IEA Bioenergy
Task 34
Direct Thermochemical Liquefaction
PyNe 44

July 2019

Many new faces with strong commitment

Figure 1: Task 34 at KIT together with IEA Bioenergy Technical Coordinator Luc Pelkmans (to the left)

The first Teak 34 meeting of this triennium took place at KIT, Karlsruhe/ Germany, June 25-26th, 2019. It was very exciting due to the fact that almost all task members have changed and there were many new faces to meet. Naturally, a strong focus of this first meeting was on getting to know each other better. Participating countries were represented by their team leads (Benjamin Bronson/ Canada, Lasse Rosendahl/ Demark, Christian Lindfords/ Finland, Axel Funke/ Germany, Bert van de Beld/ The Netherlands, Paul Bennett/ New Zealand, Linda Sandström/ Sweden, Justin Billings/ USA) and additionally IEA Bioenergy technical coordinator Luc Pelkmans was present as special guest.

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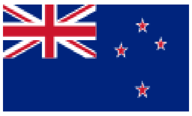

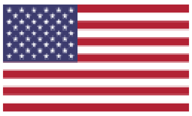

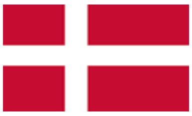

Introduction

Luc started with a general introduction of IEA Bioenergy, the different tasks, communication strategies, and related workflows. Subsequently, presentation of the country reports commenced. Each NTL has prepared a presentation to summarize activities/ policies related to DTL in their countries. We allowed almost the whole first day to focus on the country reports to provide a good basis for everybody to understand the countries different perspectives. A short break-out session around the expectation of the NTL's associated with their Task 34 work was conducted in between the country reports to provide a reflection for the future work in the Task.

The first day ended with a special diner organized in conjunction with KIT's guest house – a buffet with specialties from each country that takes part in IEA Task 34 this triennium. Still one of the best ways to experience other cultures.

Discussion of Task 34 Work Packages

All leads for work packages from the IEA proposal have been discussed and assigned among the meeting participants. The dissemination activities will be conducted by the Task lead/ KIT. The Task also discussed additional topics among the participants. Few of them were involved in the creation of the proposal for this triennium and it was fascinating to see what thoughts and ideas came up. We will sort them to see what we can work on this triennium and what will need to be directed more towards the next triennium.

Site Visits and Workshops with KIT Stakeholders

Other KIT researchers invited to join a lab tour, which started with a workshop on hydrothermal liquefaction activities at KIT. This was followed by a brief presentation of research in the field of bio-oil upgrading. IEA task members were taken around to see experimental facilities for hydrothermal and solvothermal liquefaction.

The last item on the agenda was a site visit of the bioliq® pilot unit. Prof Dahmen presented the concept and guided IEA Task 34 through the fast pyrolysis unit, the pressurized entrained flow gasifier, and the gasoline synthesis via DME. Finally, there was the chance to get a brief glance over the site of KIT's Energy Lab for investigation of energy system integration.

Yours sincerely,
Axel Funke
Task lead and NTL Germany

Fig. 1. Visit of the bioliq® pilot plant at KIT, led by Prof Nicolaus Dahmen (center).

Introduction to the members of IEA Bioenergy Task 34: 2019-2021

During the course of the meeting, we also asked all Task 34 participants the same three questions to describe themselves:

- What is your current professional area of interest?
- What is your specific motivation for and within Task 34 (in the upcoming triennium)?
- Describe yourself with ten words!

Let them speak for themselves and see what they have answered in the following article

Benjamin Bronson
CanmetENERGY, Canada

What is your current professional area of interest?
I am a research engineer working with CanmetENERGY- Ottawa of Natural Resources Canada where we endeavour to lead in science and technology solutions for the economic and environmental benefit of Canadians. I have the opportunity to participate broadly across various approaches for thermochemical conversion of biomass, which includes the direct thermochemical liquefaction technologies. The objective of the work I lead, is to perform targeted R&D to aide in the development viable pathways to convert low-value or underutilized biomass resources (surplus forestry residues, agricultural residues, and biogenic wastes) into biofuels and bioproducts as well as enabling applications of those products.

What is your specific motivation for and within Task 34 (in the upcoming triennium)?
My specific motivation is to enable open communication on challenges and successes that others have had in the direct thermochemical liquefaction of biomass, so that we can all leverage the lessons learned from others to improve our own national research, development and demonstration efforts to accelerate the transition biofuels and bioproducts derived from sustainable biomass feedstocks.

Describe yourself with ten words!
Researcher, inquisitive, engineer, pragmatic, quiet, reflective, analytical, direct, persistent, industrious

Christian Lindfors
VTT Technical Research Centre
Finland

What is your current professional area of interest?
Status of fast pyrolysis and bio- oil upgrading
Sealing up the pyrolysis technology into industrial scale

What is your specific motivation for and within Task 34 (in the upcoming triennium)?
More international collaboration

Describe yourself with ten words!
Ambitious, enthusiastic, good- hearted, glad, introvert, helpful

Linda Sandström
RISE Energy Technology Center, Sweden

What is your current professional area of interest?

I am interested in the pyrolysis process and currently mostly co-upgrading of bio-oils

What is your specific motivation for and within Task 34 (in the upcoming triennium)?

I am hoping that the work within the task 34 will lead to interesting new cooperations, which will take the work within DTL forward. I am also hoping, that the compilation of available knowledge and information that is performed within the task will be of assistance to various actors, thereby acceleration innovation and commercialization within the area.

Describe yourself with ten words!

Calm, happy, prestigeless, cooperative, ambitions, Swedish, like to learn new things, play the piano and ski

Bert van de Beld
BTG Biomass Technology Group bv, Netherlands

What is your current professional area of interest?

Fast pyrolysis process, development and implementation.
Development of application of FPBU Energy (diesel engines crep), Biofuels and corefinieries and Pyrolysis of fractionation and using it as raw material for bio-based products together with fossil feedstock in refinery infrastructure.

What is your specific motivation for and within Task 34 (in the upcoming triennium)?

Networking, worldwide development, especially for fast pyrolysis

Describe yourself with ten words!

Chemical engineering, professional dedicated to renewables, open minded but difficult to convince

Lasse Rosendahl
Aalborg University, Denmark

What is your current professional area of interest?

HTL, advanced biofuels and intermediates from HTL

What is your specific motivation for and within Task 34 (in the upcoming triennium)?

To help moving HTL out of the labs and into large scale implementation; facilitating a green transition with liquefaction and biofuels to contribute to a motivation of HTL in terms of analytics, sectoral integration and understanding as well as standardization of methods.

Describe yourself with ten words!

Easy going, conscientious, quality-oriented, open, approachable, focused, humor, trustworthy, team- player, flexible

Axel Funke,
Karlsruhe Institute of Technology, Germany

What is your current professional area of interest?
Design of auger reactors and condensation systems for fast pyrolysis applications. Investigate fast pyrolysis process design within the scope of the bioliq® concept.

What is your specific motivation for and within Task 34 (in the upcoming triennium)?
Further extend the work to better incorporate and represent hydrothermal liquefaction in the task. And of course to enjoy networking activities.

Describe yourself with ten words!
Open-minded, honest and direct, creative, mediating, structured, introverted, music

Paul Bennett
Scion, New Zealand

What is your current professional area of interest?
Commercialization of biomass technologies

Ensuring robust data in information is used to shape policy for bioenergy technologies will be the key.

What is your specific motivation for and within Task 34 (in the upcoming triennium)?
N2 most likely biofuel feedstock will be woody biomass to convert this into liquid biofuels. DTL

Describe yourself with ten words!
Focused, determined, approachable, honest, fun, influencer

Justin Billing
Pacific Northwest National Laboratory (PNNL), USA

What is your current professional area of interest?
Hydrothermal liquefaction of wet waste feedstocks and the challenges of separations in continuous systems. I also enjoy integrating the great work of others and working in collaboration.

What is your specific motivation for and within Task 34 (in the upcoming triennium)?
My specific motivation is to help integrate what is known about HTL into the task and help open doors to application through traditional task strength such as standardization and analyzed methods development. The general motivation is to provide steady representation of US interests and activities in pyrolysis and liquefaction

Describe yourself with ten words!
Observational, outgoing, impressionistic, funny unconventional, analytical, curious, improvisational, distractible, handsom

Kai Toven
Rise

What is your current professional area of interest?
At RISE PFI I am heading the research within biorefining and bioenergy. Within this area we are addressing both thermochemical and biochemical biomass conversion but the main focus is on thermochemical conversion of biomass. Here, key topics for our research are pyrolysis processes for direct thermochemical liquefaction, pyrolysis liquid upgrading for fuels and chemicals, carbonization processes and applications for biocarbon. In Norway RISE PFI is a leading R&D actor within pyrolysis technology.

What is your specific motivation for and within Task 34 (in the upcoming triennium)?
The main motivation factors for participating in Task 34 is to support Norwegian initiatives for producing advanced biofuels and biochemicals based on pyrolysis technology and to establish an international network with leading actors within this field. Knowledge sharing within the IEA Task 34 network
May contribute to the resolution of critical technical issues and speed up the implementation of thermochemical liquefaction processes for fuels and chemicals. In Norway there are industrial initiatives for production of advanced transportation biofuel based on hydrothermal liquefaction and fast hydropyrolysis technology and for production of biocarbon reductant material for the Norwegian ferroalloy industry based on novel carbonization technology.

Describe yourself with ten words!
I am an enthusiastic, dedicated, creative, flexible, joyful and stubborn person which probably focus too much on work.

Alexandra Böhm
Karlsruher Institute of Technology, Germany

What is your current professional area of interest?
Project management and organizing, event management and supporting my colleague, learning new things, getting more knowledge and experience in the field of international networking and dissemination.

What is your specific motivation for and within Task 34 (in the upcoming triennium)?
To increase the efficiency through the “feel-good” effect, make the work for the NTLs as easy as possible, so they can concentrate on the real important things.

