is difficult to completely decarbonize via electrification or using hydrogen as a fuel. In this regard, biomass provides a ready-to-go solution to produce sustainable and defossilized liquid fuels which are chemically identical to their fossil counterpart.

This is the topic of the new project "LowCarbfuels.dk", funded by the Innovation Fund Denmark. In this project, Aalborg University (AAU) is member of a consortium of 18 partners, from both Denmark and other European countries, with the scope to explore the potential of hydrothermal liquefaction (HTL) as a flexible technology to produce marketable drop-in aviation and marine fuels from urban and agricultural residues (Fig. 1).

HTL converts biomass into a carbon-rich liquid product, named "biocrude", which can be used for fuel production. However, HTL biocrude should be regarded as an intermediate, still containing considerable amounts of oxygen, nitrogen, and inorganics, and thus incompatible with existing fuel standards: hence the need for an additional refining step.

Over the years, AAU Energy has put constant focus on the downstream refining of biocrudes, reaching a high level of expertise in pretreatment and continuous hydroprocessing [1–3]. By means of these operations, biocrude can be upgraded into a mixture of hydrocarbons, therefore representing a source of "drop-in fuels", which are combustibles that can be directly introduced in the current mobility infrastructure, as they are equivalent to fuels already on the market.

In collaboration with the other partners in the Lowcarbfuels.dk project, AAU is committed to explore the hydroprocessing of biocrudes (both stand-alone and co-refining with fossil streams) and test/understand catalyst deactivation over long period of times, coking propensity, process stability, complete deoxygenation and >99 % denitrogenation. The final aim is that of establishing a process that is able to overcome the current technological bottlenecks, therefore paving the way to a commercial implementation of HTL for the production of sustainable biofuels.

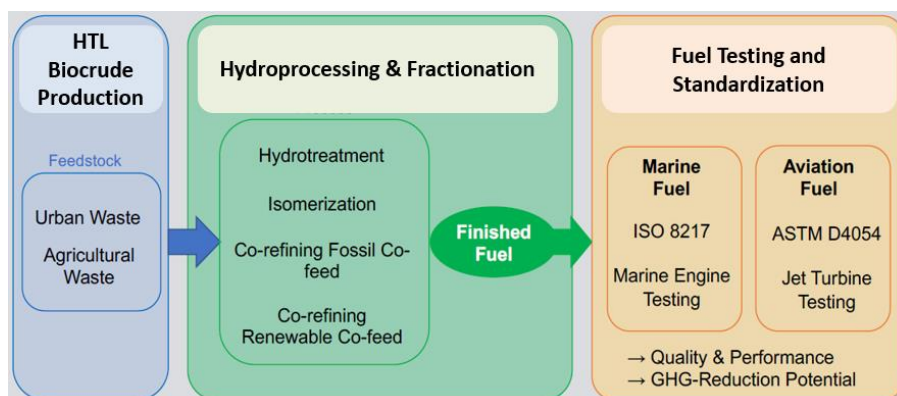First achievements: almost 2000 h continuous hydroprocessing

Fig. 1: Outlook of "LowCarbFuels.dk" project

Fig. 2: Continuous hydrotreater at AAU

In the LowCarbFuels.dk project, HTL biocrude is produced in the continuous bench scale (CBS) plant in Aalborg, Denmark [4]. Researchers from AAU and Steeper Energy Aps have worked together and produced biocrudes from urban and agricultural residues. These biocrudes underwent continuous hydroprocessing in a bench scale hydrotreater at AAU (Fig. 2). The experimental facility is constituted by a two-stage trickle-bed hydrotreater, with a usual throughput of around ~50 mL/h [1]. $NiMo/Al_2O_3$ and Mo/Al_2O_3 catalysts were utilized, which were acquired from Topsoe A/S.

Hydroprocessing activities at AAU are largely focused on catalyst testing, catalyst grading, process optimization and intensification. An important aspect is represented by achieving smooth continuous operations, that is the ability to run the upgrading process without premature failure due to catalyst bed clogging. HTL biocrude can indeed undergo unwanted polymerization when exposed at high temperatures (>250-400 °C, depending on the specific product), unless a proper upgrading strategy is adopted.

