Newsletter
Direct Thermochemical Liquefaction

IEA Bioenergy
Technology Collaboration Programme
Task 34

PyNe 53

July 2023

The most recent member country that joined Task 34 is India and we have had the pleasure to meet in India earlier this year. India is represented by the Hindustan Petroleum Green R&D Centre, from which Pramod Kumar and Lavanya Meesala were chosen as national team lead to join and support our work programme. The Task 34 meeting took place January 30th-31st, 2023 at the HP Green R&D Centre in Bengaluru. As always, one day was reserved to meet Indian stakeholders active in the field of DTL. It was impressive to meet active researchers but also representatives from industry on site and enjoy the vivid exchange that took place.

We also were given the opportunity for detailed lab tours around the HP Green R&D Centre, which has been built up and developed in recent years.

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IEA Bioenergy
Technology Collaboration Programme

The quick ramp up of relevant equipment and facilities as well as the technical capabilities was truly impressing. Last but not least, this meeting was wrapped up with a site visit of Shell's IH2 demonstration facility close zo Bengaluru to learn more about this process and its commercialization.

The amount of relevant activities and motivation of all stakeholders underlined the importance of having India as member in Task 34. We sincerely hope to continue the fruitful work and enjoy another meeting in India in the upcoming years!

Of course, successful continuation of our work also includes publication of this PyNe 53. It includes a report on the Pyroliq II, which this year was again organized in an excellent environment. You will find it on page 17. Read more about the CO-HTL4BIO-OIL project (branded CoBiol), which aims at producing transport fuels from food waste streams via HTL to meet the ambitious target outlined in the European Renewable Energy Directive to increase the share of renewable energy in the transport sector up to 10% by 2020 and decrease GHG to 40% compared to 1990 levels by 2030 (page 7).

There are also two contributions from CanmetENERGY Ottawa (CE-O)/ Canada. You will find one article about driving innovations in pyrolysis and upgrading technologies. This article aims to provide readers with a concise overview of CE-O's experimental capabilities in pyrolysis and biocrude upgrading research. Read more on page 3.

The second article revolves around the topic of novel rotor design based ablative centrifuge pyrolysis system. It aims at reducing the requirement of large volumes of carrier gases relative to biomass feed which, besides cost escalation, leads to cumbersome gas separation and thermodynamic penalties (page 10).

You will find interesting information about the project "Refineries for future", which develops processes and supply scenarios for the future demand of synthetic fuels. REF4FU will evaluate pyrolysis oil based on bio-residues, such as straw or waste wood, but also methanol from renewable feedstocks, Fischer-Tropsch oil and renewable hydrogen. Focus is on technologies available at TRL 5 or higher and how they can be ramped up to meet future demand for sustainable fuels. Read more on page 13.

And last but not least please find a report of a exciting symposium, on "Chemical Engineering for a sustainable world" held at the University of Twente in the Netherlands, where over 50 participants from Karlsruhe Institute of Technology, Laboratoire Réactions et Génie des Procédés Nancy and University of Twente – primarily PhD students – vividly discussed and exchanged ideas about their work towards innovative processes for the transition of our economy. You can find it on page 16.

Yours sincerely,

Axel Funke, Task Lead

CanmetENERGY-Ottawa: Driving innovations in pyrolysis and upgrading technologies

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Introduction
Canada possesses extensive forests, spanning around 362 million hectares, with 90% of them owned by provincial or territorial governments [1]. In 2018, Canada's forest sector proved its economic significance by exporting forest products valued at C$ 38 billion. Additionally, Canada ranks among the top ten producers of agricultural crops, with 38 million hectares of crop land. The agriculture sector contributes more than C$ 134 billion of Canada's gross domestic products (GDP) [2].
Nonetheless, agricultural and forestry operations generate substantial volumes of residues that often go unused, lea ding to their decay on roadsides and the emission of methane and carbon dioxide. The presence of unutilized forestry residues also poses a significant risk of accidental fires, resulting in significant forest loss and public concerns due to air pollutant emissions. Fortunately, the use of these biomass residues presents a unique opportunity for Canadian industries to reduce their carbon footprint by harnessing local and sustainable resources.

At the forefront of thermochemical technologies for the conversion of Canadian biomass resources is CanmetENERGY-Ottawa (CE-O)'s Bioenergy Systems Group. CE-O's research and development efforts in pyrolysis focus on the primary conversion of raw biomass into liquid products and the subsequent upgrading of these liquids into market-compatible products such as renewable diesel and sustainable aviation fuel (SAF). This article aims to provide readers with a concise overview of CE-O's experimental capabilities in pyrolysis and biocrude upgrading research.

CE-O's pyrolysis facilities and specialized equipment
CE-O's research and development endeavors in pyrolysis are supported by a range of state-of-the-art facilities and specialized equipment. CE-O operates three continuous pilot-scale reactors, forming a robust research platform that allows for comprehensive exploration across a spectrum of pyrolysis conditions, from slow to fast pyrolysis. Table 1 provides an overview of the key design and operating

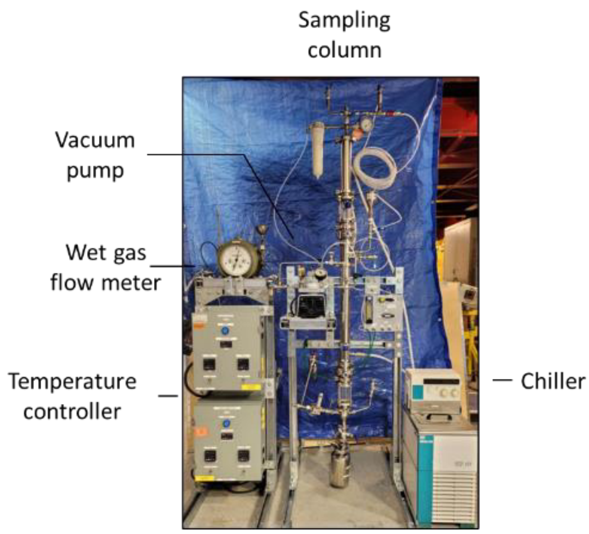

Fig. 1: State of the art sampling column

parameters of these reactors. By conducting experiments with different pyrolysis techniques and feedstock approaches, CE-O gains valuable insights into the benefits and trade-offs associated with each method. This research plays a vital role in facilitating informed decision-making for industry and policy makers.

