BL2F Concept / IHTL

BL2F Summer School
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BL2F
Transforming Black Liquor to Biofuel

This project has received funding from the European Union Grant Number 884111

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- About BL2F project
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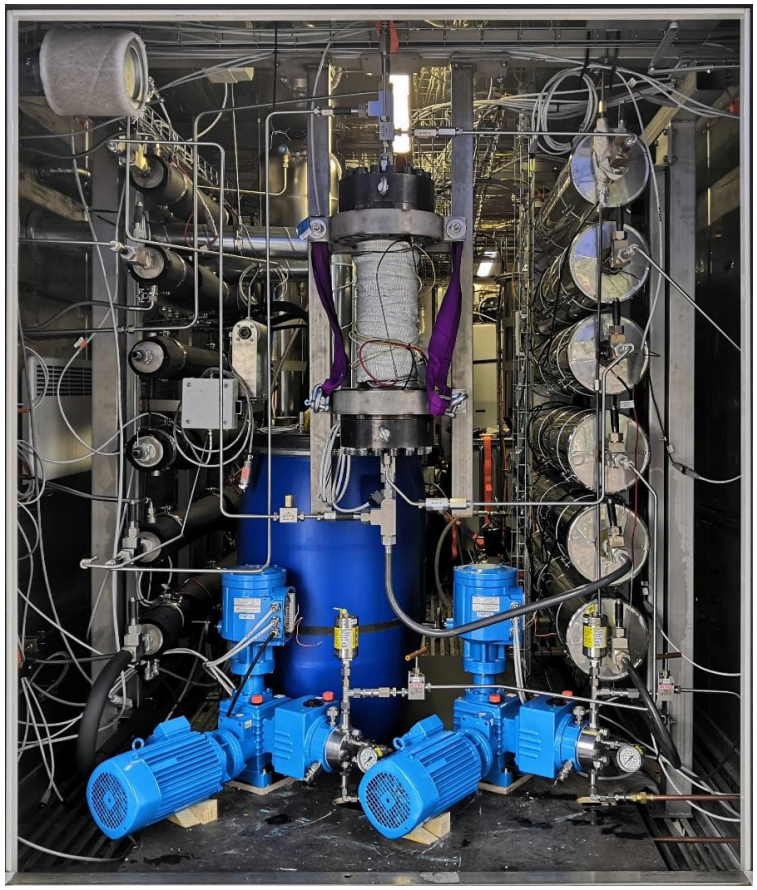

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High temperature liquefaction (HTL) processing

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- One method of liquefaction of a raw material into an oil-type product

- Operating near critical conditions or under supercritical conditions

- Four applications can be referred to: Hydrothermal Liquefaction (HTL), Supercritical water liquefaction (SCWL), Hydrothermal Gasification (HTG) or Hydrothermal Carbonization (HTC).

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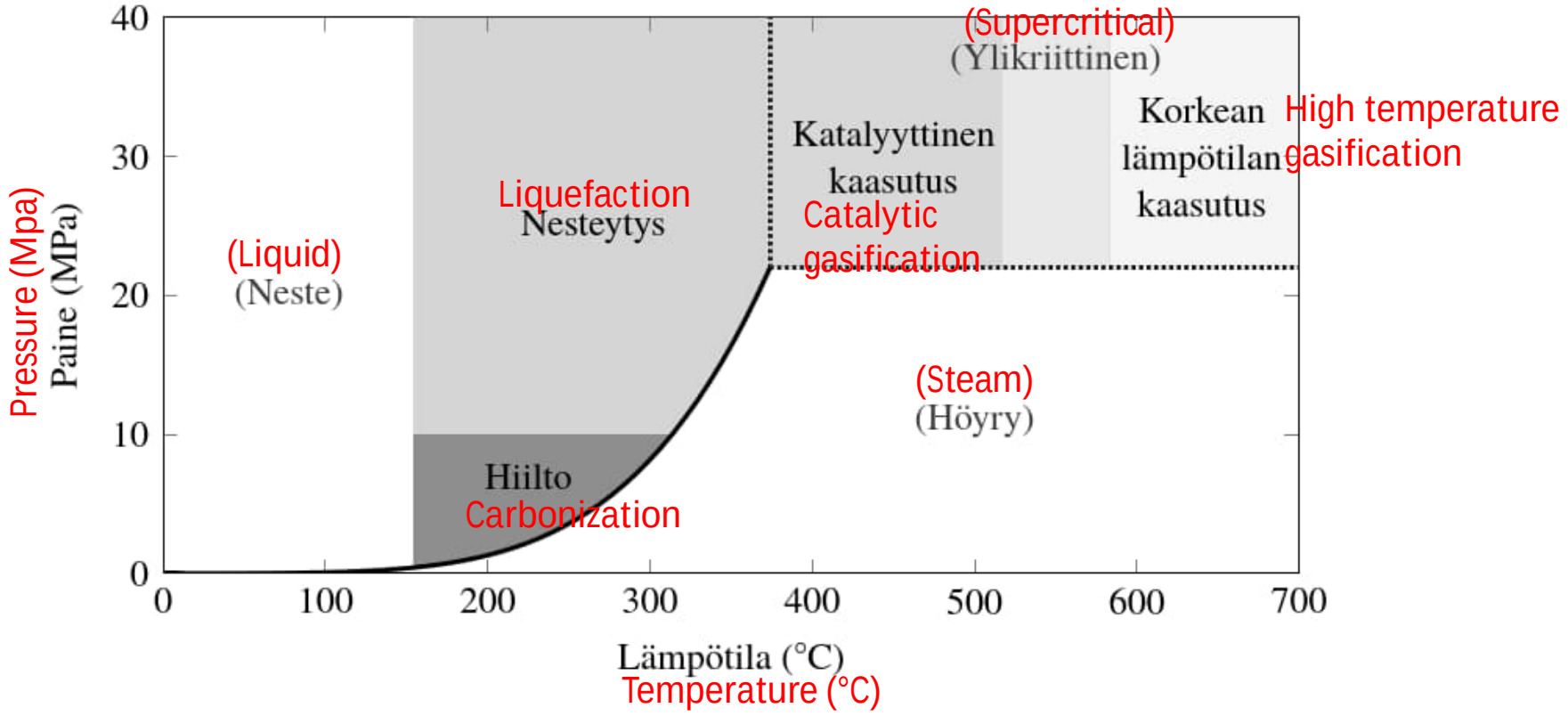
Operating zones based on water phase diagram



