Effektiv cirkulær økonomi med HTL som omdrejningspunkt

LASSE ROSENDAHL
AALBORG UNIVERSITY
DENMARK

EUBIA

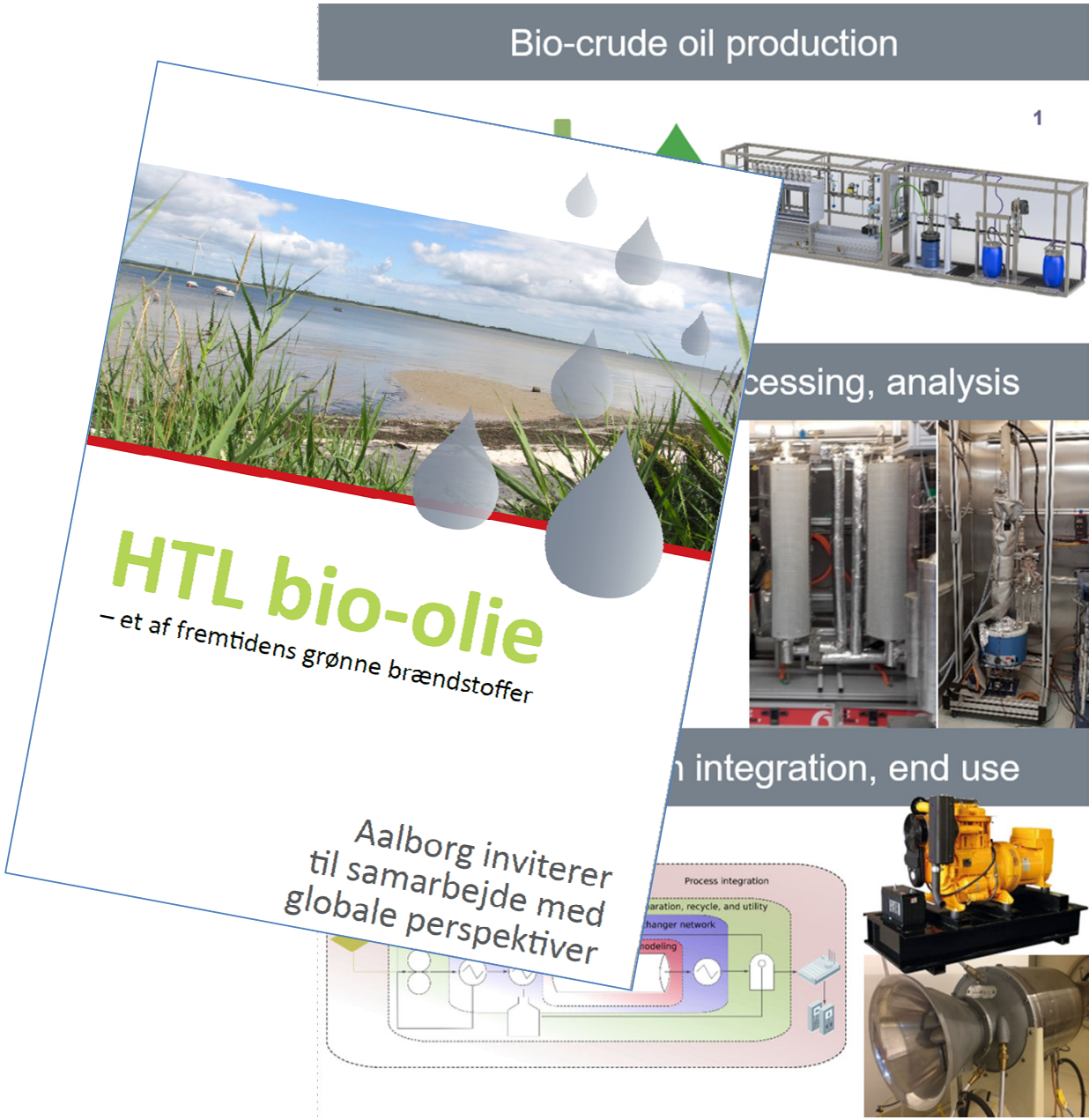
IEA Bioenergy
Task 34

AALBORG UNIVERSITY
DENMARK

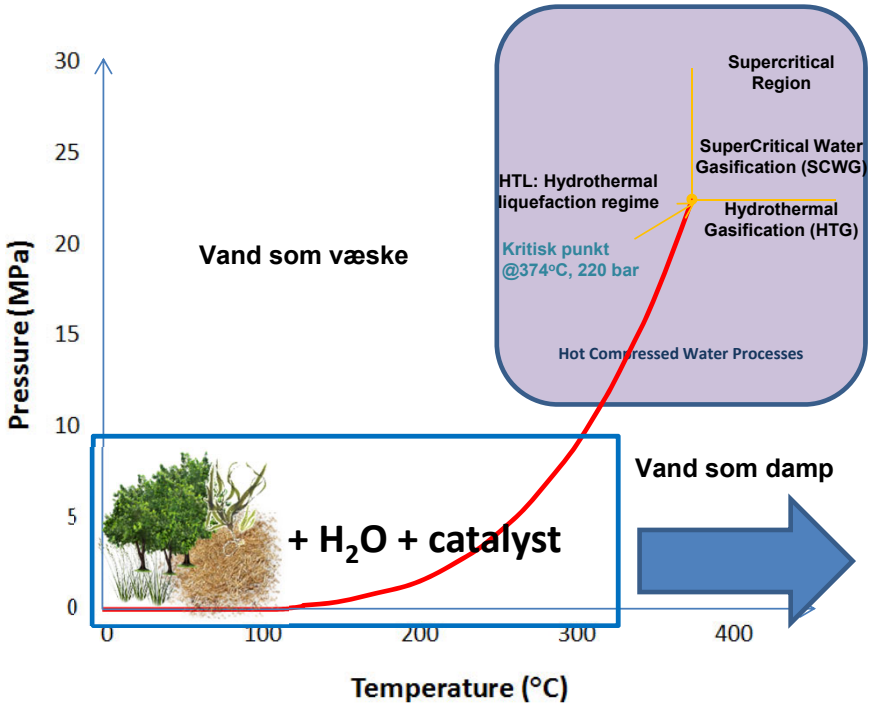
EERA
European Energy Research Alliance
BIOENERGY

Program

- HTL – en kort indføring
- Implementering og bæredygtighed
- Ud af laboratoriet – implementering og demonstration