To ensure efficient collection and accurate tracking of the intermediary bioproducts, CE-O's pyrolysis units are equipped with advanced product recovery trains. Notably, an innovative absorption column (Figure 1) was developed to address the challenges associated with sampling condensable vapors from biomass pyrolysis and gasification. This cutting-edge device replaces the commonly used impinger trains for collecting condensable vapors. In comparison to impingers, the absorption column offers simplified operation, reduced leakages, and minimized labor requirements and solvent exposure associated with measuring condensable vapors. Besides its role in vapor sampling, the device also serves to safeguard gas chromatographs used for measuring process gas compositions.

CE-O's upgrading facilities

Oxygen removal is essential to stabilize and upgrade pyrolysis liquids (bio-oils), to improve their properties and obtain hydrocarbons as drop-in transportation fuels.

CE-O’s upgrading approach involves catalytic hydrodeoxygenation of pyrolysis liquids using an unsupported dispersed sulphided molybdenum catalyst generated in-situ. Unsupported dispersed catalysts have a number of advantages (less coke formation and catalyst deactivation) over supported catalysts [6]. The tests were performed in a 1-3 kg/h continuous process development unit (PDU). High degree of deoxygenation was achieved (more than 93%). The jet fuel and diesel fuel fractions that CE-O produced met most of the ASTM D7566 and D975 specifications respectively [7]. Product quality and carbon intensity is being further improved. Figure 2 provides a snapshot of the PDU and products from recent studies.

1. Hydrocarbon products
2. Naphtha
3. Jet fraction
4. Heavy middle distillates
5. Heavy gas oil

Fig. 2: Snapshot of CE-O’s 1-3 kg/h PDU and product range achieved

Table 1: CE-O's pilot scale pyrolysis units

		Pyrolysis systems		
Reactor types		Ablative centrifuge [3]	Fluid-bed [4-5]	Screw
				
Feed size variability		Flexible	Milled	Flexible
Flow type		Continuous	Continuous	Continuous
Pyrolysis regimes		Fast - medium	Fast	Slow - medium
Design feed rate (kg/h, dry basis)		5-10	5-10	5-15
		Continuous	Continuous	Continuous
Process conditions	Pressure	Atmospheric	Atmospheric	Atmospheric
	Temperature, °C	400-500	400-550	200-800
	Solid	15	10	30
	Liquid	70	70	30
	Gas	15	20	40

Conclusions

CE-O is at the forefront of pyrolysis-based conversion and upgrading technologies, which are driving advancements in the bioenergy sector. Their expertise, advanced facilities, and specialized equipment enable comprehensive exploration of diverse biomass-to-liquid fuel scenarios. Through active collaborations with industrial partners, academia, and government agencies, CE-O is maximizing the potential of pyrolysis liquids and contributing to Canada's low-carbon economy.

Acknowledgement

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References

1. Natural Resources Canada, The State of Canada's Forests: Annual Report, 2022 ISSN 1196-1589
2. Gupta, M. and Preto, F., "Potential of carbon sequestration potential in Canada", 2022 Biochar and Bioenergy Conference, Morgantown, WV, USA, 8-12 August 2022.
3. Gupta, M., McFarlan A., Nguyen, L. and Preto, F., "Design and development of a novel centrifuge ablative pyrolysis approach for biomass conversion to bio-oil and bio-char" E3S Web of Conferences 61, (2018)
4. Matta, J., Bronson, B., Gogolek, P., Mazerolle, D., Thibault, J. and Mehrani, P., "Comparison of multi-component kinetic relations on bubbling fluidized-bed woody biomass fast pyrolysis reactor model performance." Fuel, 2017, 210, 625-638.
5. Mazerolle, D., Rezaei, J., Bronson, B., Nguyen, L., and Preto, F., "Sieving and acid washing as a pretreatment to fast pyrolysis of a high ash hog fuel." Energy & Fuels, 2019, 33, 5352-5359.
6. Zhang, Y., Monnier, J., and Ikura, M., "Bio-oil upgrading using dispersed unsupported MoS_2 catalyst", Fuel Processing Technology 2020, 206, 106403.
7. Monnier, J. and Zhang, Y., "Biojet and diesel fuel components from fast pyrolysis bio-oil using highly dispersed catalysts", TC Biomass 2019.

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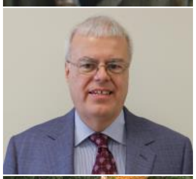

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CoBiol-A pathway to decarbonization and public engagement at large

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MSCA and CoBiol

The transport sector arises as one of the largest consumers of fossil fuels, accounting for 40% of the final energy consumption of which 80% relates to road transport. Subsequently, this results in an annual release of 7 billion tons of greenhouse gases (GHG), mainly carbon dioxide (CO_2) and nitrogen oxide (NO_x), contributing to potentially catastrophic changes in climate, environment, biodiversity, and public health. To achieve a cleaner and healthier environment, there is a strong focus on the development of sustainable low-carbon, high yield, and cost-competitive liquid bio-crude oil as an alternative to conventional fossil crude oil [1]. Particularly as outlined in the Renewable Energy Directive (RED), EU set an ambitious target to increase the share of renewable energy in the transport sector up to 10% by 2020 and decrease GHG to 40% compared to 1990 levels by 2030.