Describe yourself with ten words!
enthusiastic, creative, honest, reliable, (a little bit) crazy, motivated, passionate, sensitive, supportive, warm-hearted

Application of ashes from fast pyrolysis bio-oil production of different waste streams may improve soil quality

Maraike Probst, PhD; Marina Fernández-Delgado Juárez, PhD; Felix Kurzemann, MSc; Dr. María Gómez-Brandón; Prof. Dr. Heribert Insam

Institute of Microbiology, Leopold-Franzens Universität Innsbruck, Innsbruck, 6020, Austria

Global concerns about greenhouse gas emissions and limited availability of fossil fuels urge the development of alternative energy sources and environmental responsibility demands their substitution by sustainable options. Woody biomass fulfills these requirements, and technologies, such as fast pyrolysis can conserve around 70% of its energy content. During fast pyrolysis, the biomass is separated into aqueous vapors, pyrolysis gas and charcoal by high temperatures of around 500 °C within seconds. The condensed vapor, which is fast pyrolysis bio-oil (FPBO), can substitute fossil fuels (Bridgewater et al. 1999), e.g. for residential heating.

Contributing to the efficiency and environmental compatibility of the process, the charcoal and gas are combusted to process energy. Resulting fly ash (FA) has a high pH and contains high amounts of minerals and salts present in the biomass used

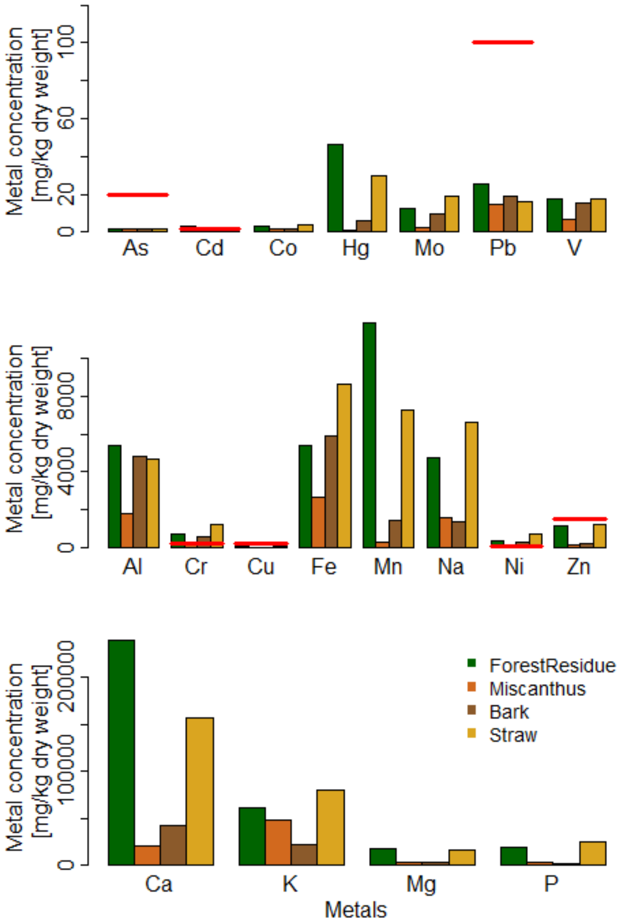

Fig. 1. (Heavy) Metal concentrations in fly ashes obtained from fast pyrolysis charcoal of different biomass wastes. Red lines indicate maximum allowed concentrations according to Austrian Compost Ordinance (BMLFUW 2001) and the Guidelines for the use of biomass ash in Austria (BMLFUW 2011).

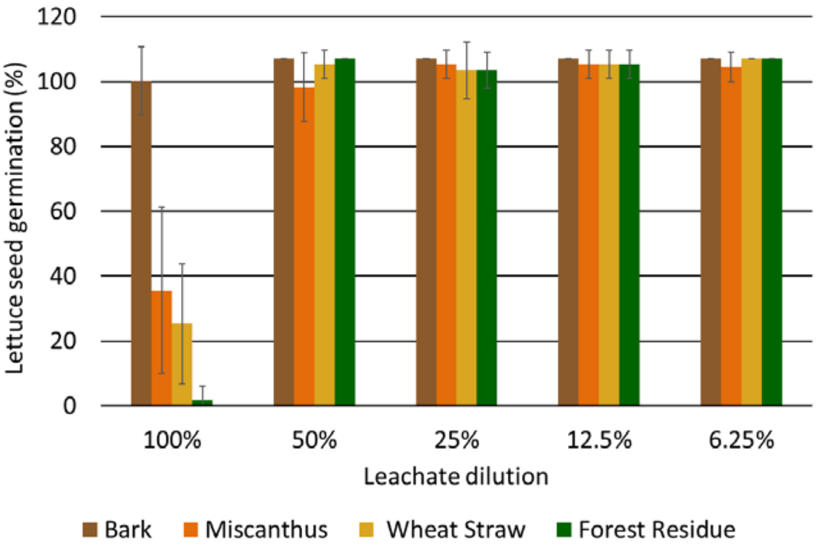

Fig. 2. Phytotoxicity effect of fly ashes from fast pyrolysis charcoal of different biomass wastes. Seed germination refers to how many seeds out of initial 10 germinated during the test period.

for FPBO production (Fernández-Delgado Juárez et al. 2018). Since soil acidity and lack of micronutrients often limit plant growth, FAs might be useful as soil amendment. Some studies have already shown a positive effect of FA application on soil properties and plant growth (Schönegger et al. 2018; Bougnom et al. 2009).

On the other hand, high levels of heavy metals (HM), alkali metals and silicon have also often been found in FAs (Tchounwou et al. 2012). High HM levels restrain FAs' potential environmental benefit and might harm ecosystems. Therefore, FAs are usually landfilled or used in the cement industry. However, the concentrations of HMs in FAs depend on the substrate combusted in the ash generating process (Maresca et al. 2017). In the project *Residue2Heat*, FPBO is produced from different woody biomass wastes, namely wheat straw, bark, forest residues and *Miscanthus sp.* (https://www.residue2heat.eu/).

Using solely clean biomass for FPBO production might result in FAs, which are suitable for soil amendment and might even have a positive effect on soil properties and plant growth. As a result, the production process of FPBO would be more efficient and profitable reducing the need of FA landfilling and the return of micronutrients to agriculture and forestry reduced human impact in the sense of a circular economy. Therefore, we characterized the FAs generated during combustion of fast pyrolysis charcoal from different biomass wastes and tested the environmental effect of ashes with promising properties from a chemical and microbiological viewpoint in a field trial.

Fly ashes from bark, forest residues and Miscanthus sp. have promising characteristics for soil application

Fly ashes derived from fast pyrolysis charcoal of wheat straw, bark, forest residues and *Miscanthus sp.*, respectively, were characterized based on their contents of (heavy) metals and polycyclic aromatic hydrocarbons, their pH, electrical conductivity (EC) and carbon content. As expected, the biomass source determined the characteristics of the FAs.

However, all FAs investigated had a pH around 12 and a high nutrient content (0.6-3%$_{\text{dry mass}}$ total inorganic C and 1.4-18%$_{\text{dry mass}}$ total organic C). Underlining their potential use as soil amendment, the EC of the FAs (0.5-5 mS cm^{-1}) indicated a high mineral and salt content. Further supporting the utilization of FAs as soil amendment, the concentrations of polycyclic aromatic hydrocarbons were very low. Although generally low HM concentrations were detected, for all FAs tested except for *Miscanthus,* the Cd, Cu, Pb and Zn concentrations slightly exceeded the

Austrian Compost Ordinance (BMLFUW 2001) and the Guidelines for the use of biomass ash in Austria (BMLFUW 2011) (Fig. 1).

For the majority of FAs tested, leaching experiments showed that Ni and Cr, which were those HMs found in highest concentrations, were barely mobilized. However, in the case of wheat straw FA, the mobilization of Ni and especially Cr was enhanced. Taken together, the characteristics of the FAs, especially of *Miscanthus sp.*, but also from bark and forest residues, were promising in terms of their potential utilization as soil amendment. The low metal mobilization might balance their slightly too high metal concentrations.

Subsequently, the effect of FA leachates on the germination and root elongation of garden cress (*Lepidium sativa*) and lettuce (*Lactuca sativa*) was analysed. Only undiluted leachates impaired the germination of the garden cress and lettuce (Fig. 2). For all FAs tested, the diluted leachate had no effect on seed germination. The phytotoxic effect of FAs was observed, however, on the root elongation of the plants. Undiluted and 50% diluted leachate negatively affected the plants' root development. For higher dilutions, no inhibiting effect was observed.

In agreement with the increased metal concentrations, FAs from wheat straw and forest residues had the strongest phytotoxic effect, while bark FA had the lowest impact on plant growth (Fig. 2).

No negative effect of fly ash application to soil was observed during a one-year field trial

The FAs obtained after FPBO production from selected biomass wastes (i) increased soil pH; (ii) had a high (micro-)nutrient content; (iii) contained low concentrations of (heavy) metals and polycyclic aromatic hydrocarbons; and (iv) did not show a phytotoxic effect if applied in a reasonable dose. Therefore, the FAs obtained from *Miscanthus sp.*, bark and forest residues were applied to an agricultural grassland soil in a field trial. The test area covers 160 m^2 and produces hay for cattle fodder. In line with the Austrian recommendations ("Richtlinien für sachgerechte Düngung", BLMFUW, version 2010.8.4), the soil was fertilized with cattle slurry at an amount of 180 N kg ha^{-1} y^{-1}. In a randomized block design (4x4 plots with 10 m^2 each), the effect of FA application (500 kg ash ha^{-1} y^{-1}, according to the Austrian guidelines for biomass ash application (BLMFUW, 2011)) was tested and compared to control plots without ash application (Fig. 3).