  - NextGenRoadFuels og andre projekter
  - Aalborg projektet
- Afrunding

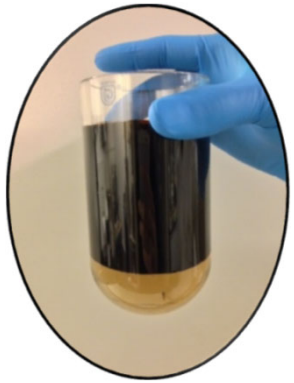


HTL – HydroThermal Liquefaction

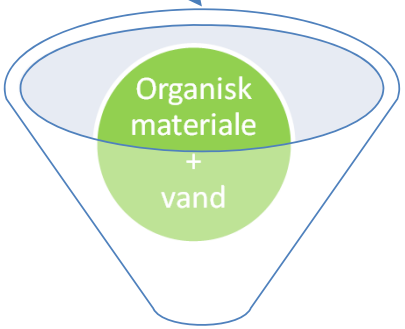


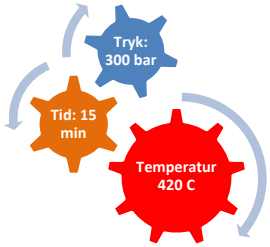
Forhold sammenlignelige med de som fossil råolie og kul er dannet ved: tryk omkring 2-300 bar, temperaturer omkring 250-450 grader