Under this frame, the CO-HTL4BIO-OIL project (branded CoBiol), an EU-H2020 funded ambitious project under Marie Skłodowska-Curie Actions (MSCA-IF), is working to meet these challenges with a dense research plan. CoBiol complete title is: "Catalytic co-hydrothermal liquefaction of binary and ternary mixtures of rye straw, shellfish, and beef tallow for sustainable production of high-grade biocrude-oil to drop-in transport fuel". The project was conceived and lead by Fatma Marrakchi, and it was hosted by Aalborg University, Denmark, Advanced BioFuel research Group at AAU Energy department from December 2020 to February 2023.

CoBiol@Research

As shown in Figure 1, the CoBiol project addresses a number of key-issues, providing pioneering insights into looking for more valuable management methods of carbonaceous food waste streams that have the added potential of producing salable, surrogate and competitive fuel for petroleum oil and reducing the environmental cost associated with their disposal. Scaling of the catalytic co-hydrothermal liquefaction (CO-HTL) process for continuous operations and employing novel predictive quantitative models based on biomass composition and HTL process variables aim at enhancing the yield/quality of biocrude-oil, provide an estimate of techno-economic analysis, and serve as a great perspective for biorefinery integration.

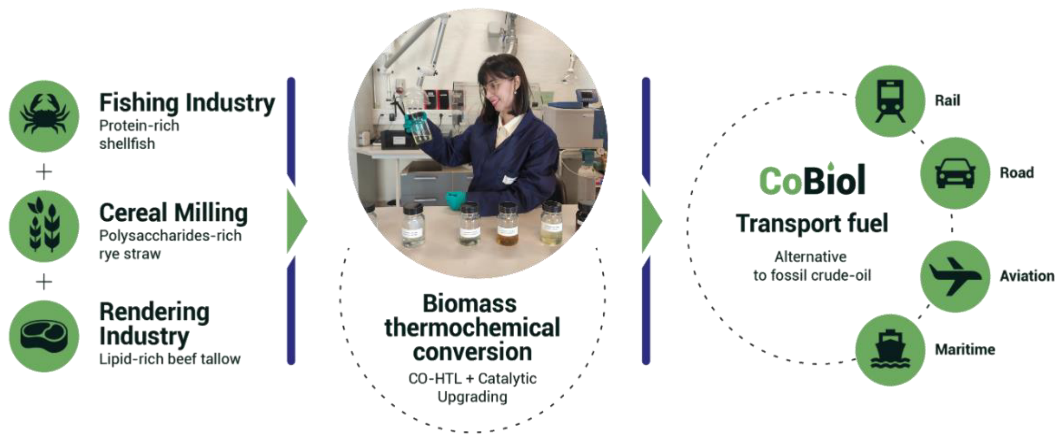

Fig.1: Outlook of CoBiol project

Shellfish, such as crab waste, one of the by-products that CoBiol project experimented on, consists of 20%–50% calcium carbonate ($CaCO_3$), 20%–40% protein, and up to 15%–40% chitin. Based on "The EU Fish Market" published by the European Market Observatory for Fisheries and Aquaculture Products (EUMOFA), the EU total production exceeds 6 to 8 million tons of shellfish, and approximately 750,000 tons of crab shells are wasted every year. Shellfish are often just dumped in landfills or returned to the sea [2]. However, this approach is not economically viable for many businesses as traditional disposal routes become increasingly restricted and expensive at £60–£300 per ton. To target the circular economy, CoBiol explored the thermocatalytic route for turning crab waste into biofuels via a two-step process: first through hydrothermal liquefaction (HTL) to obtain a biocrude oil, followed by catalytic upgrading [3] to obtain drop-in fuels. Smashed crab waste (20 kg) was provided by Polar Seafood Company. The fed slurry was pumped to a continuous unit at a flow rate of 0.5 L/h. It was directed first to a preheater at 200 °C, then to a pressurized reactor at 250 bar. The main reactions of crab waste conversion took place for 15 min at 350 °C. The HTL products were collected at a sampling temperature of 60 °C. The HTL process was successfully operated for more than 30 hours. The obtained HTL products were 35% of biocrude oil, 40% of aqueous phase, 20% of solid residues, and 5% of gases. When characterizing the produced biocrude oil by using an elemental analyzer apparatus (CHNO analysis), the bio-oil contained 79% of C, 12% of H, 5% of O, and 4% of N. Therefore, further catalytic upgrading should be considered to remove the residual O and N compounds and make the biofuel meet transportation specifications.

CoBiol@School

CoBiol did not feature only research activities but also included a significant focus on communicating research to a general audience. This effort was embodied by CoBiol@School: an outreach activity to bring CoBiol@Research close to the public, impact, and share the wonder of science with young generations. CoBiol@School is a five-activity learning session:

Activity One is a dialogue, The Soul of CoBiol, where pupils were engaged to get answers to the question "What is CoBiol?".
Activity Two is a story titled Find Your Radiance! It consists of 3 parts, starting from Marie Curie's Story to Making Marie Curie, and finally Her Story ("Her" refers to Fatma).
Activity Three is a CoCreate game, presenting the cocreation of three consecutive games called Search (Crossword), Puzzle, and Discover (Cards).