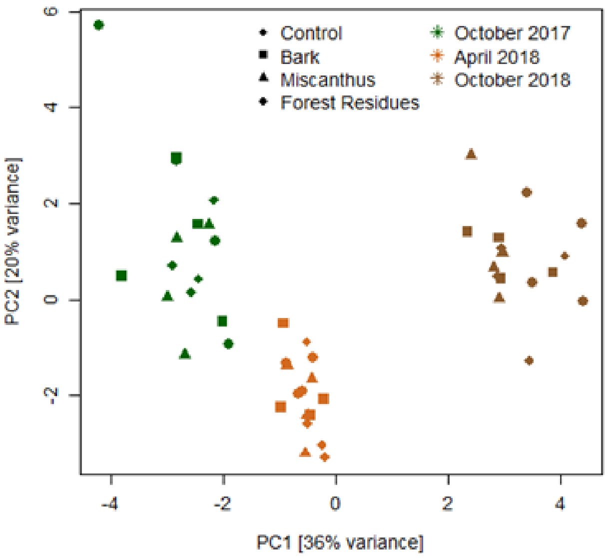

Fig. 3. Effect of fly ash (FA) application to soil. Fly ash from fast pyrolysis charcoal of different biomass wastes was applied to a grassland soil. The effect of FA application on soil physicochemical and microbial properties was summarized to principal components. Each symbol in the plot corresponds to a sampling site and distances between symbols represent differences in soil properties.

According to common agricultural practice, plant biomass was harvested three times during the growing season. Over a timeframe of one year, the soil characteristics and plant productivity were measured. Before FA application, at the beginning and in the end of the growing season, topsoil was sampled and analyzed in terms of physico-chemical and microbial properties. Plant composition and yield were measured and compared.

A variety of properties was monitored, including moisture content, pH, EC, (heavy) metal concentrations, organic matter content, nitrogen content and microbial basal respiration. Despite the feedstock-dependent differences between the FAs, there were no differences between the FA treated plots and the controls (Fig. 3). The samples clustered by season and not by treatment, indicating that FA addition did not affect soil properties during the experimental period. The field trial is ongoing in order to evaluate the long-term effects of FA application on plants and soil. Summarizing, the results underline that FA are not to be considered *generally hazardous* and a circular use of FAs is thus advised. Current and further research is and will be necessary to provide information on process optimization in terms of waste management towards a sustainable future.

The Residue2Heat project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement #No. 654650.

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https://www.residue2heat.eu/
https://www.uibk.ac.at/microbiology/

Co-upgrading of HTL oil and fossil oil in FCC MAT

Elena Wikberg, Linda Sandström
RISE Energy Technology Center AB

There is an increasing worldwide demand for biofuels and upgrading of liquefied biomass in existing refinery technology is a promising technology for converting solid biomass into a liquid transportation fuel.

Co-processing of fossil oil together with various bio-oils, including “raw” and upgraded pyrolysis oil and hydrothermal liquefaction (HTL) oil, using Fluid Catalytic Cracking (FCC) conversion process and FCC catalysts has been studied in several publications [1-4]. Untreated pyrolysis oil results in higher coke formation and lower liquid yields than when the bio-oil is hydrotreated prior to the FCC process [3].

The newly installed FCC MAT (Fluid Catalytic Cracking Micro Activity Test) unit at RISE Energy Technology Center (RISE ETC), Figure 1, can be used to test various catalysts and to study upgrading of bio-oils, alone or co-fed with fossil feedstock. The unit is designed to allow performing the experiments according to the ASTM standardized methods but also includes an extra feature of two separate feeding lines to be used for co-processing

Fig.1. FCC MAT unit.

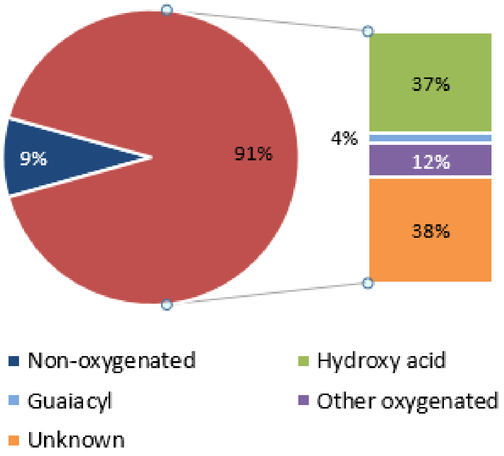

Fig. 2. Chemical characterization of the HTL bio-oil, MS area %.

experiments of two non-miscible feedstocks, such as fossil and bio-oils. The feeding is performed by two syringe pumps.

The FCC MAT unit has been used to study upgrading of bio-oil derived via hydrothermal liquefaction (HTL) of hydrolysis lignin from straw. The HTL oil was produced at RISE Processum, Sweden. The bio-oil was co-fed with commercial FCC fossil feedstock at the ratio of 20/80. Due to the non-miscibility of the HTL bio-oil with the fossil feed, composed for entirely non-oxygenated hydrocarbons, two separate feeding lines were used during the co-upgrading process. This also allows preheating of the feedstocks in accordance with their thermal properties and stability. The upgrading process was performed at 500 °C reaction temperature using commercial FCC catalyst (so-called E-cat). 9 g of catalyst was used to upgrade 1.8 g of feed resulting in a catalyst to oil ratio (C/O) of 5. The amount of reaction gas formed was determined by water replacement, and the composition was measured by µ-GC (Agilent) and GC-FID (Varian). The composition of the derived liquid products was analyzed using simulated distillation method in accordance with ASTM D-2887 and GC MS/FID (Shimadzu QP 2010 Ultra, DB-PETRO Agilent; 100 m, 0.25 mm, 0.50 µm).

Figure 2 represents the overall chemical characterization of the HTL bio-oil including component groups that represent a share larger than 2 %. The HTL bio-oil is mainly composed of oxygenated hydrocarbons (presented in red) with a small share of non-oxygenated hydrocarbons. The unidentified components are because of the characteristics of the mass spectra assumed to be oxygenated compounds.

Other oxygenated compounds are represented by a majority of hydroxy ketone and aldehyde components. Moreover, a high share of hydroxy acids can be observed from the figure as well as a small share of lignin derived guaiacyl components.

The results of the FCC MAT co-upgrading of HTL and fossil oils were compared to the results of pure commercial FCC fossil feed upgrading as presented in Figures 3 and 4. By comparing the results with the pure commercial FCC fossil feed based liquid product, an influence on the product quality and yield can be observed. Based on the results, the coke formation is higher when bio-oil is fed to the reactor, as also observed in similar co-feeding experiments with pyrolysis bio-oils [2]. The yield of gasoline range products is on the other hand slightly lower when bio-oil is present in the feedstock. Furthermore, the produced liquid product is more aromatic when the bio-oil feedstock is added, mainly due to higher presence of benzene derivative monoaromatic compounds.

The FCC MAT unit and its reactor will now be modified with the aim to increase the closure

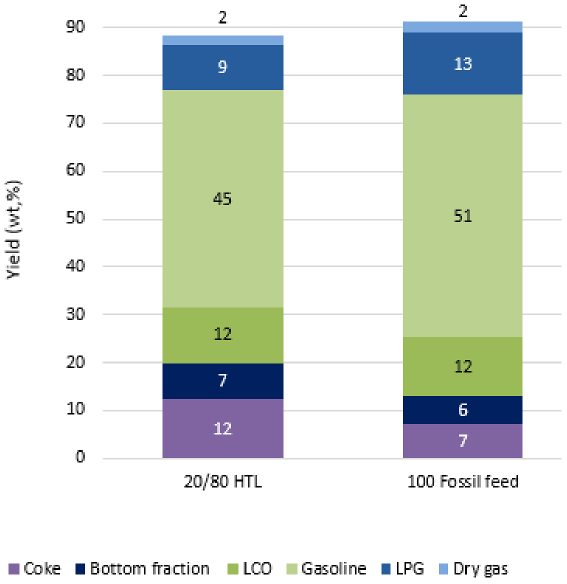

Fig. 3. Comparative chart for the products yield.

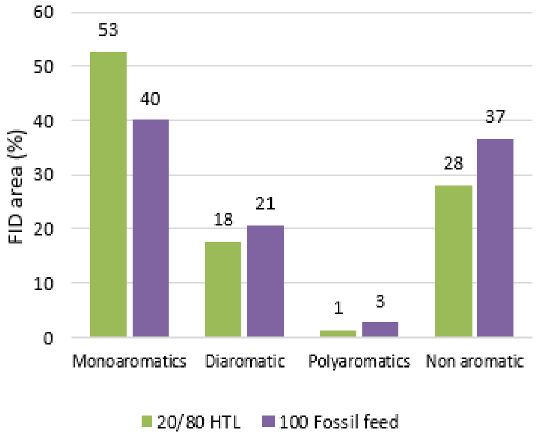

Fig. 4. Chemical composition of the liquid products.

of the mass balance. The work on upgrading various bio-oils will then be continued in several research projects to assess the introduction of bio-based feedstock to the commercial FCC refining process.

Moreover, the FCC MAT unit will be used to investigate the influence of applying different catalysts with varying properties on the bio-oil upgrading performance. The influence of bio-oil pre-treatment prior to the FCC process, such as hydrotreatment, will also be investigated.

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Co-processing biomass thermal liquefaction bio-oil/bio-crude in refineries

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Introduction

Increasing efficiency of biogenic carbon incorporation into conventional fuels is a critical step in biofuels development and adoption. Co-processing petroleum feedstocks with biomass derived feedstocks leverages the existing petroleum refining infrastructure, which significantly reduces Capex for the overall conversion technologies for biomass to fuel (Figure 1). The co-processing opportunity is significant as most refineries have conversion capabilities using hydrotreating/hydrocracking (HT/HC) and/or fluidized catalytic cracking (FCC). Research to date has explored FCC co-processing of raw pyrolysis bio-oil with vacuum gas oil (VGO) at low blend levels (< 10 vol% with 2 wt% biogenic carbon incorporation)[1-3] and HT/HC co-processing of vegetable oils, animal fats, and waste cooking oils.[4-7].

Many data gaps still exist and foundational knowledge through applied research and development is required to 1) understand the impact of co-processing on FCC and HT/HC chemistry, reaction kinetics, catalysts, equipment, gas products and fuel product quality; 2) determine if modifying existing FCC and HT/HC catalysts for co-processing of bio-oil/bio-crudes is required; and 3) quantitate biogenic carbon incorporation in co-processed fuels.