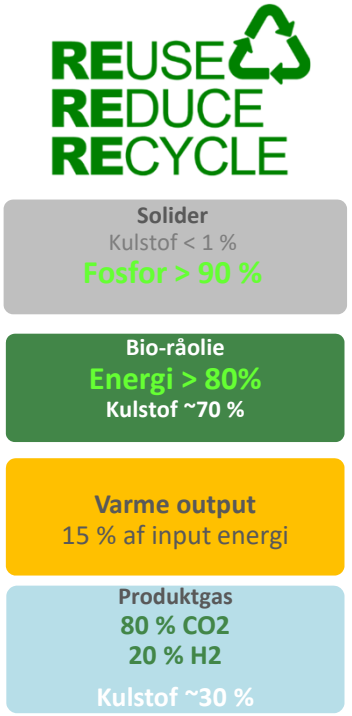
Bortset fra tiden: 100 mio. år vs 15 minutter!

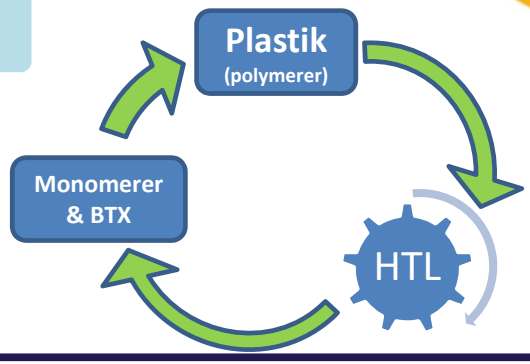


HTL – cirkulær *key enabling technology*



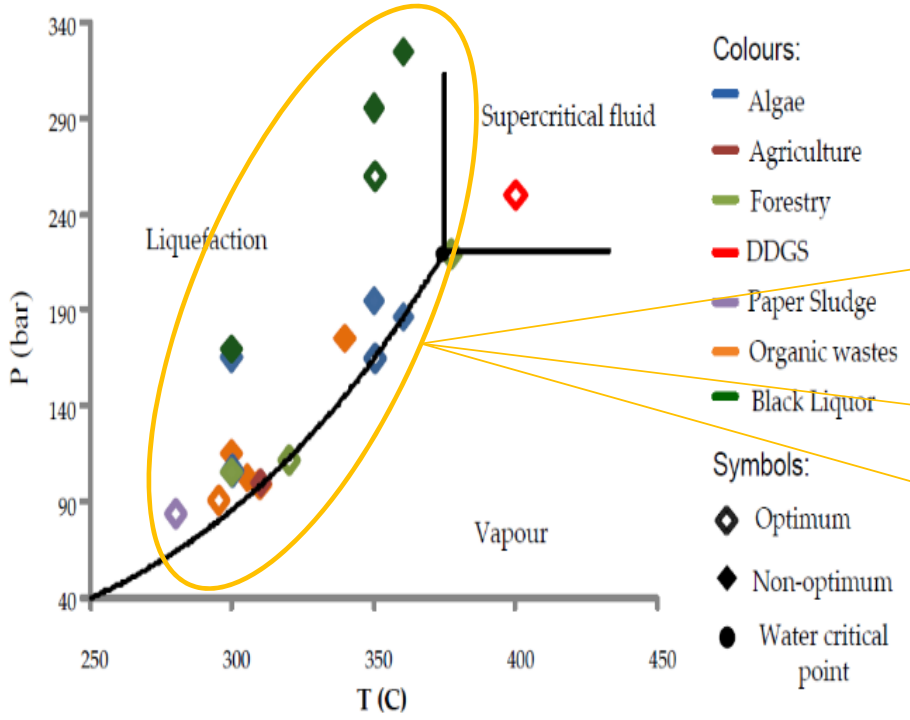






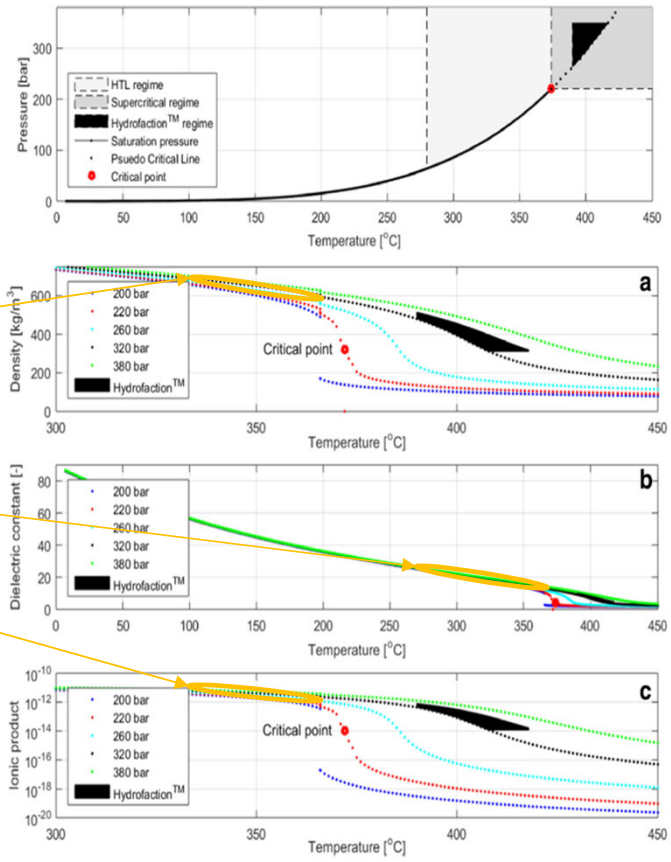