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HTL processing

- The main product is biocrude oil, which is a product similar to fossil crude oil.
- Higher oxygen content (20%, crude oil 1%) → upgrading is required
- May operate between 280 – 450 °C, 100 – 350 bar
  - (BL2F: 400 °C, 300 bar)
- Catalysts and additional inputs can be added, such as H_2, CO, organic hydrocarbons
- The calorific value of the product is usually 30 – 36 MJ/kg and residual oxygen 10 – 20% (feed biomass: 10 – 20 MJ/kg and oxygen 30 – 50%)

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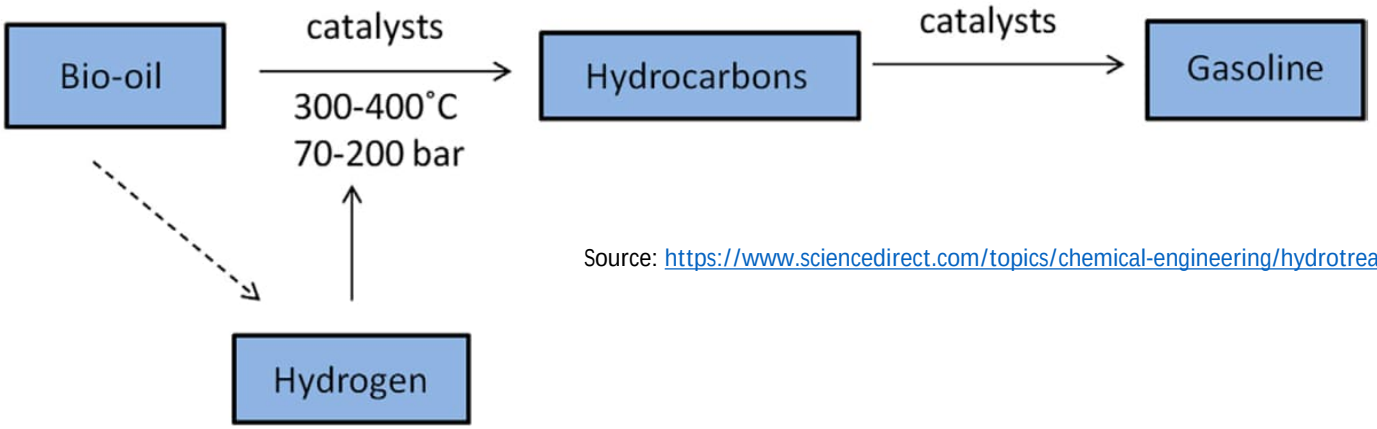
Biocrude oil upgrading using H_2 treatment (HDO)

Example reaction: $CH_{1.4}O_{0.4} + 0.7H_2 \rightarrow 1''CH_2'' + 0.4H_2O,$



Source: https://www.sciencedirect.com/topics/chemical-engineering/hydrotreating

Goal: removal of oxygen → improved calorific value, equivalent to fossil crude oil (Abbreviation HDO = hydrodeoxynation)
- High pressure & catalyst improves the process