Here, we report our recent work on co-processing biomass liquefaction intermediates in FCC at NREL and HT/HC at PNNL as well as the development of biogenic carbon tracking method at LANL in 2018. We evaluated co-processing of woody fast pyrolysis (FP) and catalytic fast pyrolysis (CFP) bio-oils and wastewater sludge hydrothermal liquefaction (HTL) bio-crudes in FCC and HT/HC to evaluate product distribution and impact on FCC and HT/HC chemistry by using laboratory scale reactors. We also evaluated isotope methods, such as $\delta\ ^{13}C$ methods, for tracking biogenic carbon in co-processed products.

Co-processing in Hydrotreating/hydrocracking at PNNL

For co-processing in HT/HC, three types of bio-oils/bio-crudes, including fast pyrolysis bio-oil

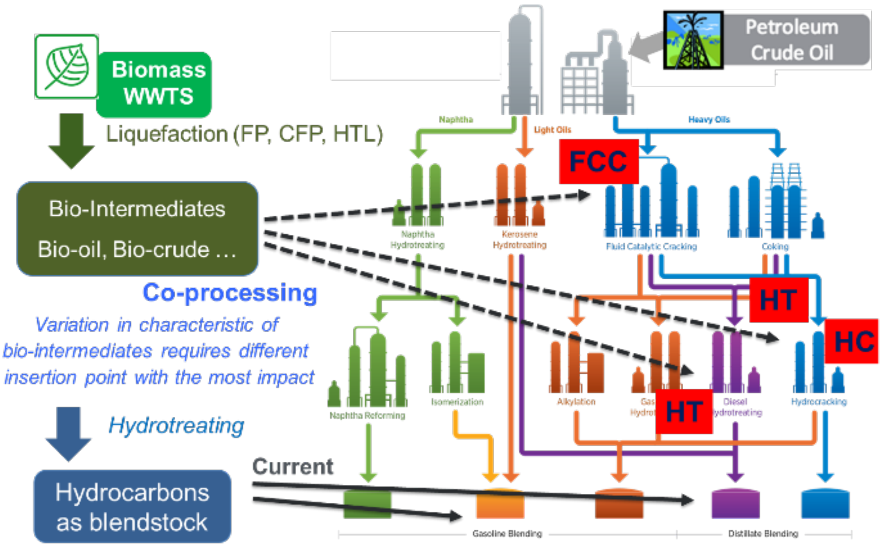
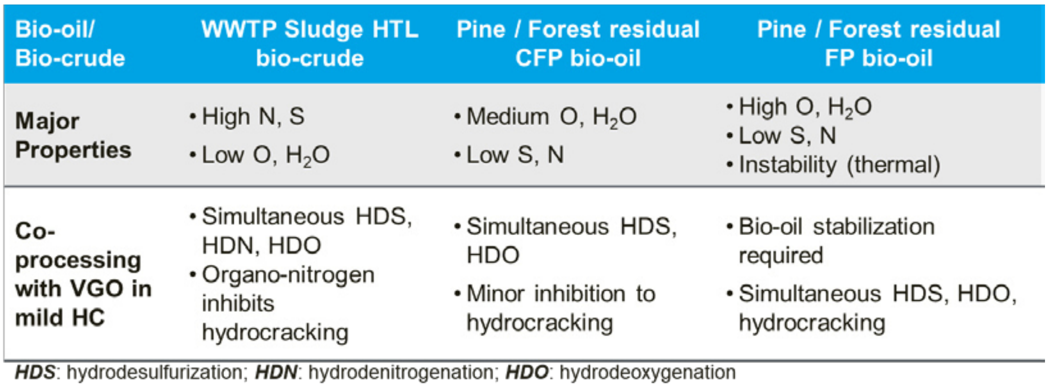


Fig. 1. Co-processing to leverage the existing infrastructure for biofuel production.

Table 1 Summary of co-processing different bio-oil/bio-crude with VGO via mild hydrocracking



Bio-oil/ Bio-crude	WWTP Sludge HTL bio-crude	Pine / Forest residual CFP bio-oil	Pine / Forest residual FP bio-oil
Major Properties	• High N, S • Low O, H_2O	• Medium O, H_2O • Low S, N	• High O, H_2O • Low S, N • Instability (thermal)
Co-processing with VGO in mild HC	• Simultaneous HDS, HDN, HDO • Organo-nitrogen inhibits hydrocracking	• Simultaneous HDS, HDO • Minor inhibition to hydrocracking	• Bio-oil stabilization required • Simultaneous HDS, HDO, hydrocracking

HDS: hydrodesulfurization; ***HDN***: hydrodenitrogenation; ***HDO***: hydrodeoxygenation

(from pine and forest residue; generated at NREL), catalytic fast pyrolysis bio-oil (from pine and forest residue; generated at NREL), and HTL bio-crude (from wastewater sludge; generated at PNNL), with a vacuum gas oil (VGO, from British Petroleum, BP) over a conventional sulfide catalyst for mild hydrocracking (~400 °C, 1-2 h^{-1} WHSV, 5, 10, 20 wt.% bio-oil/bio-crude blending) were tested to establish a baseline. The hydrocracking performance, including removal of heteroatom (S, N, O) and yield of products (gas, fuel, distillate), for co-processing were determined and compared to the VGO only baseline. The biogenic carbon distribution was then determined by mass and carbon balance calculation as well as isotope tracking.

As shown in Table 1, co-processing of woody CFP bio-oil and stabilized FP bio-oil showed simultaneous HDS and HDO and a minor impact on hydrocracking. Product with low O and S content in the distillate range was obtained and biogenic carbon was incorporated in these products. For instance, for forest residue CFP bio-oil co-processing, 95-98% of carbon in bio-oil was converted to organic products and 75-82% of carbon in bio-oil was converted to distillate products (boiling point <350 °C in sim-dist). The yield for distillate fuel from VGO was maintained. For co-processing of sludge HTL bio-crude, products with much reduced S, N, and O content were obtained with more than 90% of bio-crude converted to oil product. However, the nitrogen containing species in bio-crude at high content compete with active sites for HDS and HDO and inhibits the hydrocracking activity of the catalyst.

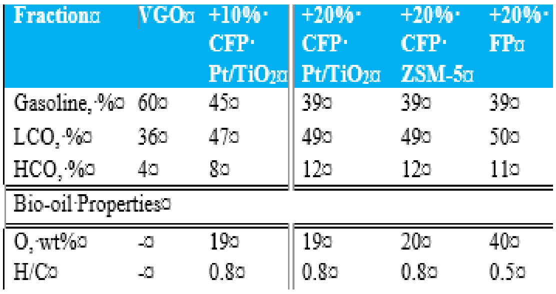
Ongoing work for this effort includes development of separate two stage HT-HC for co-processing HTL bio-crude with HT pretreatment to lower nitrogen content, determining fuel quality and impacts to reactor and catalysts, and determining kinetics of co-processing in HT/HC and requirement for catalyst modification.

Co-processing in FCC at NREL

FCC co-processing experiments were conducted with VGO and bio-oil in a microscale vertical reactor coupled with a condenser to collect the liquid product fractions for analysis. Two different *ex situ* catalytic fast pyrolysis bio-oils from pine were used to assess impact on product composition: one produced in a lab-scale fluidized bed pyrolyzer coupled to a fixed-bed of Pt/TiO_2 catalyst and the other produced in a Davison circulating riser (DCR) pilot scale system over a HZSM-5 type catalyst. In addition, another blend was prepared using non-catalytic pine bio-oil. Co-processing blends were prepared and heated to 40°C prior to the co-processing experiments to improve the homogeneity of the blends.

Table 2 shows how the yields for gasoline, light cycle oil (LCO) and heavy cycle oil (HCO) range fractions changed with bio-oil blend levels. The proportion of LCO and heavies (HCO) increased when bio-oils were blended with VGO. This increase could be due to either the presence of LCO and HCO components in the bio-oils or to the enhancement of LCO and HCO products by cracking of the blend. The data in Table 2 shows proportions of products from the liquids collected during the co-processing experiments and not as a function

Table 2 Co-processing different bio-oils with VGO via FCC



Fraction	VGO	+10% CFP Pt/TiO_2	+20% CFP Pt/TiO_2	+20% CFP ZSM-5	+20% FP
Gasoline, %	60	45	39	39	39
LCO, %	36	47	49	49	50
HCO, %	4	8	12	12	11
Bio-oil Properties					
O, wt%	-	19	19	20	40
H/C	-	0.8	0.8	0.8	0.5

of the feed weight. Blending VGO with bio-oils reduced the gasoline range fraction due to the presence of oxygen containing fractional groups which are more recalcitrant to cracking. These oxygenates increased deactivation rates of the catalyst indicating that a higher catalyst-to-oil ratio (CTO) is required during co-processing to produce gasoline yields similar to yields from neat VGO. Other impacts included 1) the LCO and HCO boiling range fraction increased in the liquid product; 2) the LCO and HCO fractions increased with amount of bio-oil added; 3) yields are impacted by bio-oil oxygen content and hydrogen to carbon ratio; 4) catalyst coking increased; 5) the liquid collected from VGO/bio-oil blends contained oxygenated species (simple phenols); and 6) both CO and CO_2 were observed when bio-oil was added to VGO. Current micro-scale work is assessing the impact of catalyst composition on FCC co-processing with varied bio oils.

Pilot scale continuous co-processing using the DCR was conducted with 10 wt% pine CFP oil in VGO using 10% HZSM-5 type zeolite in 90% E-Cat (low metals refinery equilibrium catalyst, Y-zeolite and additive) at 550 °C and 1 sec residence time in the riser. Condensed liquid product was analyzed by ^{14}C analysis for biogenic carbon determination, which showed 4% biogenic (modern) C. Based on the initial 4 wt% biogenic carbon incorporation in co-processed product, work continues on optimizing the feeding temperature and rate of bio oil addition and on developing efficient catalysts that target each feed component to meet or exceed 5 wt% biogenic carbon in co-processed fuel.