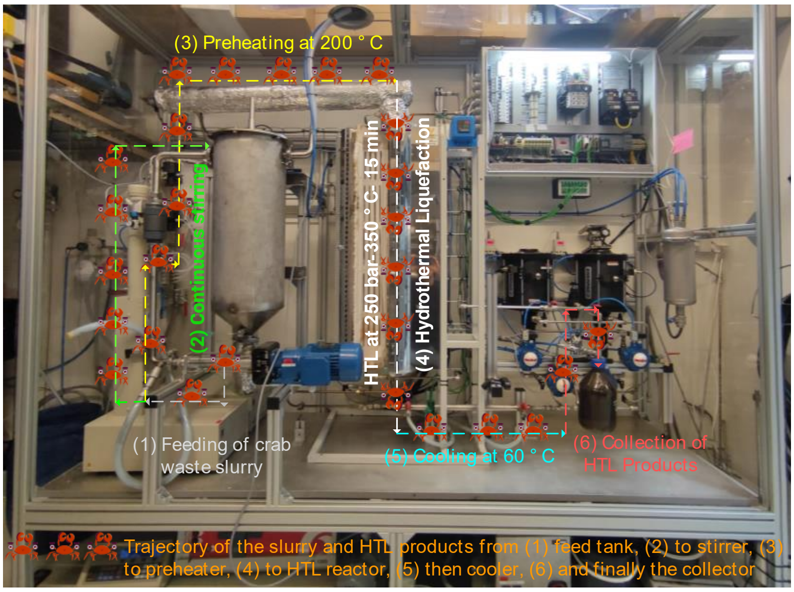

Fig. 2: Continuous HTL of crab waste

Activity Four is a poem "The NextGen Heroes!" with an enthusiastic message, aiming to raise awareness in the young audience by transmitting long-term objectives of building a sustainable planet.
Activity Five is a Tour in the Advanced Biofuel Lab where the pupils visited lab-scale and continuous HTL, hydrotreater, and distillation units.
The first CoBiol@School activity was held at AAU Energy on April 27th, 2023, and saw the participation of 24 enthusiastic pupils (Key Stage 7) from the Skipper Clement Skolen at Aalborg.

Figure 3. A banner for the 1st CoBiol@School activity was held at AAU Energy on April 27th, 2023.

Acknowledgments
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References

[1] F. Marrakchi, S. Sohail Toor, A. Nielsen, T. Pedersen, L. Rosendahl, Bio-crude oils production from wheat stem under subcritical water conditions and batch adsorption of post-hydrothermal liquefaction aqueous phase onto activated hydrochars, Chemical Engineering Journal. (2022) 139293.
[2] M.J. Hülsey, Shell biorefinery: A comprehensive introduction, Green Energy & Environment. 3 (2018) 318–327.
[3] D. Castello, M. Haider, L. Rosendahl, Catalytic upgrading of hydrothermal liquefaction biocrudes: Different challenges for different feedstocks, Renewable Energy. 141 (2019) 420–430.

Learn more about CoBiol Project:

CORDIS EU research results: https://cordis.europa.eu/project/id/895710

CoBiol: https://www.cobiol.energy/

https://www.linkedin.com/company/cobiol/

https://www.youtube.com/@cobiol3576

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A novel rotor design based ablative centrifuge pyrolysis system

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Background

Heat transfer rates (heating as well as quenching) play an important role for qualitative and quantitative distribution of solid and liquid yields in pyrolysis processes. Depending upon the heating rates of the biomass particles and the residence time of the vapours, many reactor configurations have been proposed for fast pyrolysis in the last few decades [1,2]. These configurations include shallow moving bed or transported beds (vacuum pyrolysis), fluid beds and ablative reactors. In the ablative pyrolysis process, a biomass particle is pressed against a hot surface while the particle is in relative motion with respect to heating surface. Due to rapid surface renewal of biomass particle, very high heat transfer rates can be achieved [3]. Since the pyrolysis reactions are not kinetically controlled rather, they are primarily controlled by the heat transfer mechanisms, ablative process facilitates rapid pyrolysis of large biomass particles.

In the past few years, there have been different directions in development of ablative reactors. In vortex and cyclone reactors, biomass particles are suspended in a flow of supersonic velocities to ensure enough centrifugal forces for pressing the particles against the heated reactor surface. Although simple in design, the main problem with these reactors is their requirement of large volumes of carrier gases relative to biomass feed which, besides cost escalation, leads to cumbersome gas separation and thermodynamic penalties.