By mid of year 2022, smooth continuous hydroprocessing of food waste biocrude was achieved for 1928 hours on-stream in-one-go, representing one of the most long-lasting hydrotreating campaigns for HTL biocrude. In total, 38 kg of biocrude were hydroprocessed (Fig. 3). The key towards these successful operations was the selection of proper process conditions (temperature, space velocity and pressure) and the optimized grading of catalyst in the reactor bed. A fundamental contribution is given by the multi-stage upgrading strategy developed at AAU over the last years.
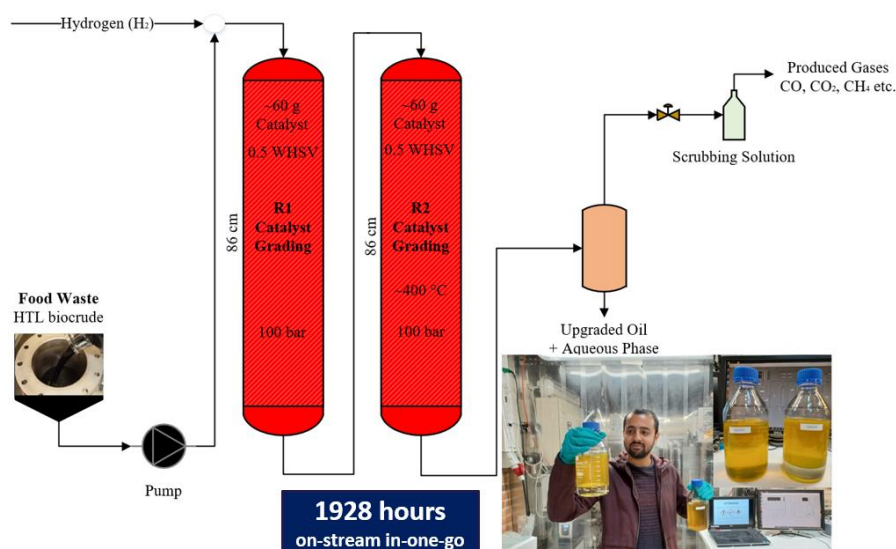

Fig. 3: Simplified process scheme with upgraded oil samples

Fig.4: Different components of the jet fuel fraction.

Towards on-spec fuels

A selected sample from the hydrotreating campaign, obtained at 400 °C, underwent fractional distillation in a 15:5 distillation column (ASTM D2892) [5]. The produced fuels, i.e., jet, diesel, and marine, were collected and are under evaluation according to ASTM D7566, EN-590, and ISO-8217 respectively.

Furthermore, a complete Tier α prescreening [6] of jet fuel fraction (Fig. 4) is also currently underway, thanks to project partners DLR (Germany) and IFP Energies Nouvelles (France). Results will offer precious indications on how to tune the upgrading process to obtain on-spec fuels and valuable information for all involved stakeholders.

Acknowledgments

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Valorization of eucalyptus, giant reed Arundo, fibre sorghum and sugarcane bagasse via fast pyrolysis and subsequent bio-oil gasification

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This article is a summary from the research article published in the Energy & Fuels[1].

Production of liquid intermediates by fast pyrolysis in decentralized units and further upgrading of the liquids in centralized upgrading plant has been recognized as a potential strategy to overcome the issues related to the logistics of low energy density biomass feedstocks. The liquid produced by fast pyrolysis, i.e., fast pyrolysis bio-oils (FPBOs), have higher energy density, and they are easier to store and transport to centralized utilization sites compared to bulky biomass feedstocks.

FPBO production has entered the market with currently four pyrolysis plants in operation in Europe2. The primary utilization of the FPBOs is for energy generation through combustion3,4, but recently, Pyrocell started to co-feed FPBO in a fluid catalytic cracking (FCC) system for the production of advanced biofuels as well[2]. Another robust but less matured valorization pathway is the gasification of FPBOs into syngas[5,6], which was the focus of this study.