Biogenic carbon tracking at LANL

Biomass including C3 and C4 plants can be characterized by their stable carbon isotope composition (⍰^{13}C). ⍰^{13}C of bio-oil, bio-crude, and their co-processing products were analyzed using Costech EA coupled with Finnigan MAT 253 for biogenic carbon tracking. Samples were packed under Ar-atmosphere in tin tubes. To increase the ^{13}C signal intensity, a small amount (0.0478%) of ^{13}C-enriched fatty acid was blended with the HTL bio-crude for co-processing with VGO via mild hydrocracking. The $\delta\,^{13}C$ of bio-crude co-processing products show significant correlation with the bio-crude blending levels (0% to 17.6%). At the same bio-crude blending level (9.7%), different reaction conditions cause appreciable $\delta\,^{13}C$ change, suggesting the applicability of using $\delta\,^{3}C$ to track biogenic C and to guide the optimization of bio-crude co-

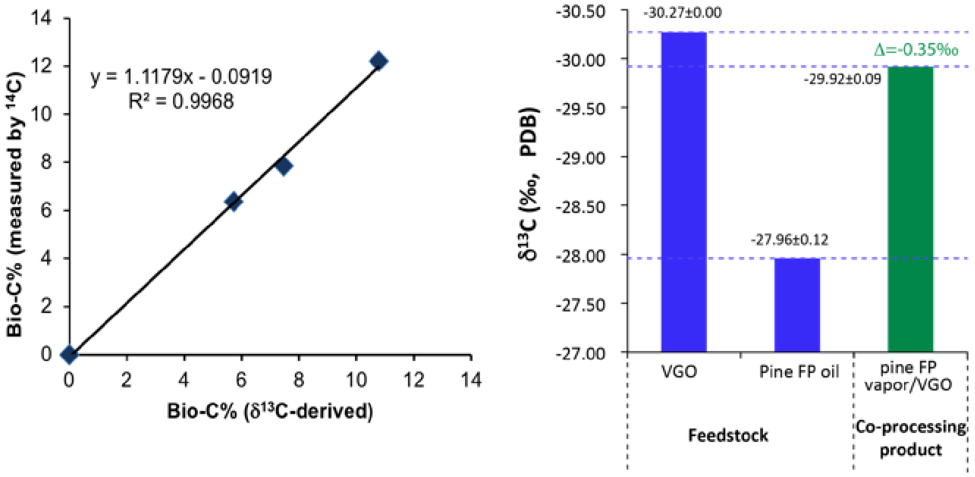


Fig. 2. Comparison of biogenic C content measure by by δ 13C and 14C methods (left) and incorporation of small amount of biogenic C in the co-processing product revealed by δ 13C analysis (right).

processing. The δ^{13}C traceability was verified by comparing with ^{14}C data obtained by AMS (Accelerator mass spectrometry), as shown in Figure 2 (left). Although the δ^{13}C value of VGO is close to the value of the bio-oil feedstock (pine FP oil), δ^{13}C analysis appears to be able to track the biogenic C during co-processing. Based on the isotope mass balance calculation, a small amount of biogenic C was incorporated in the co-processing product (Figure 2, right). It is anticipated that the use of C4 plant feedstock will greatly increase the biogenic C traceability through ^{13}C/^{12}C ratio analysis for bio-oil co-processing.

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Choosing Pumps for Pyrolysis Condensates: A Case Study

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Foreword

The pyrolysis tank farm of the bioliq® I plant contains 6 tanks with a volume of 20 m^3 each. A wide range of feedstocks is handled. In the past, the following materials were stored in the tanks:

- Organic condensate from bioliq®
- Aqueous condensate from bioliq®
- Model fuel: Monoethylene glycol + approx. 20% straw char or wood char and straw ashesPyrolysis oils from external sources: BTG Biomass Technology Group BV and proFagus GmbH
- Monoethylene glycol, for cleaning and rinsing purposes
- bioliq® II wastewater: interim wastewater from the bioliq® II plant

Media containing solids - such as model fuel or organic condensate - tend to sediment. Even so to say solids-free pyrolysis oils, such as the "proFagus low-viscosity" (currently used in gasification experiments at bioliq® II) can form various phases (aqueous / organic). Both settling of solids and the formation of a heavier organic phase in the lower part of a tank should be avoided, as otherwise pumps and piping can be blocked. Therefore, all tanks have continuously operating agitators and circulation lines. By a pump, a certain volume flow of the medium is continuously transported from the bottom of the container upwards, resulting in a homogenization. In order to allow the highest possible flexibility of the tank occupancy, the installed pumps should have satisfactory service life with all of these media. This short report compares 3 different tank farm pumps used between January 2015 and autumn 2018.

The pumps used were chosen because they can promote both high-viscosity (pyrolysis oils) and low-viscosity media (water, ethylene glycol). However, the main focus is on the suitability of the pumps for pumping pyrolysis oils and on their durability with regard to the problematic medium (viscosity, solids, chemical composition).

Progressive cavity pumps

The used progressing cavity pumps of the Allweiler Company are unfortunately generally considered poorly suited for pyrolysis oils, due to their highly complex chemical composition. Media-contacting parts of these pumps are partly made of plastics such as the stator and the sleeve on the propeller shaft. Used materials for these parts are e.g.

- NBR (Nitrile butadiene rubber) "Perbunan“
- HNBR (Hydrogenated nitrile butadiene rubber)
- EPDM (Ethylene propylene diene monomer rubber)
- FKM (Fluoroelastomer) "Viton"
- CSM (Chlorosulfonated polyethylene synthetic rubber) "Hypalon"

In order to find the most suitable material for the pumps, laboratory tests with material media were stored in the tanks one after the samples were performed according to manufacturer’s advice.

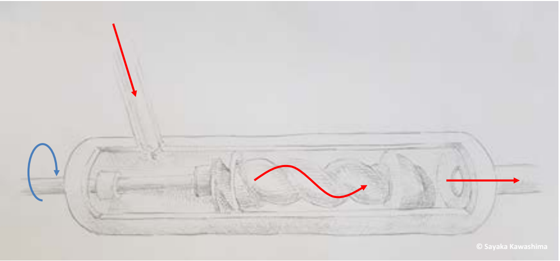
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Fig. 1. Schematic sketch of a progressive cavity pump.

Table 1 Percentage change of various parameters after storage test of several materials in aqueous condensate

Organic condensate

Sample material	relative deviation (%) Mass	Hardness Shore A	Diameter	Thickness
NBR (Nitrile butadiene rubber) "Perbunan N"	25	-23	7	14
NBR (Nitrile butadiene rubber) "Perbunan A"	21	-29	6	8
NBR (Nitrile butadiene rubber) "Perbunan soft"	28	-31	7	14
HNBR (Hydrogenated nitrile butadiene rubber)	22	-22	7	4
EPDM (Ethylene propylene diene monomer rubber)	4	-18	1	3
CSM (Chlorosulfonated polyethylene synthetic rubber) "Hypalon"	16	-20	5	12
PU (Polyurethane)	28	-22	9	17
Butyl rubber	8	-21	5	3
Natural rubber	13	-27	4	7
FKM (Fluoroelastomer) "Viton"	7	-22	0	6
Silicone rubber	3	-9	1	1

Table 2 Percentage change of various parameters after storage test of several materials in organic condensate

Aqueous condensate

Sample material	relative deviation (%) Mass	Hardness Shore A	Diameter	Thickness
NBR (Nitrile butadiene rubber) "Perbunan N"	21	-24	6	9
NBR (Nitrile butadiene rubber) "Perbunan A"	22	-29	4	6
NBR (Nitrile butadiene rubber) "Perbunan soft"	26	-30	8	13
HNBR (Hydrogenated nitrile butadiene rubber)	16	-22	5	8
EPDM (Ethylene propylene diene monomer rubber)	4	-14	1	1
CSM (Chlorosulfonated polyethylene synthetic rubber) "Hypalon"	27	-38	7	30
PU (Polyurethane)	23	-18	7	11
Butyl rubber	6	-17	2	6
Natural rubber	12	-25	10	5
FKM (Fluoroelastomer) "Viton"	34	-48	NA	35
Silicone rubber	4	-12	2	1

One set of the material samples were stored for 14 days in aqueous condensate at room temperature, another set in organic condensate at 60 °C.

Mass, hardness and dimensions of the samples at the beginning and at the end of the 14-days test were measured and compared. The results of the test can be found in the tables below.

The picture on the next side shows the sample of FKM before and after the storage test in aqueous phase. It is evident that this material is not suitable as it is chemically attacked by components present in the aqueous phase.

The samples of EPDM, butyl and silicone rubber were affected only slightly by both media. It must be said that these laboratory tests are idealized and static, i.e. there is no mechanical stress or changes in temperature and composition of the medium during storage. Nevertheless, the results obtained led to the selection of the material for the pumps. In the application case, frequent failures occurred due to chemical attack (swelling of the stator and sleeve) as well as abrasion (scoring in the stator, material partially ruptured). Often, the rotor, drive shaft, propeller shaft and seals were damaged. Whether this was caused by the swelling of the stator or happened independently of it, can´t be definitely said.

However, it is likely that, for example, a torn-out piece of the stator, which is transported through the pump, has led to damage to the shaft or mechanical seals. Since different other and a (time-consuming) inspection did not take place after each change of media, it is

Fig. 2. Sample of FKA before and after storage test.

difficult to determine how long the service life was until one of the components got damaged.

Examples of service life

With organic condensate it came to a defect after a maximum of 4600 operating hours and with a mixture of BTG pyrolysis oil and model fuel after a total of about 5150 h. At another pump of this type with profagus pyrolysis oil (about 1330 h) and then circulating with pure monoethylene glycol (about 5970 h) after a total of about 7300 h.

Although replacement parts for the pumps were procured over time for damage to be repaired quickly, the on-site repair on the tank is relatively expensive and time-consuming. The pump must be dismantled from the tank. This is critical with regard to operation with sedimenting and tough media.