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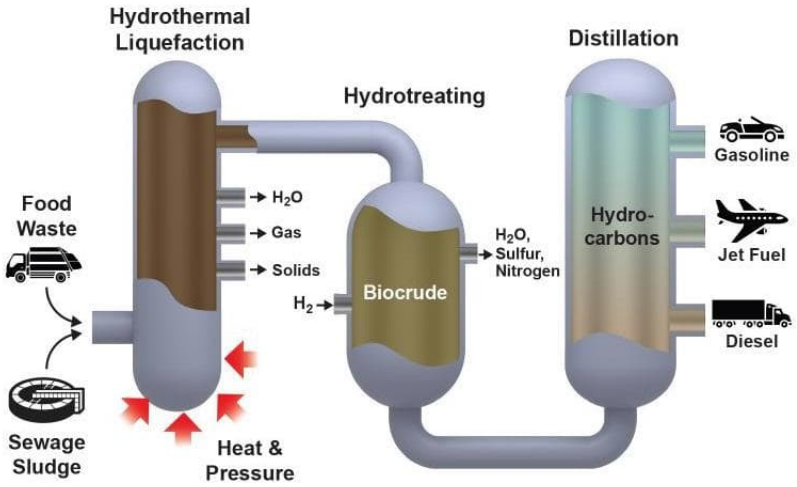
Hydrothermal liquefaction



Challenges:

- Its disadvantages include the use of high temperatures and pressure which requires an expensive equipment
- Intrinsic challenges in treating different feedstock
- A flexible reactor and process design which can handle different feedstocks and their coliquefaction

Benefits:

- High quality and high yield of biocrude
- Wet and different feedstocks can be used.
- Resource intensive drying of wet biomass is not required

Different feedstocks/ projects undergoing at Tampere University:

1. Biomass
2. Municipal solid waste
3. Textile waste
4. Plastic waste

Project: ILPO, Financed by: EU/EAKR/6Aika

5. Black Liquor ➡ Project: BL2F, Financed by: EU H2020

Projects related with HTL technology in the European Union

BL2F
Transforming Black Liquor to Biofuel

HyFlexFuel

WASTE2ROAD

4refinery

NEXTGEN roadfuels

BIO4 FUELS

Heat to Fuel

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The BL2F Project

Black Liquor to Fuel (BL2F) is a H2020 project that will transform Black Liquor into a new, clean biofuel for aviation and shipping

12 partners

8 countries

42 months

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Project Goals

Create a high-quality drop-in biofuel

Decrease carbon emissions from aviation and shipping

Decrease the use of fossil fuels

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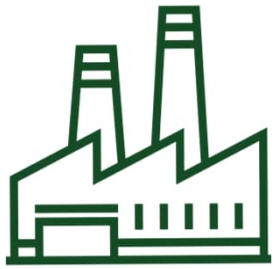
The BL2F Process