Superkritisk HTL – giver nogle ekstra håndtag

Subcritical HTL: **only** T
Supercritical HTL: **both** T and p



Colours:
- Algae
- Agriculture
- Forestry
- DDGS
- Paper Sludge
- Organic wastes
- Black Liquor

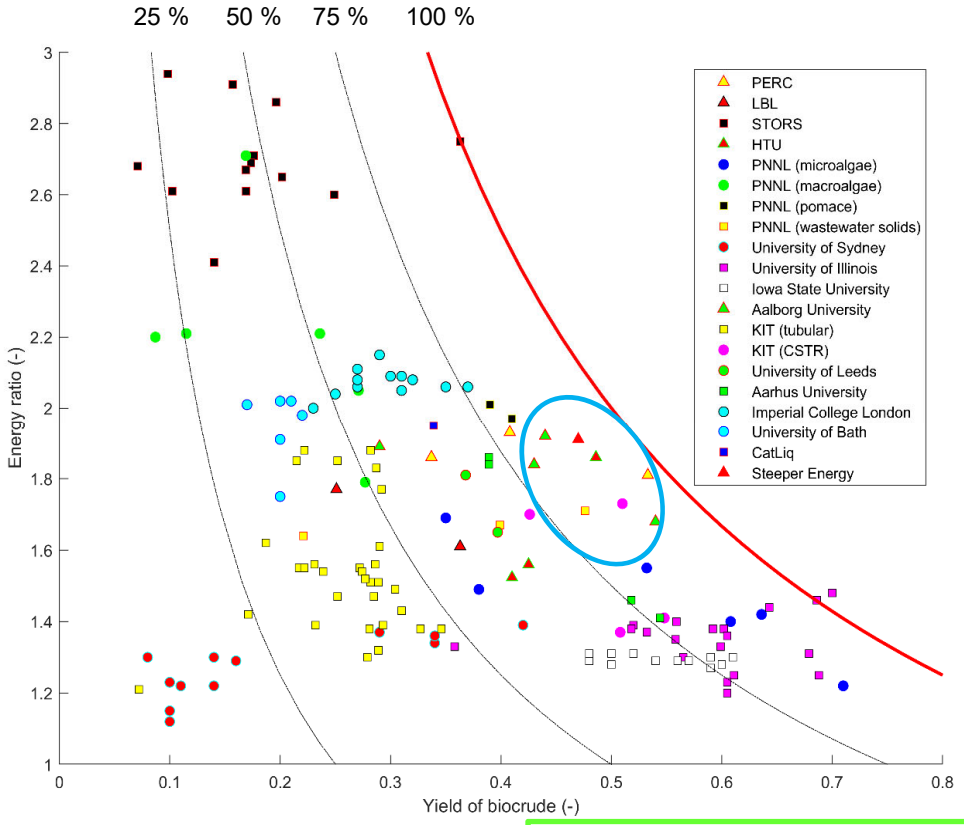
Symbols:
- Optimum
- Non-optimum
- Water critical point