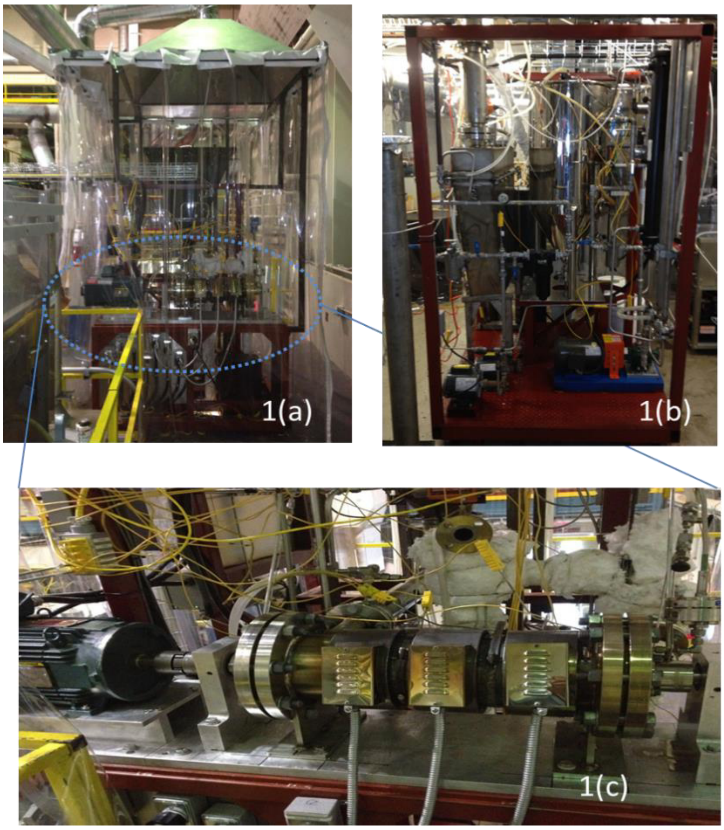

Fig. 1: CanmetENERGY's 10 kg/hr pilot scale centrifuge pyrolysis reactor; 1 (a) The upstream deck with biomass feeder and reactor; 1(b) The downstream with char separation and vapour handling; 1(c) Inset shows the compact centrifuge ablative reactor.

Challenge in design and operation of ablative reactor with low or negligible carrier gas

The key challenge relates to using appropriate mechanism to apply the required force on small or large biomass particle in a continuous ablative pyrolysis reactor with nil or minimal use of a carrier gas. Such ablative reactors would be quite compact and can process large amounts of biomass in small volumes and will be best suited for onsite mobile pyrolyzer applications. Bridgewater et al. 2009 attempted a rotating metal blade to directly press the biomass particles against the heated cylinder [4]. Whereas, in their pursuit for continuous ablation, Bech et al 2009, used a thermo-mechanical rotor at very high rpm to create required centrifugal forces (4-17 kG) for pressing the biomass particles against the heated walls of a concentric shell [5]. This design used radial blades and spirally-twisted flow guides rings welded on the inner surface of the heated reactor wall, to provide continuous centrifugal force and axial motion of the particles.

Recently CanmetENERGY has designed and developed a modular centrifuge ablative pyrolysis unit. Unlike previous designs, this new approach consists of an innovative rotor based on annular blades providing continuous ablation and axial motion to reactor feed and product streams [6,7]. In addition, this novel blade design can run the unit at variable modes e.g. slow as well as fast pyrolysis regimes.

This ablative centrifuge reactor with a design capacity of 10 kg/hr biomass feed has been installed on two vertical platforms. The upstream section which includes biomass feeder and ablative reactor, is installed in the upper portion while the downstream section handling solid char and pyrolysis vapours has been built on the lower platform (see Figure 1). The modular reactor system is compact and capable of being mounted on a trailer for mobile pyrolysis applications.

Summary Results

Prior to a full-fledged hot pyrolysis run, fine cellulose powder was used in cold runs to assess the solid flow at different rotor speeds. Subsequently, formal pyrolysis runs were carried at 500 °C with softwood and hardwood feedstock. The ablative centrifuge pyrolysis unit ran successfully at a rotor speed of 2000 rpm without any unplanned interruptions.

Figure 2 compares the performance of the ablative centrifuge pyrolysis unit with a fluid bed unit with the same capacity and with similar modular components except the reactor block [6]. The outcomes indicates that bio-oil properties are comparable to fluid bed pyrolysis conducted on similar feedstock. Similar trends were obtained in char properties also. No char build-up or clogging inside the reactor system hindered the operation and majority of fine char particles exited from the centrifuge unit to the two cyclones.

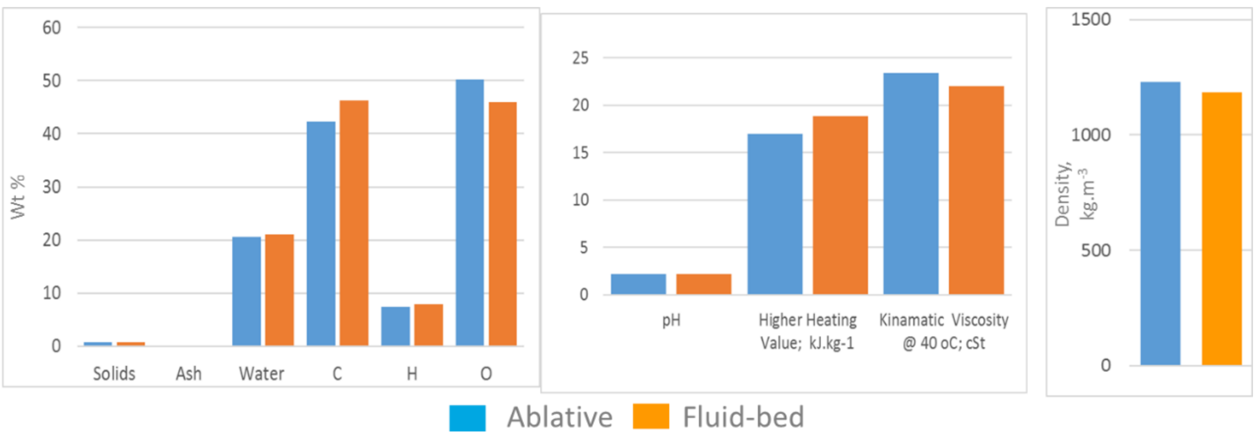

Fig 2: Comparative properties of bio-oil obtained from ablative and fluid-bed pyrolysis of hardwood.