Pulp Mill

Oil Refinery

Distribution

Black Liquor

Fuel Intermediate

Water and gases

Refining step to create a drop-in biofuel

Fuel used in jet & marine engines

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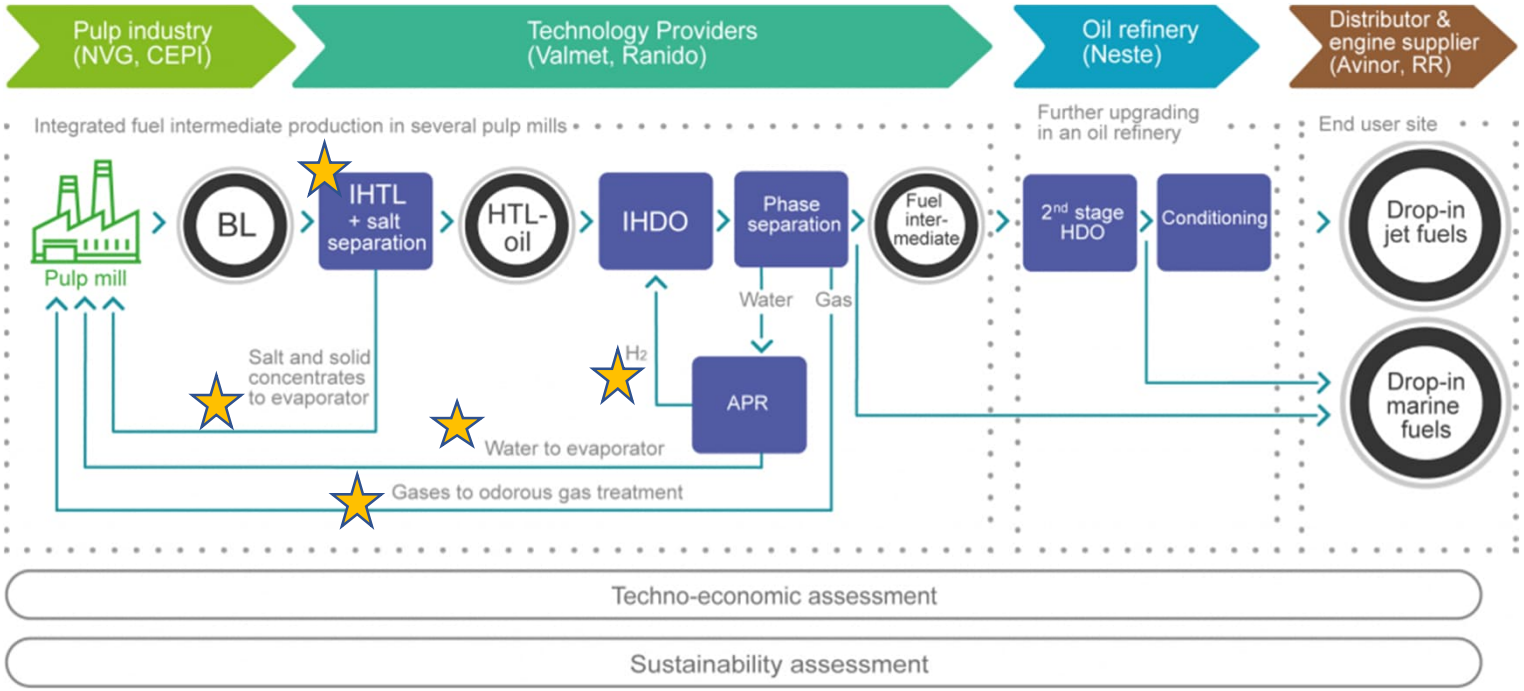
The BL2F value-chain



1. Salt separation
2. Solids/salt handling
3. Water handling
4. Gas handling
5. Hydrogen production

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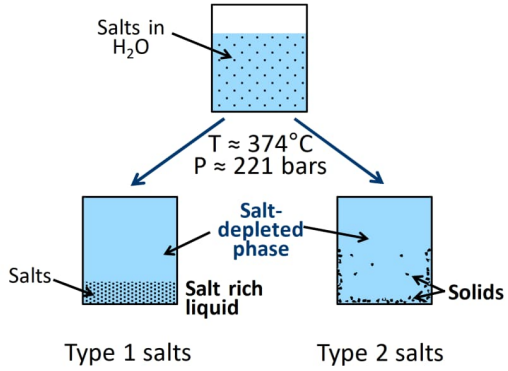
Salt separation Integrated-HTL

- Salts have limited solubility in supercritical water
- Salts 1 and 2 behave differently
- Black liquor contains both types



Ions	HO^-	Cl^-	CO_3^{2-}	SO_4^{2-}
Mg^{2+}	2	1	2	2
Ca^{2+}	2	1	2	2
Na^+	1	1	2	2
K^+	1	1	1	2

Lappalainen, Jukka, David Baudouin, Ursel Hornung, Julia Schuler, Kristian Melin, Saša Bjelić, Frédéric Vogel, Jukka Konttinen, and Tero Joronen. "Sub-and Supercritical Water Liquefaction of Kraft Lignin and Black Liquor Derived Lignin." *Energies* 13, no. 13 (2020): 3309

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Reactor Design at Tampere University

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- Objective:
- Effective HTL reaction
- Simultaneous removal of salts
- Requirement:
- Uniform temperature distribution
- Sufficient residence time

Design challenges:

- Wall heat transfer not effective because of thickness of the reactor walls
- Plugging of reactor due to crystallization of Type-2 salts
- Products extraction