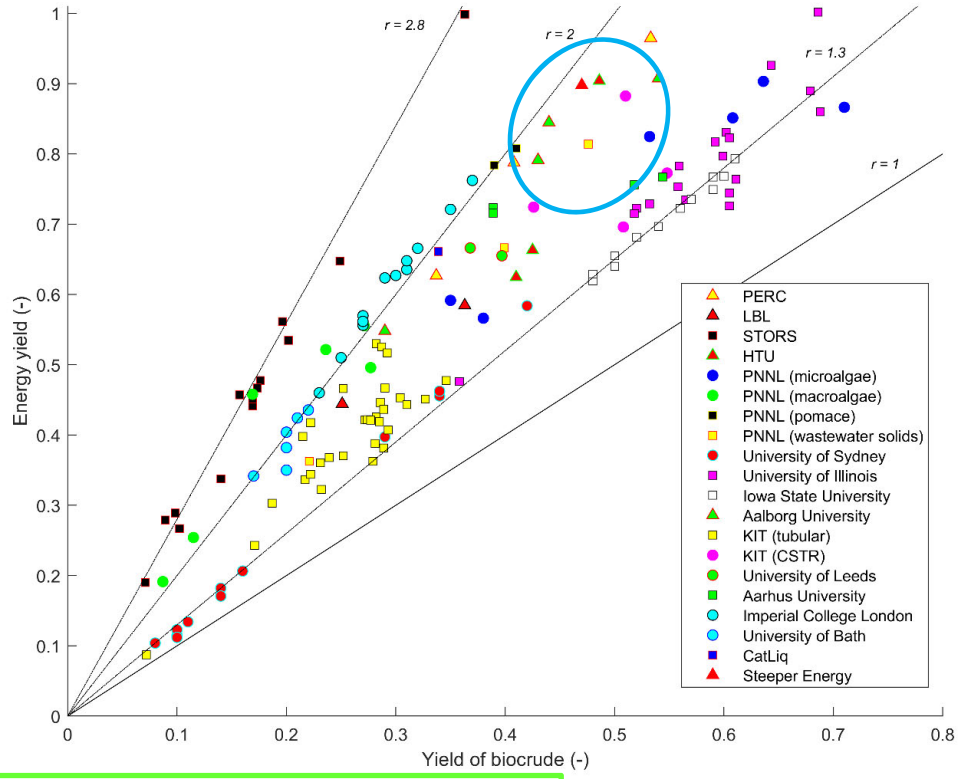


Supercritical HTL

Jensen, CU, Guerrero, JKR, Karatzos, S, Olofsson, G, Iversen, SB 2017. 'Fundamentals of Hydrofaction™: Renewable crude oil from woody biomass.' Biomass Conv.Bioref. 7:495-509, DOI 10.1007/s13399-017-0248-8