Compared to direct biomass gasification, the gasification of FPBO has an additional benefit that a large part of the tar precursors (primarily lignin[7]) does not enter the gasifier as it is converted to char in the pyrolysis process. Tar concentrations in FPBO gasification are therefore typically much lower than for direct biomass gasification[8]. In addition, decentralized production of FPBO combined with centralized gasification could increase the economically available biomass resources for gasification and to give freedom to build larger gasification plants, which is favorable due to the economics of scale.[9]

As the plant size goes up, it is likely that there will be more variation in the type of available biomass feedstocks and FPBOs produced from them. These feedstocks could be blended already in the pyrolysis phase, or the produced FPBOs could be blended in centralized gasidication site. Several researchers published results on the gasification of pyrolysis oil in various gasifiers, including non-catalytic entrained flow systems[5,10–13] and various catalytic gasification systems[6,14–16].

Most research involved the gasification of wood derived pyrolysis oils, with some straw derived results included as well. However, a direct comparison of multiple feedstocks in the same system is not previously reported. Primary goal of this work was to prove the technical feasibility and assess the efficiency of FPBO gasification process with varying feedstocks
.

Fast pyrolysis experiments were performed in a bench-scale bubbling fluidized bed unit operated in 480 °C. Detailed unit description can be found elsewhere[1]. Feedstocks used were eucalyptus, giant reed arundo, fibre sorghum and sugarcane bagasse. When the product yields are considered, the organic liquid yields from bagasse runs were the highest (59 - 62 wt%). In addition, the char, gas and pyrolytic water yields were the lowest

Table 1: Mass balances from the pyrolysis experiments

Feedstock Batch			Arundo	Eucalyptus		Sorghum Batch 1		Sorghum Batch 2		Bagasse	
Duration, h			5.9	8.0	9.3	4.0	4.1	6.0	8.0	6.1	3.0
Feed rate, g/h			1531	702	1226	854	558	722	747	1165	1256
	Mass balance, wt% on dry mass basis										
Char			33	21	20	24	24	26	27	16	17
Gases			9	12	15	13	14	20	19	12	10
Organic liquid			39	53	49	42	34	42	41	62	59
Pyrolytic water			15	10	12	16	12	11	10	9	9
SUM			96	97	95	95	84	99	97	99	96

with bagasse. With eucalyptus, decent organic liquid yield was also achieved (49 - 53 wt%), but with Arundo and sorghum, the yields were rather low (39 and 34 - 42 wt%, respectively). Bagasse and eucalyptus have lower ash contents but also higher volatile contents, which are expected to be the main reasons for higher organic liquid yields[17].

Product yields are presented in Table 1. After the pyrolysis experiments, produced FPBOs were gasified in an oxygen-blown autothermal catalytic reforming system for the production synthesis gas.

Detailed unit description can be found elsewhere[1]. To ensure proper atomization of the FPBOs in the gasifier, 20 wt% of bioethanol was added to reduce the viscosity of the fuel and prevent formation of large droplets. This requirement is particularly important for the small scale of the experimental setup; for a full-scale gasifier pure FPBO can be used as discussed in the introduction.

The dry syngas composition for the four FPBOs is presented in Figure 1. Hydrogen was around 50 vol% for all feedstocks, with 19-23% CO and 23-28 vol% CO_2. The H_2/CO/CO_2 concentrations (and that of H_2O) were close to the thermodynamic equilibrium of the water-gas-shift reaction.

The total syngas production was 1.71 Nm^3/kg FPBO for Arundo, 1.75 Nm^3/kg FPBO for Eucalyptus, 1.68 Nm^3/kg FPBO for Sorghum and 1.68 Nm^3/kg FBPO for bagasse, showing not only the gas composition but also the gas production is similar for all for fuels.