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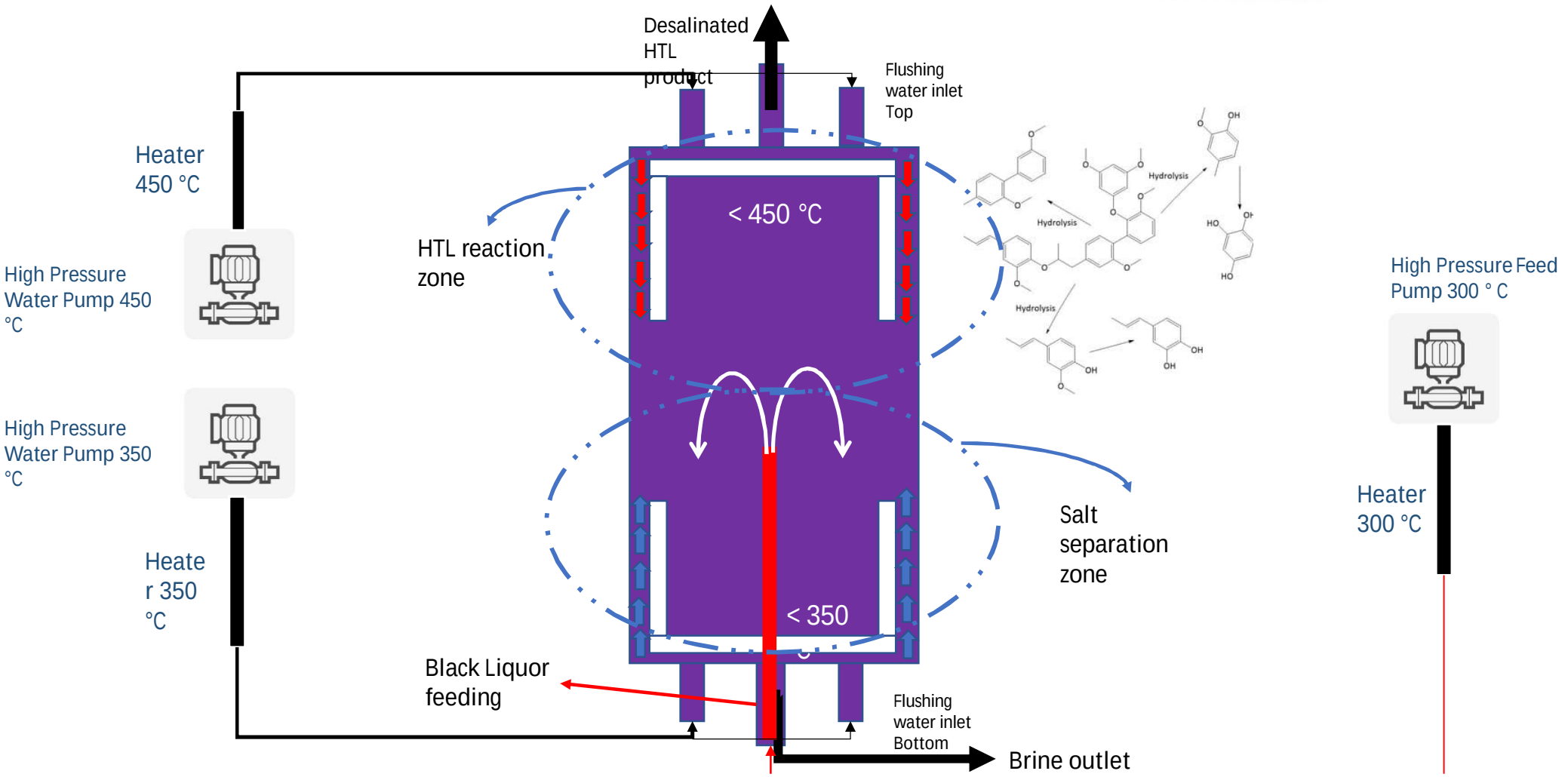

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Continuous HTL facility developed at Tampere University

Continuous Reactor Facility - EHTA

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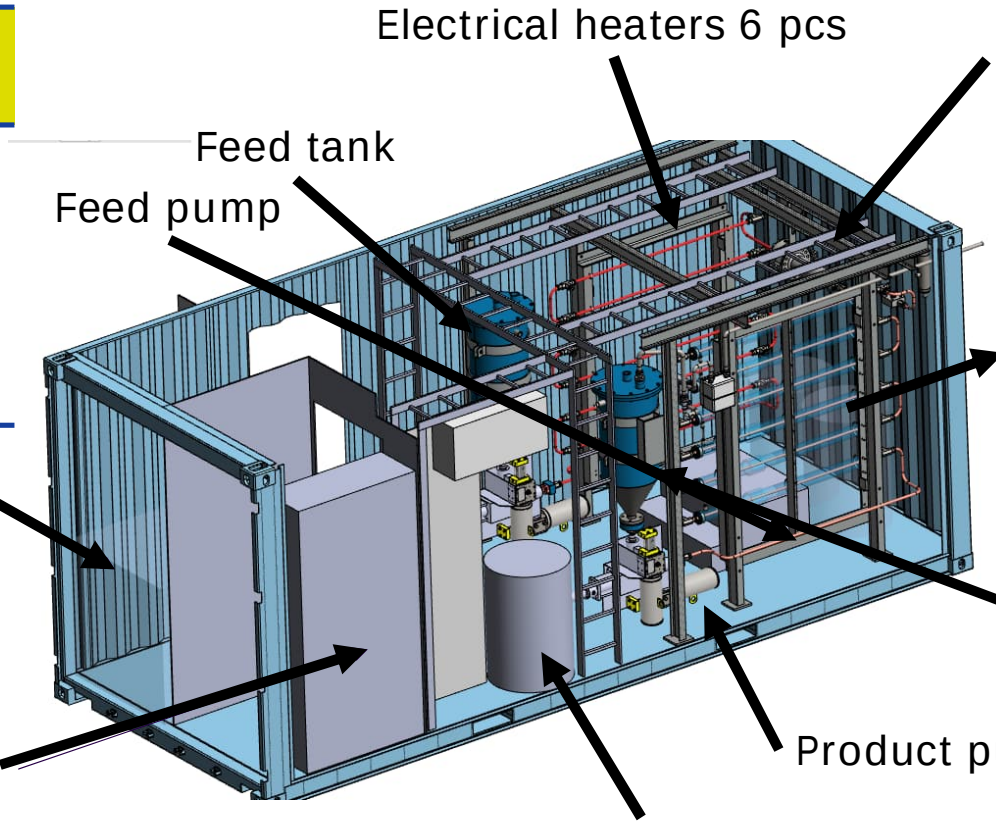
Process conditions	Maximum value
Temperature	400 °C
Pressure	300 bar
Feeding rate	13.2 l/h