Centrifugal pump

A pump from the manufacturer "Egger" was procured in early 2015 and installed in the tank farm. It is a centrifugal pump with a free-flow wheel (see blue arrow in the scheme). Characteristic for this type of pump is a large free passage. Solids up to the diameter of the discharge outlet do not cause any problems, so blockages are very unlikely. Another advantage is the wear insensitivity due to the recessed free-flow wheel. The pump was operated with all media used in the bioliq® I tank farm except the organic condensate. Operation over 3 years (more than 24,600 operating hours) has always proved to be easy.

Fig. 3. Damage to rotor in Allweiler pump after operation with organic condensate and model fuel

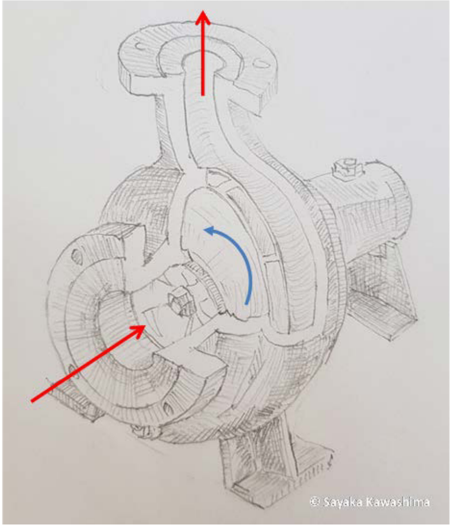

Fig. 4. Schematic sketch of a centrifugal pump before and after storage test.

In December 2017, loud noises were detected. The pump had to be repaired at the factory after damage to the drivetrain for unknown reasons. The construction of the pump makes on-site inspection or maintenance quite difficult. We as well as the manufacturer exclude any damage caused by an inserted medium.

The high reliability of the pump and its suitability for solids laden and aggressive media are a plus point. On the other hand,

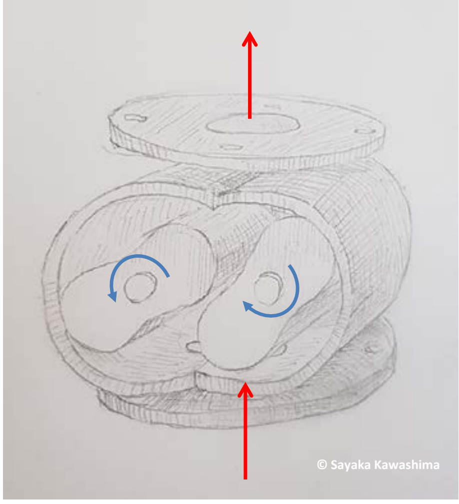

Fig. 5. Schematic sketch of a lobe pump.

however, difficult inspection or maintenance and high costs militate against procurement of this type of pump in comparison to other manufacturers.

Lobe pump

Two pumps of the type AL50 from Börger with double-winged rotary lobe were procured in 2015 and installed in the tank farm. These pumps have since then been operated with all media mentioned above. 23000 hours of operation without damage, ease of maintenance and low purchase value compared to the other pump types speak for themselves. So far, there have been very few problems with these pumps.Due to foreign objects (torn stator parts of a previously operated Allweiler pump on this tank) it came to blockage and short-term failure in one of the installed pumps. However, this was quickly remedied by opening the pump and removing the debris. Inspection, maintenance and repair are relatively easy thanks to a quick-release cover on site.

Piping or the drive train need not be removed for this.Due to the good experience with this type of pump, four more pumps have been ordered and the pumps previously used on the other 4 tanks have been replaced.At a recent on-site appointment with the sales manager of the company Börger, the perfect condition of all installed pumps was attested. Spare parts for the case of need were ordered and stored.

Conclusion

Rotary lobe pumps have proven to be the best option for the bioliq® I tank farm.
Positive aspects are:

- reliable operation
- less effort for inspection and maintenance
- low procurement costs compared to the other approved pump types

Finally, it should be mentioned that the service operations and the response times of all pump manufacturers were very good and we would like to thank them for their extremely constructive cooperation.

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Fast pyrolysis bio-oil for small scale cogeneration in micro gas turbines

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The interest in the EU on the use of bio-derived fuels for energy generation is linked by the recent European policies. The first EU Renewable Energy Directive (RED) stimulated fundamental and applied research as well industrial investigations on biofuels and bioliquids, setting the ambitious target of 20% of renewable energy sources (RES) within final energy use by 2025: the new RED II further boosted this target up to 32% by 2030. Although a wide definition of RES within RED involves many different energy sources, we now focus on one particular group, which is well defined within RED and now REDII, i.e. Bioliquids.

These are "liquid fuels for energy purposes other than for transport, including electricity, heating and cooling, produced from biomass". The difference from biofuels and bioliquids is significant, as in the first case (transport) the fuel must be upgraded to the specifications defined in the existing norms and standards for use in engines and during the entire logistic chain (i.e. transport, storage, etc), while in the second case (stationary energy generation) the technology can be adapted to meet the fuel characteristics. Bioliquids can thus be raw liquids, biocrude, intermediate energy carriers than can be employed in technologies specifically modified to adapt to the fuel properties, whereas biofuels are roughly following a drop-in approach and do not require specifically modified power generation technologies for their exploitation. A comprehensive overview on the state-of-the-art and the main barriers related to the use of bio-liquids in gas turbines are reported in a paper recently published by the authors of this article.

Authors at the RE-CORD and the University of Florence have been investigating small scale non-regenerated gas turbine operated with viscous, acidic and aqueous bioliquids - such as Fast Pyrolysis Bio Oil, FPBO – for a long time and over several research contracts. A gas turbine test rig based on a Garrett GTP 30-67 Micro Gas Turbine (MGT) was developed with several new components replacing the original ones.

The MGT combustor was redesigned, in order achieve higher temperature in the primary combustion zone. Details of the combustor re-

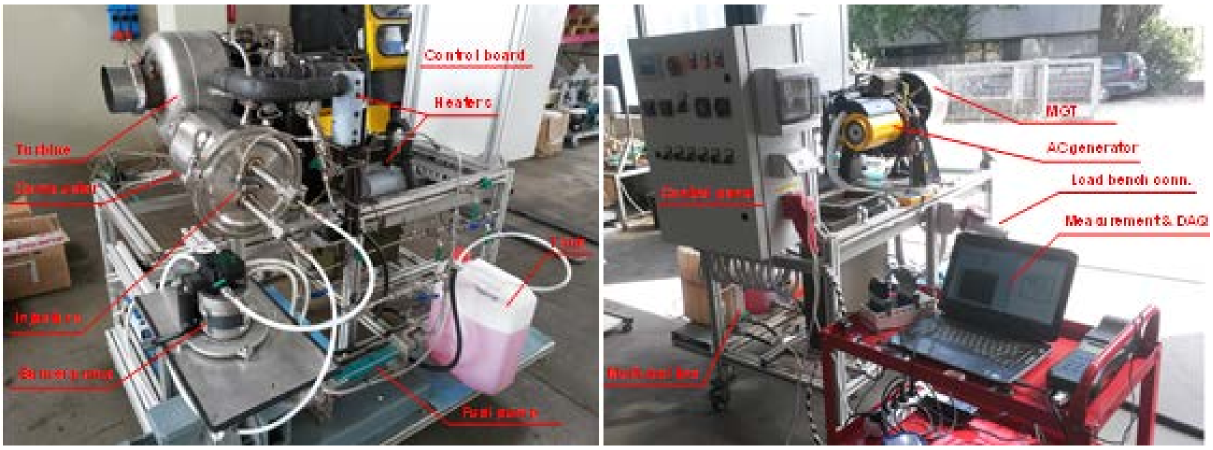

Fig. 1. Garrett-AiResearch GTP 30-67 biofuel test bench (left); MGT unit during operation (right).

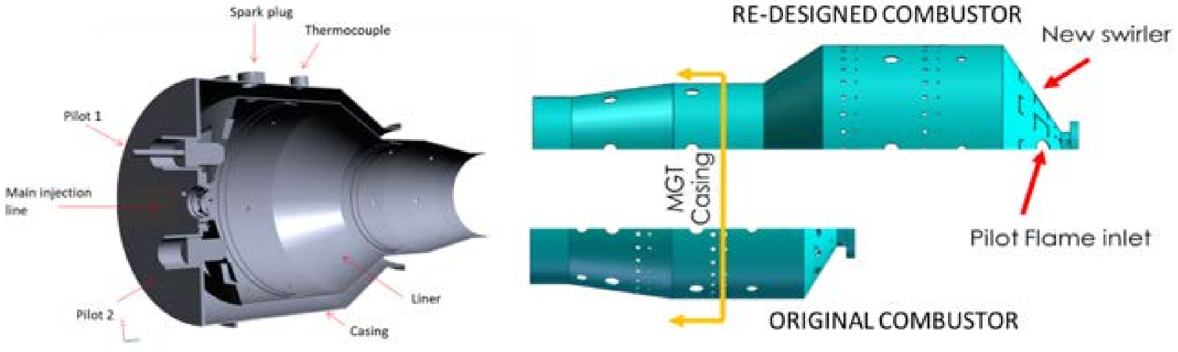

Fig. 2. 3D model of the full combustion system (left) and in detail, the silo combustors of the Garrett GTP 30-67 model (right).

design were reported in a paper recently published by the same authors. The target has been the enlarging the combustion volume to maximize droplets residence times. Thus, the re-designed MGT rig includes: a new re-designed combustor, two pilot flames for start up/shut down, a new control system, and a new injection line based on a tri-fuel system.

Beside these work, preliminary studies on the spray performance were also carried out at RE-CORD/Univ.of Florence in order to estimate the quality of the atomization. Then, test campaigns were carried out to evaluate the MGT performance and emissions with reference diesel fuel and ethanol, comparing the original and the new configuration of the combustors (at equal spray conditions).

The modified configuration of the test rig allowed stable MGT operation at different loads, with blends of pyrolysis oil/ethanol at 20/80 and 50/50 % (volume fractions). First tests with diesel oil and ethanol validated the design of the new combustor, showing lower CO emissions and slightly higher NOx emissions at full load compared to the original configuration.