Conclusions

These initial outcomes confirmed the performance of this novel ablative centrifuge pyrolysis reactor. Compared to existing state of the art, the proposed design is extremely simple and compact. Over the course of further development, the outputs from the unit can be further refined by optimizing various parameters e.g. rotor speed, blade angle, reactor temperature.

Such thermo-mechanical pyrolyzers can be operated in multiple pyrolysis regimes, ranging from slow to fast pyrolysis and for large biomass particles without need for large quantities of expensive carrier gases. Although scale up for large and centralized pyrolysis plant may be an issue, these ablative centrifuge pyrolysis units can be adapted in a modular approach for small to medium size facilities.

Acknowledgement

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References

[1] Mohan, D., Pittman, C.U. and Steele, P.H., “Pyrolysis of wood/biomass for bio-oil: A critical review”, Energy & Fuels 2006, 20, 848-889.

[2] Vamvuka, D., “Bio-oil, solid and gaseous biofuels from biomass pyrolysis processes-An overview”, International Journal of Energy Research, Volume 35, Issue 10, 835-862.

[3] Scholl., S., Klaubert, H. and Meier. D., “Bio-oil from a new ablative pyrolyser”, Science in Thermal and Chemical Biomass Conversion, Vol. 2, Edited by A.V. Bridgewater and D.G.B. Boocock, 2006, pp. 1372-1379.

[4] Bridgewater, A.V., Peacocke, G.V.C. and N.M. Robinson, “Ablative thermolysis unit”, US Patent No. US 7,625,532 B2, Dec 1, 2009.

[5] Bech, N., Boberg, L. M., Jensen A.J. and Dam-Johansen, K., “Modelling solid-convective flash pyrolysis of straw and wood in the pyrolysis centrifuge reactor”, Biomass and Bioenergy 33 (2009) 999-1011

[6] Gupta, M., McFarlan, A., Nguyen, L. and Preto, F., ‘Design and development of novel centrifuge ablative pyrolysis approach for biomass conversion to bio-oil and bio-char”, E3S Web of Conferences 61, 00016 (2018)

[7] Gupta, M., McFarlan, A., Khosa, K. and Preto, F., “Reactor and method for ablative centrifuge pyrolysis”, Publication Number WO/2020/146945, International Application No. PCT/CA2020/050040.

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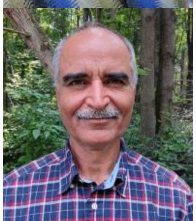

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Renewable Fuels from Green Refineries

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Fig. 1: Even in case of increasing electrification, renewable liquid fuels will be needed for heavy-duty, air, and ship transport. (Photo: Markus Breig, Amadeus Bramsiepe, KIT)

A consortium of science and industry develops processes and supply scenarios to meet for the future demand of synthetic fuels by a federal funding of around EUR 7.5 Million

Synthetic fuels from renewable energy sources are needed to reach the climate goals in the transport sector.

The so-called refuels promise to reduce CO_2 emissions by more than 90 percent compared to conventional fossil fuels.

To cover future needs of heavy-duty vehicles, airplanes, and ships and provide the chemical industry with green fuels and chemicals, the corresponding industrial technologies and facilities are required. Researchers of Karlsruhe Institute of Technology (KIT) and their partners have now launched the REF4FU project to estimate the refuel quantities needed for the different applications and what future green refineries will have to look like to produce these quantities.

Renewable resources as a basis for refuels production

REF4FU starts from hydrogen, pyrolysis oil based on bio-residues, such as straw or waste wood, methanol from renewable feedstocks, as well as Fischer-Tropsch oil that corresponds to green crude oil.

The advantage of these renewable feedstock is that they can be transported, stored, and handled just like today’s crude oil. However, not only fuels need to be produced from these resources but also intermediates for the chemical industry.

It is important to make sure that the fuels derived from these feedstocks fit to existing vehicle fleet and fuel standards on road, air and water. Therefore, the REF4FU project aims to produce fuel components with representative process development units at a technology readiness level of 5, develops 100 percent renewable fuels by an application-

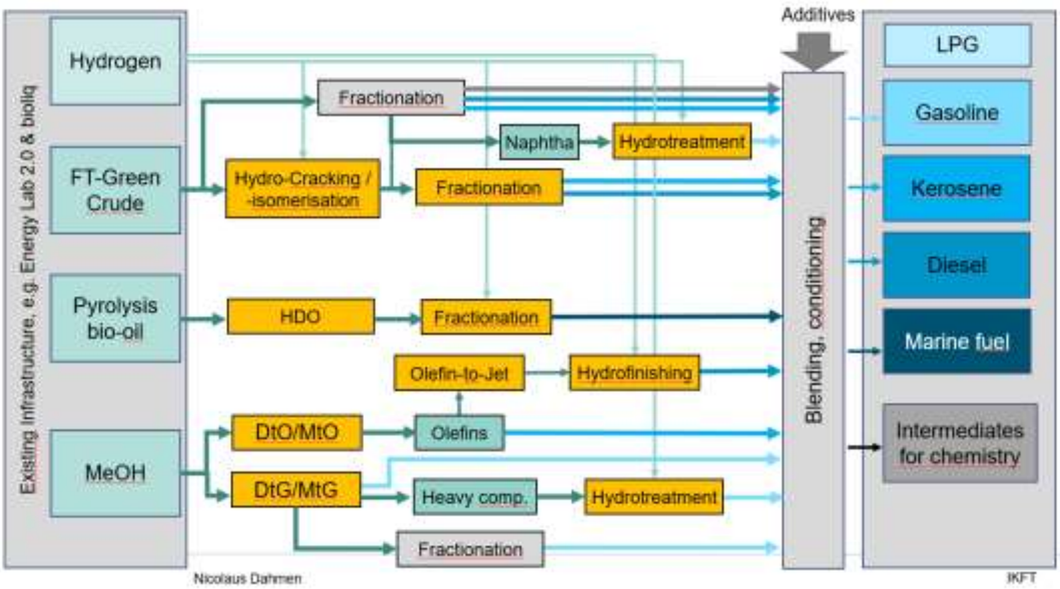

Fig. 2: Processes considered in the REF4FU project (marked in yellow).

oriented design space approach and evaluates the fuels for performance and compatibility.