BL2F Reactor

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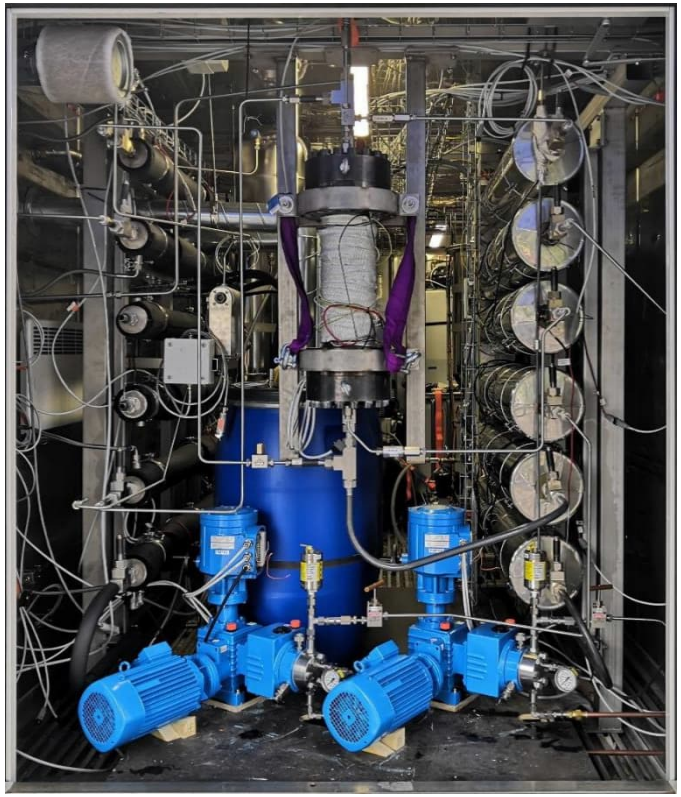

First result from our Continuous experiments

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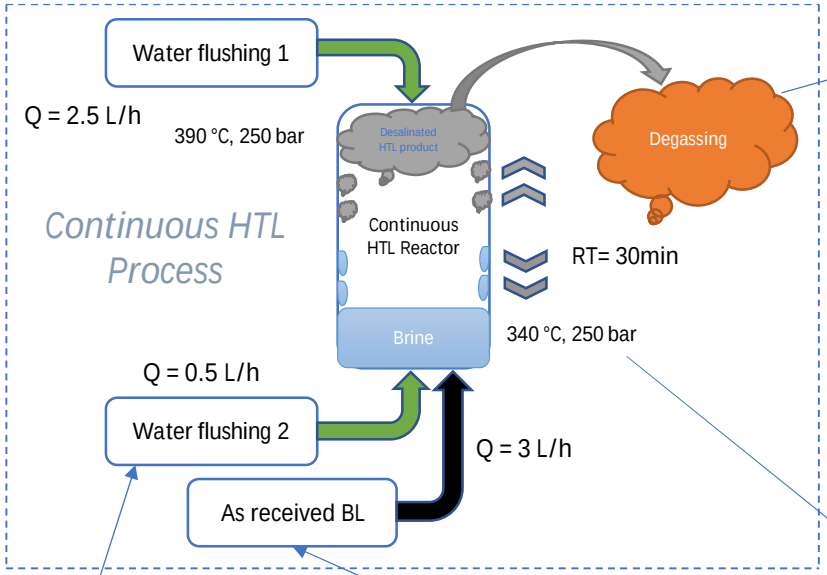


Coolers for Top product

Q = 1.8 L/h

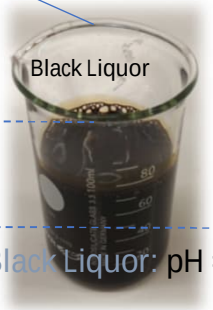
Top Product

Due to the gravity forces Most of the produced Hydrochar is transferred to the bottom product (Brine).