The effect of the larger volume of the combustor improved the quality of the combustion while maintaining similar performances. This fact can be attributed to the longer residence time (higher combustor volume) and a better distributed air inlet along the liner. The presence of pyrolysis oil in the blends significantly impacts on CO and

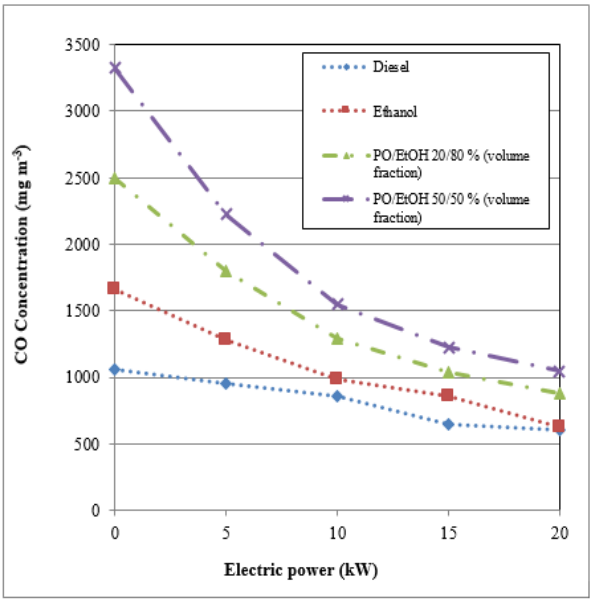

Fig. 3. CO emissions (normalized at 15% O2 in normal condition at 273.15 K) of the selected fuels (test runs nr. 3 -6) at different electrial load, new combustor.

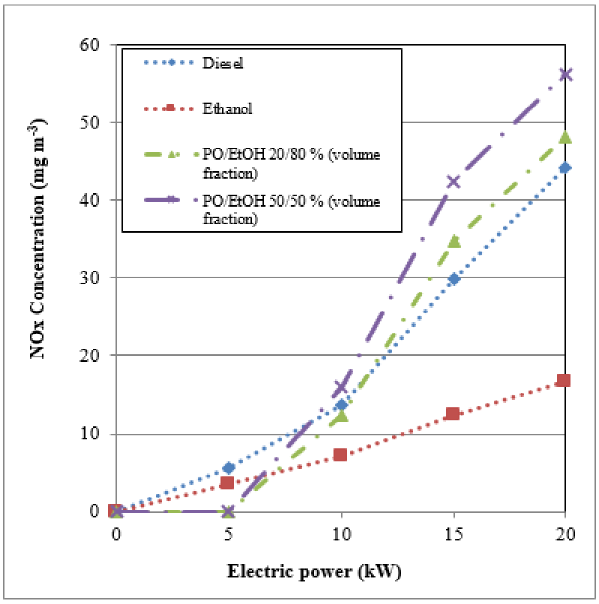

Fig. 4. NOx emissions (normalized at 15% O2 in normal condition at 273.15 K) of the selected fuels (test runs nr. 3 -6) at different electrical load, new combustor.

Fig. 5. Status of combustor after test nr.7 with 100% FPBO: a) spark plug; b) main fuel nozzle; c) external view of the liner; d) internal view of the liner.

NOX emissions compared to pure ethanol and diesel oil. By increasing the FPBO content in the blend, CO emissions also tend to increase, as larger droplets are formed by the more viscous fuel, while NOx emissions increase due to fuel-bound nitrogen. Regarding the electrical efficiency, tests with pure ethanol and PO/EtOH blends were higher than diesel. This fact was linked to the larger production of water vapor in combustion, and a well distributed air-fuel mixing in primary zone.

In order to achieve a stable combustion with pure pyrolysis oil without the support of pilot injectors, further investigation on local heat transfer on the injection nozzle are required. A possible solution could be the modification of the atomization section, as well as the increase of temperature of the primary combustion air. Test towards 100% FPBO feeding in this specific MGT unit showed unstable operation, and the analysis of carbon deposits on the hot parts of the combustor confirmed this observation. The use of 50 % (volume fraction) of fast pyrolysis bio-oil (blended with ethanol) instead allowed a stable combustion at 20 kW power output in the revised configuration of the micro gas turbine.

Such resuls confirm that the use of MGTs allows very large fuel flexibility. In ICEs the nature of high-frequency fast combustion process narrows the range of possible bioliquids and they require specifically tailored technical solutions for a specific bioliquid properties, thus fuel-flexibility is not an easy achievable target.

When FPBO is used as bioliquid in internal combustion systems as compression ignition angines or gas turbines, the degree of upgrading of the bioliquid towards the modification of the technology should always be assessed versus existing economic conditions of renewable power generation,

If the pace of the research efforts stays on a similar level as from 2009 up utill now, and the EU policy will support the continuation of this research line, significant improvements in terms of production processes, tailor-made mild upgrading, component adaptation/redesign for using highly viscous and corrosive fuels in power generation systems can be expected.

However, so far the use of biomass-based fuels in power systems does not seem the priority: nevertheless, the more the issue of grid balancing will emerge, the more the role of bioliquids in decentralised CHP unit will be of interest.

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PhD defense Dr. Douglas Elliott (PNNL, USA)

Fig. 1. Dr. Doug Elliott after the event, flanked by his wife and Dr Wang Yin, and backed by the committee, supervisors and official timekeeper.

On Friday, May 31st 2019, Doug Elliott defended his PhD thesis entitled “Catalytic Hydroprocessing of bio-oils of different types” at the University of Groningen. Needless to say, the defence was successful, and Doug Elliott was awarded the PhD degree by unanimous decision of the committee. Dougs contributions to this field are well known to most; the Linneborn prize was awarded to him last year in recognition of this. Thus, this was no ordinary PhD defence but an interesting scientific discourse with one of the main protagonists of hydrotreating of bio-oils over the last few decades. The only possible criticism was that it was too short, but the outcome, that the PhD degree was bestowed upon him, was only fitting in recognition of the contributions that Doug has brought to the field.

Fig. 2. Doug Elliott flanked by the next generation: Muhammad Salman Haider and Daniele Castello, both Aalborg University.

Leading up to the PhD defence, Professor Erik Heeres organized a very nice workshop focused on biomass liquefaction.

Lasse Rosendahl
Member of PhD committee and
Task 34 NTL Denmark

Task 34 – Orientation and Plans for 2019-2021

Task 34 aims at advancing multiple applications of liquefied biomass including heat, power, transportation fuel, and the production of chemicals. Following IEA Bioenergy objectives, there is a strong focus to promote market deployment. The scope of Task 34 was expanded during last triennium to include all direct thermochemical liquefaction (DTL) technologies for biomass conversion. We define 'Direct Thermochemical Liquefaction' to be the controlled thermal degradation of biomass in any form to derive valuable liquid energy carriers and chemical products. It includes thermal and catalytic fast pyrolysis, hydrothermal and solvothermal liquefaction. Task 34 is extending this scope to consider relevant up- and down-streaming aspects such as feedstock pre-treatment, bio-oil/biocrude upgrading and promising bio-oil applications (such as e.g. co-processing in petroleum refineries).

The technologies involved are at different levels of readiness – a fact that is reflected in the working program. In order to meet the task objectives, effort will be made to actively involve industry and decision-makers according to our understanding to follow market driven needs. Interactions with other Tasks will continue to be developed and exploited to increase the impact of IEA Bioenergy.

The objective of Task 34 is to "advance the international implementation of bioenergy technology through strategic information analysis and dissemination in the areas of direct thermochemical liquefaction of biomass (including bio-based waste) for bioenergy applications such as heat, power, transportation fuel, and the production of chemicals." Next to the challenge of developing suitable conversion technologies there is also the need to reliably characterize the product(s) for specific applications in order to achieve a large scale international implementation of biomass DTL (see Figure 1). Regarding regulations, the number of standards and guidelines for use of bio-oils and biocrudes is limited. Not having sufficient characterisation information or the relevant standards (for both analysis and use) can slow down the commercial deployment of these technologies and increase complexity and cost of transportation from producers to end users. Task 34 work packages are thus aligned along both technical and analytical challenges to support related activities.

The proposal for this triennium was developed by the preceding task and Ferran de Miguel

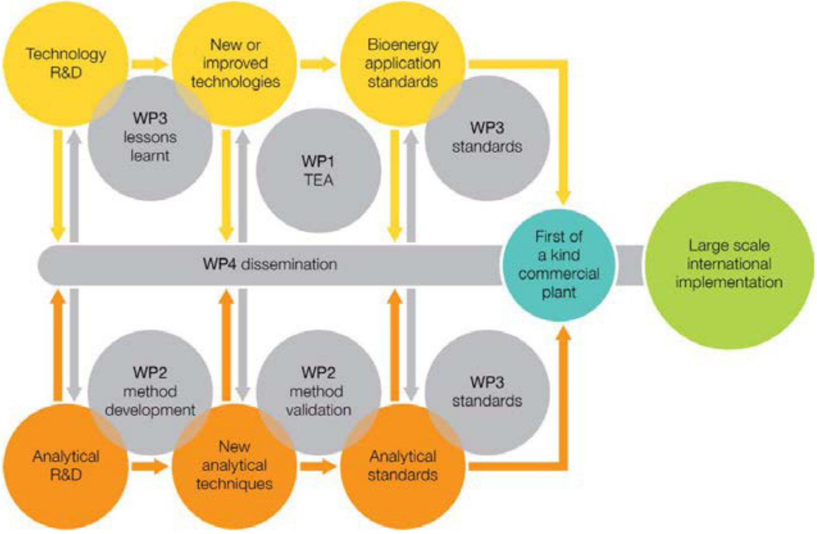


Fig. 1. Alignment of Task 34 work packages (WP) along the challenges to achieve industrial application of biomass DTL.

Mercader from New Zealand invested a great deal compiling the final proposal. I am very grateful that you have prepared such solid plans which certainly help us a lot in setting up a meaningful work this triennium!