The carbon to gas ratio depends primarily on the atomization performance, which could not be optimized for these tests but still was considered to be quite good (arundo 0.98, eucalyptus 0.94, sorghum 0.94 and bagasse 0.98). The cold gas efficiency was 76% for arundo, 83% for eucalyptus, 89% for sorghum and 80% for bagasse. Cold gas efficiencies around 80% are close to the theoretical maximum, therefore the measurement for the sorghum test seems overestimated.

Results presented here show that the combination of fast pyrolysis and gasification provides a technically feasible and feedstock flexible value chain for the production of advanced biofuels from biomass residues.
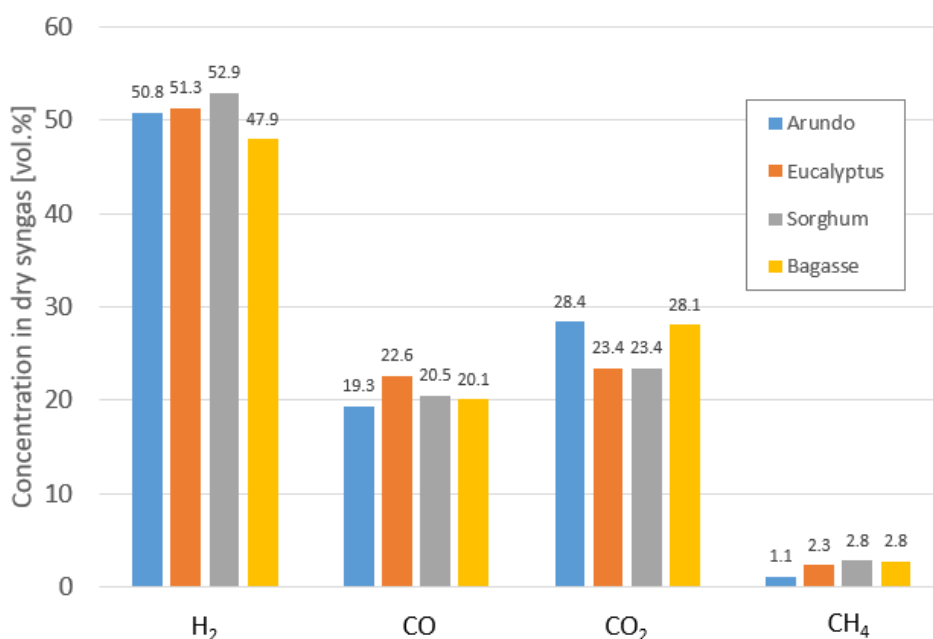
Fig. 1: Dry syngas composition obtained with the four FPBOs

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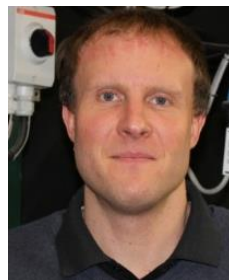
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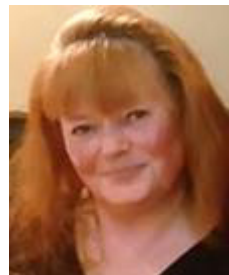
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What happened 20 years ago?

It is interesting to see how the field of direct thermochemical liquefaction developed over the years. We are thus presenting one example highlight from the PyNe newsletter twenty years ago in this regular feature...:

You can access the full article by using the following link:

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Upcoming Events

23. + 24. January 2023
20th International Conference on Renewable Mobility; Berlin, Germany
https://www.fuels-of-the-future.com/en

08. – 09. February 2023
Helsinki, Finland
https://www.wplgroup.com/aci/event/lignocellulosic-fuel-conference-europe/

15. + 16. February 2023
ACI's 11th European Biomass to Power, London, UK
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22. + 24. March 2023
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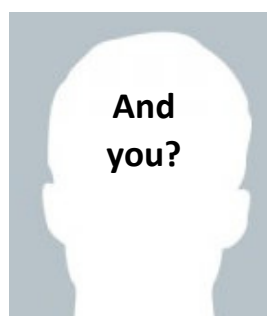
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If you would like to contribute an article to the Task 34 newsletter or have questions, please contact:

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Task 34: Direct Thermochemical Liquefaction

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