Deionized Water :

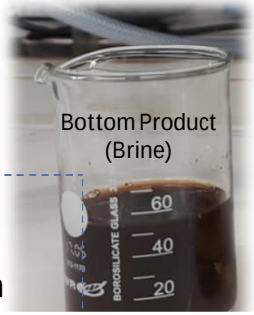
pH = 6,52 ;

Conductivity = 5,35 uS/cm



Black Liquor: pH = 13,4 ;

Conductivity = 68,9 mS/cm



Coolers for Bottom product (Brine) Q = 4 L/h

pH and Conductivity of Brine & HTL Top Product

HTL Product: pH = 8,89 ; Conductivity = 15,17 mS/cm

Brine: pH = 9,37 ; Conductivity = 41,8 mS/cm

Elemental Analysis (Biocrude)

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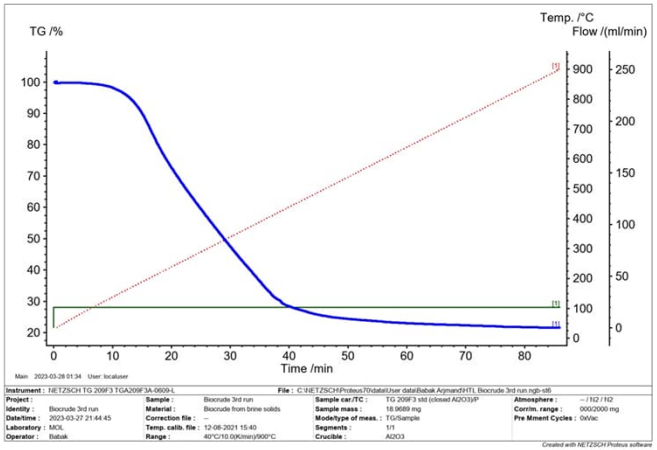
C	H	N	S	O	Ash
79.337	7.29	0.025	2.214	10.76	0.37

The disappearance of alcohol and ether moieties was in accordance with low oxygen content obtained from elemental analysis.

Thermogravimethric Analysis (Biocrude)



Moisture	VM	FC	Ash
2,7	77.3	19.63	0.37

Financial estimate of PM integration

Integration to a pulp mill

- Abundant and Pumpable feedstock
- Homogenous quality
- Thermal integration (steam system of recovery boiler)
- Evaporator for preheating/ concentration
- Solids, water and gas handling
- Existing operation and maintenance personnel

Biomass conversion technology		IHTL	HTL
Technology development level		R&D	
Plant size	1000t/a	150	180
O&M	M€/1000t	0.40	0.22
Investment	M€/1000t	0.73	2.00
Total	M€/1000t	1.23	2.22

45 % saving

Other references

- Ong et al. Co-liquefaction of BL and Radiate Pine
  Cost of ~ 0.7 €/L
- Funkerbusch et al. at large Kraft pulp, excess lignin feedstock
  - Cost of ~ 0.4 €/L

Lappalainen, Jukka, David Baudouin, Ursel Hornung, Julia Schuler, Kristian Melin, Saša Bjelić, Frédéric Vogel, Jukka Konttinen, and Tero Joronen. "Sub-and Supercritical Water Liquefaction of Kraft Lignin and Black Liquor Derived Lignin." *Energies* 13, no. 13 (2020): 3309

Ong, Benjamin HY, et al. "A Kraft Mill-Integrated Hydrothermal Liquefaction Process for Liquid Fuel Co-Production." *Processes* 8.10 (2020): 1216

Funkenbusch, LiLu T., Michael E. Mullins, Lennart Vamling, Tallal Belkhieri, Nattapol Srettiwat, Olumide Winjobi, David R. Shonnard, and Tony N. Rogers. "Technoeconomic assessment of hydrothermal liquefaction oil from lignin with catalytic upgrading for renewable fuel and chemical production." *Wiley Interdisciplinary Reviews: Energy and Environment* 8, no. 1 (2019): e319