Concepts for ramping up production

Refuels are being produced on a pre-industrial scale: "We already have processes and big, technically mature test facilities to produce tons of synthetic fuel," Dahmen says. However, it is not yet clear how these fuels will be commercialized. To find out when and where which quantities of synthetic gasoline, diesel, or kerosene will be needed, researchers process routes that also take into account political goals regarding the defossilization of traffic or the expected developments in the different transport sectors.

The refinery concepts derived from the scenarios will be evaluated with regard to technical, ecological and economic characteristics and their flexibility for future fuel requirements, possible synergies and optimization potentials will be determined on this base. Possible ways of a successful implementation are shown as examples for selected refinery concepts.

Fig 3: Participants of the REF4FU Kickoff-meeting in May 2023 at KIT in Karlsruhe

The REF4FU collaboration project coordinated by KIT is funded with around EUR 7 million (2022-2025) by the German Federal Ministry for Digital and Transport. Apart from institutes of KIT (IKFT, IMVT, EBI-CEB, IFKM, IIP), the project partners are the German Aerospace Center (DLR, Institute of Combustion Technology), DBFZ nonprofit GmbH, Technische Universität Bergakademie Freiberg, Chemieanlagenbau Chemnitz GmbH, EDL Anlagenbau mbH, and Ineratec GmbH. The MiRO refinery, Porsche AG, BASF SE, and ASG Analytik Service AG are associated project partners.

Parallel to the REF4FU project and supported by the same funding scheme a nationwide platform project INNOFUELS to accelerate the production of increasing quantities of refuels was created. This alliance of science, industry, and politics creates a network of promising research, development, and application activities, which is open for cooperation with additional partners in- and outside of Germany.

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Gefördert durch:

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aufgrund eines Beschlusses des Deutschen Bundestages

Koordiniert durch:

Projektträger:

Pyroliq II: Pyrolysis and Liquefaction of Biomass and Wastes 2023

Anthony Dufour, Franco Berruti, Manuel Garcia-Perez and Wolter Prins, Co-chairs

Following the successful Pyroliq I conference held in Cork, Ireland, in 2019, the Pyroliq II conference was organized on May 7-12 2023, in the village of Hernstein, near Vienna, with the support of Engineering Conferences International (ECI).

It has gathered 75 attendees from 21 countries and 6 continents in a friendly atmosphere at the charming Hotel Schloss Hernstein.

Pyroliq is a forum for discussion about the recent advances in the pyrolysis and liquefaction technologies of biomass and wastes.

The final program can be found in the link below:

https://engconf.us/wp-content/uploads/2023/05/Final-Program-Booklet-23-AP-WEB-1.pdf

The conference started with local Austrian wines tasting on Sunday evening! Then, the program was intense (from 7:30 am to 11:00 pm, but with an excellent networking break in the afternoons and an excursion to Vienna). The "retreat-style Banff format" of this conference, consisting of oral presentations, each accompanied by a poster, allowed for broad participation and promoted excellent face-to-face interactions during the breaks and the poster sessions held in the evenings. 67 15-minute presentations and 5 30-min plenary lectures were presented throughout the Conference.

Some of the main topics discussed were: continuous pyrolysis and hydrothermal reactors (for biomass or plastics), catalytic hydrotreatment, fundamentals of plastics and biomass pyrolysis, the structure of oligomers, thermodynamics of bio-oils, etc. Excellent overviews and potential business opportunities on biofuels (notably marine and jet fuels) and bio-oil chemicals were also presented.

We all felt the enthusiasm, energy, and growing interest in the field expressed by all participants, especially the numerous young attendees. For these reasons and by popular request, the organizers have already announced that a follow-up "PyroLiq III" will likely be held in September 2025.

Fig. 1: Group photo of the Conference participants

Chemical Engineering for a sustainable world

Axel Funke, Karlsruhe Institute of Technology

I have never experienced that reviving an old tradition could be as forward-looking as the KNT symposium on "Chemical Engineering for a sustainable world" held from March 20th-22nd, 2023 at the University of Twente in the Netherlands. During these three days, over 50 participants from Karlsruhe Institute of Technology, Laboratoire Réactions et Génie des Procédés Nancy and University of Twente – primarily PhD students – vividly discussed and exchanged ideas about their work towards innovative processes for the transition of our economy.

Such an exchange between these three universities/ research centres is a tradition that dates back to the 70s and 80s, when a regular exchange was organized among Pierre Le Goff, Wim van Swaaij and Ernst-Ullrich Schlünder, amongst others. It certainly was a hub around some of the most important and influential European chemical engineers of that time. While this exchange rested for several decades it surely was not forgotten. This year, Nicolaus Dahmen, Anthony Dufour, Sascha Kersten and Wolter Prins teamed up to organize a revival of this tradition to create an exchange between PhD students involved in the future direction of chemical engineering.

The workshop was designed to efficiently foster exchange and discussions between the PhD students. It can already be stated that important contacts have been established among them, but also to the experienced researchers that were also present.