Strategic information analysis and dissemination continues to be a strong focus of Task 34. Traditionally this includes the release of this PyNe newsletter, publication of country reports, and update of the official IEA Bioenergy Task 34 website (http://task34.ieabioenergy.com/). The latter will experience an extension in content throughout this triennium. This work is only possible due to the excellent work from past triennium in setting up a practical website frame; changes which might not always have been visible to the public.

Additional dissemination work will focus around best practice and experience from DTL R&D and commercialization activities. The idea is to collect results that are typically not suitable for publication in scientific literature but still relevant for involved stakeholders to know about. Examples could be experimental best practices, material compatibility, and equipment suitability (e.g. pumps). Success stories of commercial DTL applications will also be collected and evaluated. One specific related activity will be an inter-task project about the supply of bio-based high temperature heat to industry, led by IEA Bioenergy Task 32 on 'Biomass Combustion and Co-firing'. Surely, gathering best practices will be a 'never ending story' and thus continue in future. We will make sure that these valuable experience assets will stay available on our website.

The technical work program is designed to follow two primary aims:

1. Increasing the knowledge of analytical methods for hydrothermal liquefaction (HTL) bio-crude to approach a similar level of understanding and control as is the case for fast pyrolysis bio-oil.
2. Accompany more recent developments to extend the use of bio-oil as a feedstock for co-processing in existing refineries.

We do observe increasing activities to commercialize HTL and anticipate the need to allow HTL bio-crude to become a tradeable commodity. Task 34 has been actively supporting standardization of fast pyrolysis bio-oil in the past and will continue to do so. We seek to combine this experience with the knowledge of new HTL expert members in Task 34 to create the synergy capable of speeding up analogue achievements for HTL biocrude.

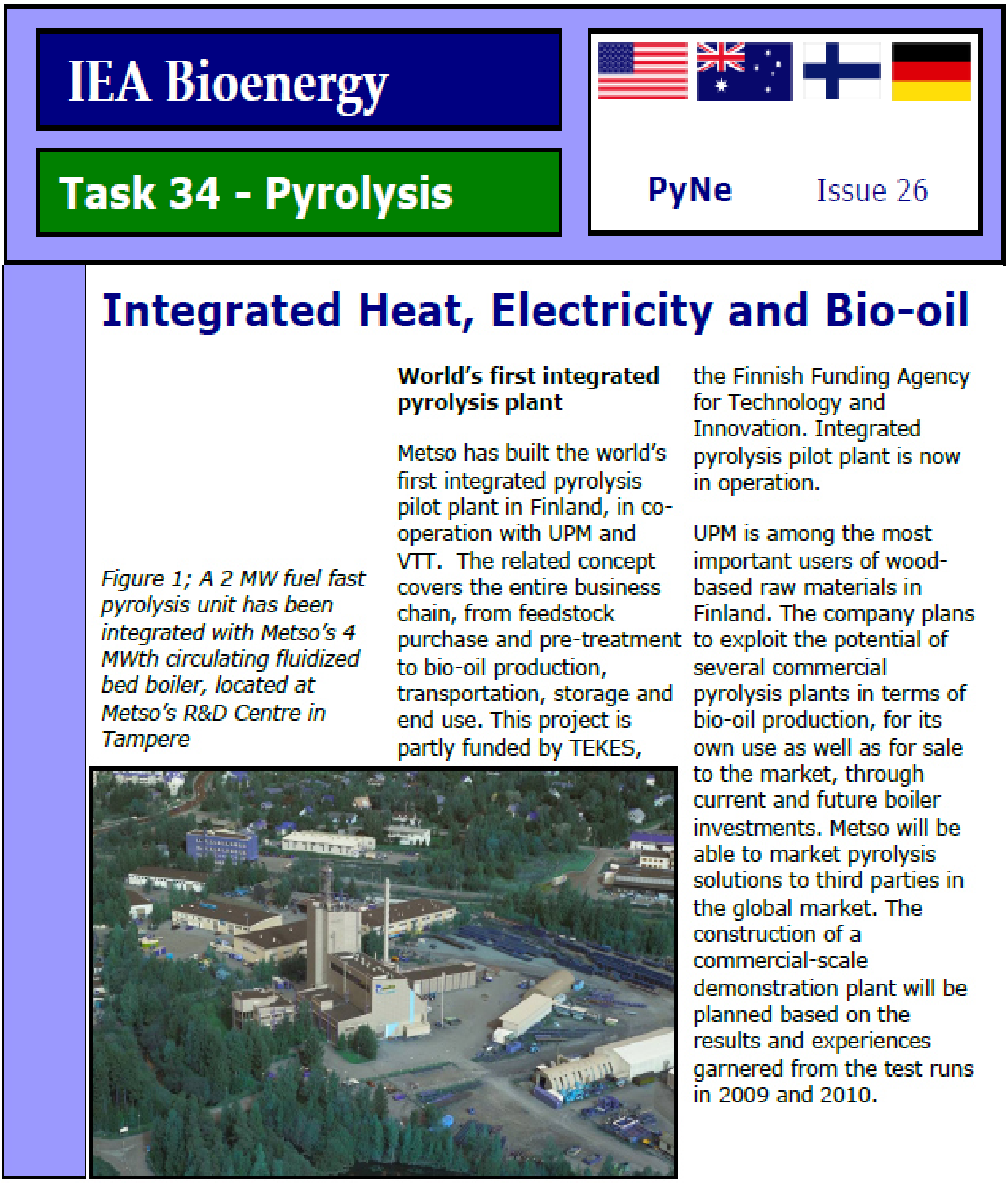
Also, there are many recent activities to realize application of (fast pyrolysis) bio-oil for co-processing in existing refineries. Some of the current Task 34 members are actively involved and will combine their experience to support implementation of fast pyrolysis bio-oil co-refining. Insights from the currently ongoing standardization process in the European Union will be evaluated to support worldwide standardization, e.g. by comparing to relevant ASTM standards. Furthermore, Task 34 and Task 39 on 'Commercialising Conventional and Advanced Transport Biofuels from Biomass and Other Renewable Feedstocks' are cooperating to further strengthen this field.

Many new participants joined Task 34 this triennium with a variety of new ideas and expectations. In our first meeting we already identified additional work packages that support above outlined strategic work. We will need to evaluate which of those we can realize with the given resources, but it is definitely worthwhile following the development and publications of Task 34 in this triennium!

Yours sincerely,
Axel Funke
Task lead and NTL Germany

What happened 10 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 ten years ago in this regular feature...:



IEA Bioenergy

Task 34 - Pyrolysis

PyNe Issue 26

Integrated Heat, Electricity and Bio-oil

World's first integrated pyrolysis plant

Metso has built the world's first integrated pyrolysis pilot plant in Finland, in co-operation with UPM and VTT. The related concept covers the entire business chain, from feedstock purchase and pre-treatment to bio-oil production, transportation, storage and end use. This project is partly funded by TEKES, the Finnish Funding Agency for Technology and Innovation. Integrated pyrolysis pilot plant is now in operation.

UPM is among the most important users of wood-based raw materials in Finland. The company plans to exploit the potential of several commercial pyrolysis plants in terms of bio-oil production, for its own use as well as for sale to the market, through current and future boiler investments. Metso will be able to market pyrolysis solutions to third parties in the global market. The construction of a commercial-scale demonstration plant will be planned based on the results and experiences garnered from the test runs in 2009 and 2010.

Figure 1; A 2 MW fuel fast pyrolysis unit has been integrated with Metso's 4 MWth circulating fluidized bed boiler, located at Metso's R&D Centre in Tampere

You can access the full article by using the following link:
http://task34.ieabioenergy.com/publications/issue-26-task-34-newsletter/

Upcoming Events

13th World Congress on

Biofuels and Bioenergy

August 26-27, 2019 Mercure Hotel Wien Westbahnhof, Vienna, Austria

Theme: Sustainable Development of Biofuels towards Green Growth

26th Aug, 2019 - 27th Aug, 2019, Vienna, Austria

https://biofuels-bioenergy.expertconferences.org

tcbiomassplus 2019

7th Oct, 2019 - 9th Oct, 2019, Rosemont, IL, USA

https://www.gti.energy/training-events/tcbiomass/registration/

international Biogas CONGRESS & EXPO
innovations in biogas

3 conferences to choose from

international Biomass CONGRESS & EXPO
Bringing biomass markets closer

22nd Oct, 2019 - 23rd Oct, 2019, Brussels, Belgium

https://www.biofuels-news.com/conference/biofuels/biofuels_index_2019.php#about

European Biomass to Power 2019

6-7 November 2019 | Helsinki, Finland

6th Nov, 2019 - 7th Nov, 2019, Helsinki, Finland

https://www.wplgroup.com/aci/event/european-biomass-to-power/

Expert workshop: **Potential of Hydrothermal Liquefaction (HTL) routes for biofuel production**

19th November, 2019, Brussels

http://task34.ieabioenergy.com/wp-content/uploads/2019/05/Joint-HTL-workshop-Flyer-002.pdf

Techno-Economic Workshop

In association with BRISK2

and EERA Bioenergy

ADVANCED BIOFUEL PRODUCTION WITH ENERGY SYSTEM INTEGRATION

✓ **Check if your idea for a new product or process has an economic future.**

Tuesday September 17th 2019, 9am-4pm

With Tony Bridgwater of EBRI, Aston University,
Bernd Wittgens of SINTEF and Nicolaus Dahmen of KIT.

REGISTER via ambition@aston.ac.uk

See next page for the workshop agenda

FIND OUT MORE AT www.ambition-research.eu

Ideal for: Early Career Scientists · Biofuels R&D Innovators

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And you?

How To Become a Member
Contact your national representative in the IEA Bioenergy ExCo to assess the benefits of joining Task 34.
https://www.ieabioenergy.com/directory/executive-committee

For more information

IEA Bioenergy Task 34 Website

www.task34.ieabioenergy.com

IEA Bioenergy

www.ieabioenergy.com

Past Issues of the Task 34 Newsletters

www.task34.ieabioenergy.com/iea-publications

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