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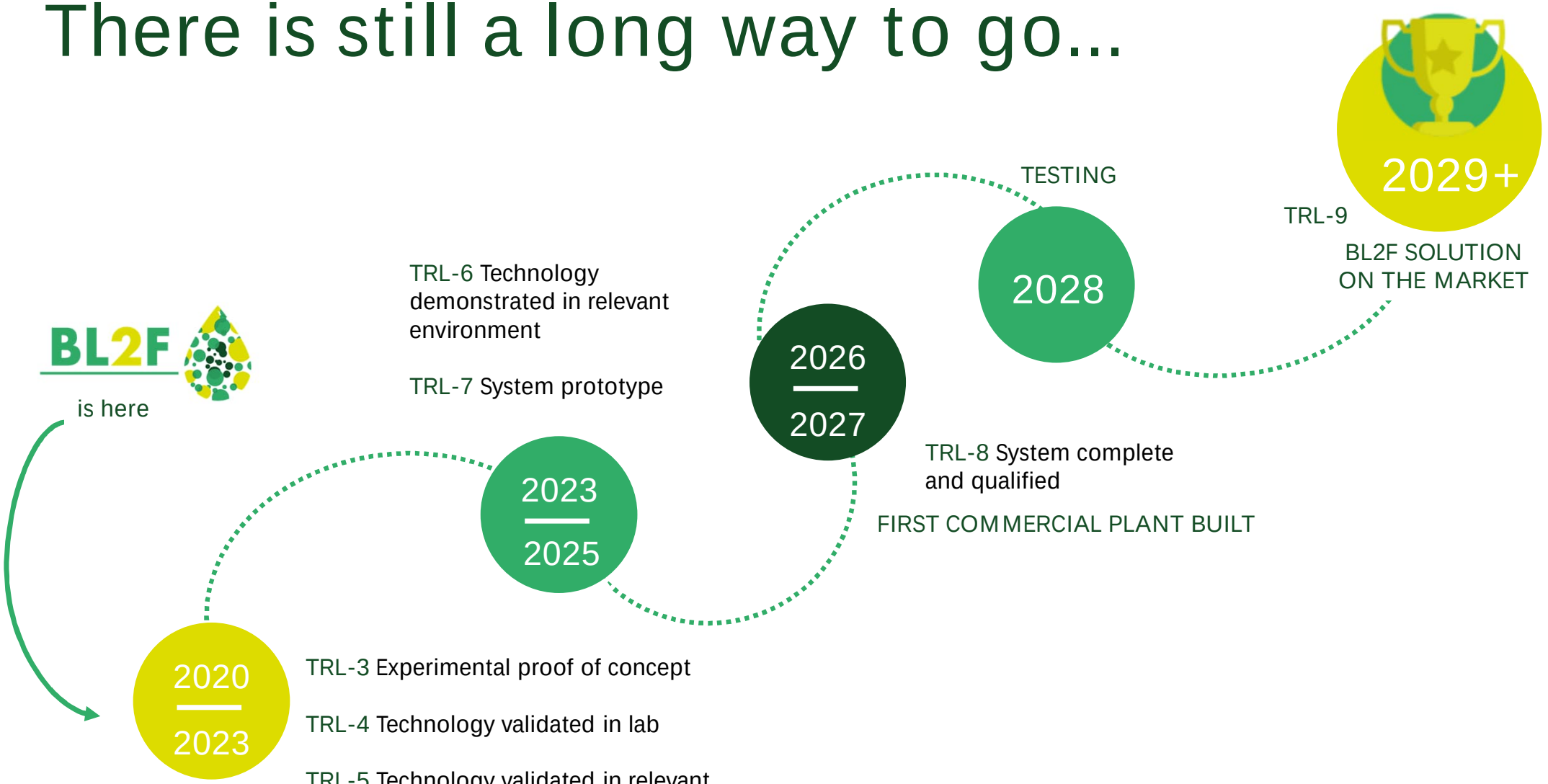
There is still a long way to go...



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Conclusion

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- HTL: liquefaction of carbon and hydrogen containing feedstocks
  - Advantage: very moist and low-grade feedstocks can be used
- BL2F project: Basics of design for larger-scale HTL demontration process
  - Black liquor as fuel, integration with chemical pulp mill
  - Biocrude oil to drop-in fuels (shipping, aviation)
  - Pilot plant testing (EHTA plant) at Tampere Unversity campus
- Pilot testing:
  - Mechanical challenges have caused schedule delays
  - First biocrure oil samples generated for further testing and processing
- Future: Long way to go to commercial (Aimed market-readiness 2029)

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BL2F Partners:

Tampere University

Brunel University London

KIT Karlsruhe Institute of Technology

SINTEF

PAUL SCHERRER INSTITUT PSI

VTT

THE NAVIGATOR COMPANY

Valmet

NESTE

Ranido

LGi sustainable innovation

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Thank you!

Get in touch with the project:

- Coordinator: Prof. Dr. Tero Joronen, Tampere University
- Website: www.bl2f.eu

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