Most talks evolved around the topics of chemical plastic recycling and biomass conversion, with a focus on pyrolysis. But also analytical methods as well as fundamental reactor understanding and remarkable new reactor concepts relevant for a future circular economy were presented. Reviving such an old tradition would be missing its most important part if history was not included. So one of the highlights surely was the opening lecture held by Wim van Swaaij, who did not only recap the developments of the bonds between Karlsruhe, Nancy and Twente, but also shared fascinating insights into the developments of chemical engineering during past decades.

Those three days of exchange were highly encouraging and the next KNT young researcher workshop is already being planned. Surely some of the research discussed there will find its way into future PyNe articles.

Fig. 1: Participants KNT Symposium Twente

Upcoming Events

23. - 27. July 2023
International Conference on Biorefinery and Biomanufacturing, Athen, Greece
https://icb2023.scievent.com/

20. + 21. September 2023
Advanced Biofuels Conference 2023, Gothenburg, Sweden
https://www.svebio.se/en/evenemang/advanced-biofuels-conference-2023/

11. + 12. October 2023
Biomass Power ON 2023, Stockholm, Sweden
https://fortesmedia.com/biomass-poweron-2023,4,en,2,1,25.html

12. – 13. October 2023
Biofuels 2023, London, UK
https://crgconferences.com/biofuels/

05. – 08. November 2023
International Bioenergy & Bioproducts Conference (IBBC), Atlanta, USA
https://tappi-ibbc.org/

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...:

Technical and non – technical barriers for implementation of fast pyrolysis technologies

By Wolter Prins, BTG Biomass Technology Group, The Netherlands

It is well recognised that implementation of advanced biomass conversion technologies is hampered by a wide range of problems and technical and non-technical barriers, and this led to adoption of a specialist group to review and address this topic in the PyNe network.

Figure 1: Co-combustion of bio-oil produced by BTG Biomass Technology Group in Electrabel's 350 MWe gas-fired power station in Harculo, The Netherlands. Photograph of the burner front side showing the pressurized bio-oil lines including the atomization pressure indicators. Reproduction of the photographs is subject to permission by Electrabel and BTG.

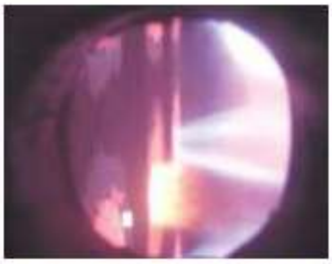

Figure 2: Co-combustion of bio-oil produced by BTG Biomass Technology Group in Electrabel's 350 MWe gas-fired power station in Harculo, The Netherlands. Photograph of the boiler room side of the bio-oil burner and its (orange) flame. Eight other burners in the boilers house (55 MWth each) were fired on natural gas (blue flame). Reproduction of the photographs is subject to permission by Electrabel and BTG.

January 2002 provided the first workshop to review barriers when Manfred Wörgetter from BLT reviewed non-technical barriers as applied to liquid fuels and Aad van Dongen from Reliant's Hemweg coal power station reviewed the project concerned with co-combustion of pyrolysis oil from Pyrovac's vacuum-pyrolysis technology. He listed 15 technical constraints for large-scale production and application of bio-oil, together with 10 non-technical barriers. Both speakers concluded that pyrolysis research and development should be concentrated in centres of excellence, and these should be more actively supported by the EU and by national governments.

In order to progress this topic, a questionnaire was completed by PyNe members to identify problems and barriers, make a priority ranking, and then decide on possible actions. These might include producing expert papers, collecting practical experiences, developing research proposals, promotion and lobbying. Results of the questionnaire were reviewed at the PyNe meeting in Hagenau in September 2002 and will form the basis for development of the topic.

It is generally recognised that demonstration of flash pyrolysis on a larger scale is a crucial step in development. Such a demonstration should include process reliability and safety, environment, economics, and product standardisation. Significant bio-oil samples will be needed to allow the development and demonstration of applications. Future research and development should focus on improvement and control of the bio-oil quality to a grade that can be recognised by authorities and accepted by consumers.

A number of non-technical topics need special attention. The public perception of biomass conversion, and especially fast pyrolysis, is poor. Promotion of the use of bio-oil, both by better networking and the distribution of publications and brochures, should be intensified. Secondly, the need for subsidies to bridge the gap from science to commercial application is still very urgent. Governmental institutions that support the introduction of biomass technologies should be convinced that fast pyrolysis is a valuable complementary technology to gasification.

It is important to distinguish between problems and barriers:

- Problems are usually well recognised and can be resolved in that solutions are, in principle, available for example through expenditure of effort.
- On the other hand, a barrier is like a closed gate; it prevents progress. For instance, insufficient financial incentives for companies to acquire, develop or promote technology is a real non-technical barrier.

The next meeting of PyNe (Florence, April 2003),will propose actions to make some progress in diminishing or demolishing the barriers for introducing fast pyrolysis technology in the market.

Despite the problems and barriers that appear to hinder the demonstration and implementation of bio-oil production and application, progress has been made in this field including at least three very successful large scale tests:

- 8 tonnes of a slurry made from slow-pyrolysis oil and char were converted to a tar free syngas in a 5 MWth entrained flow gasifier operated at 26 bar and 1200 to 1500°C in Freiberg, Germany.
- 1 tonne of real bio-oil was gasified in an atmospheric unit in Freiberg.
- 15 tonnes of bio-oil were co-combusted without problems in a 350 MWe gas-fired power station in Harculo, owned by Electrabel in The Netherlands.

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Task 34: Direct Thermochemical Liquefaction