Effectiveness evaluation of HTL

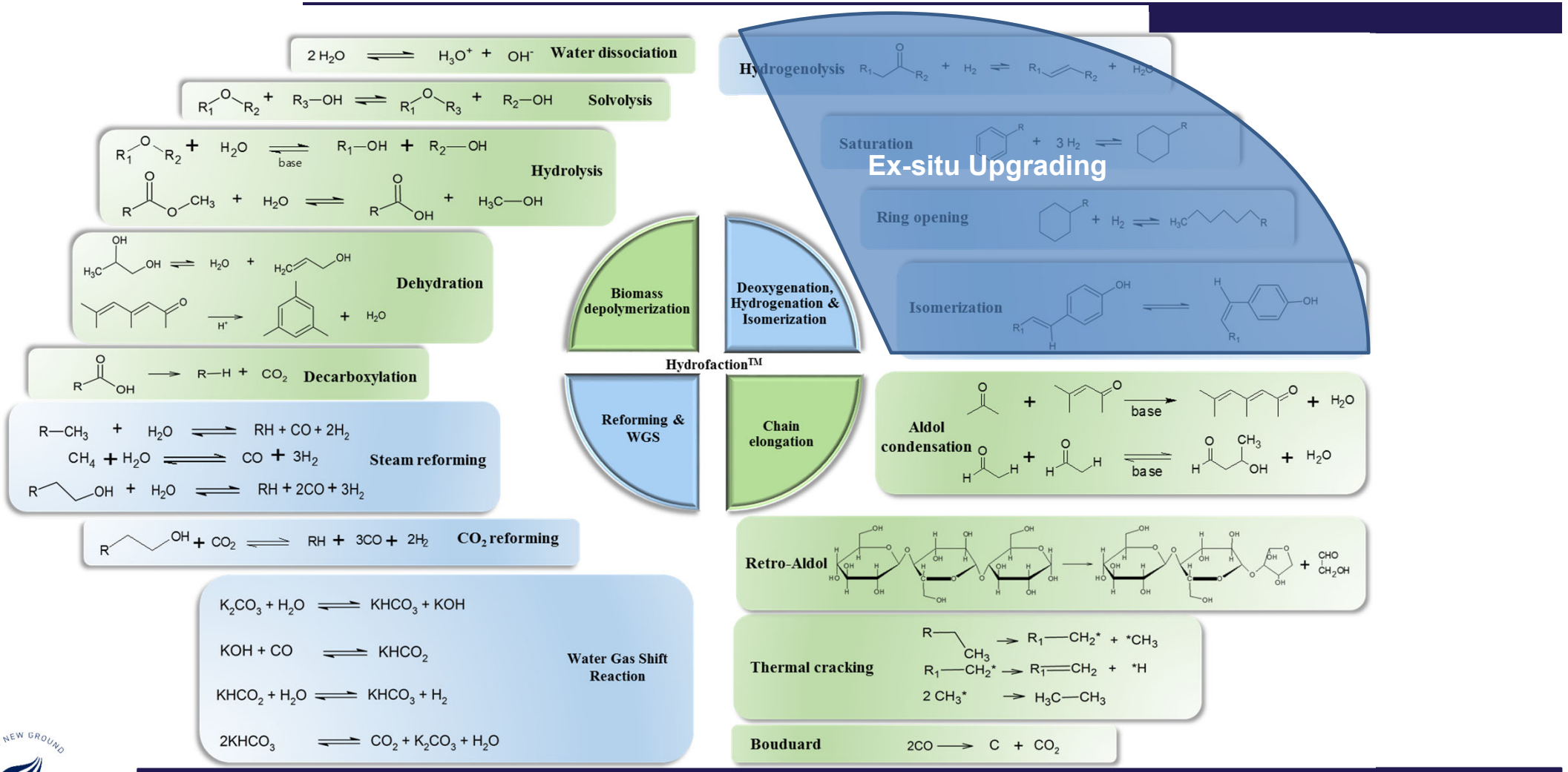




For all types of feedstocks HTL is an efficient upcycler!
Supercritical HTL superior in energy yield

Castello, Pedersen, Rosendahl (2018). Energies MDPI. https://doi.org/10.3390/en11113165

(Supercritical) HTL chemistry for organic materials



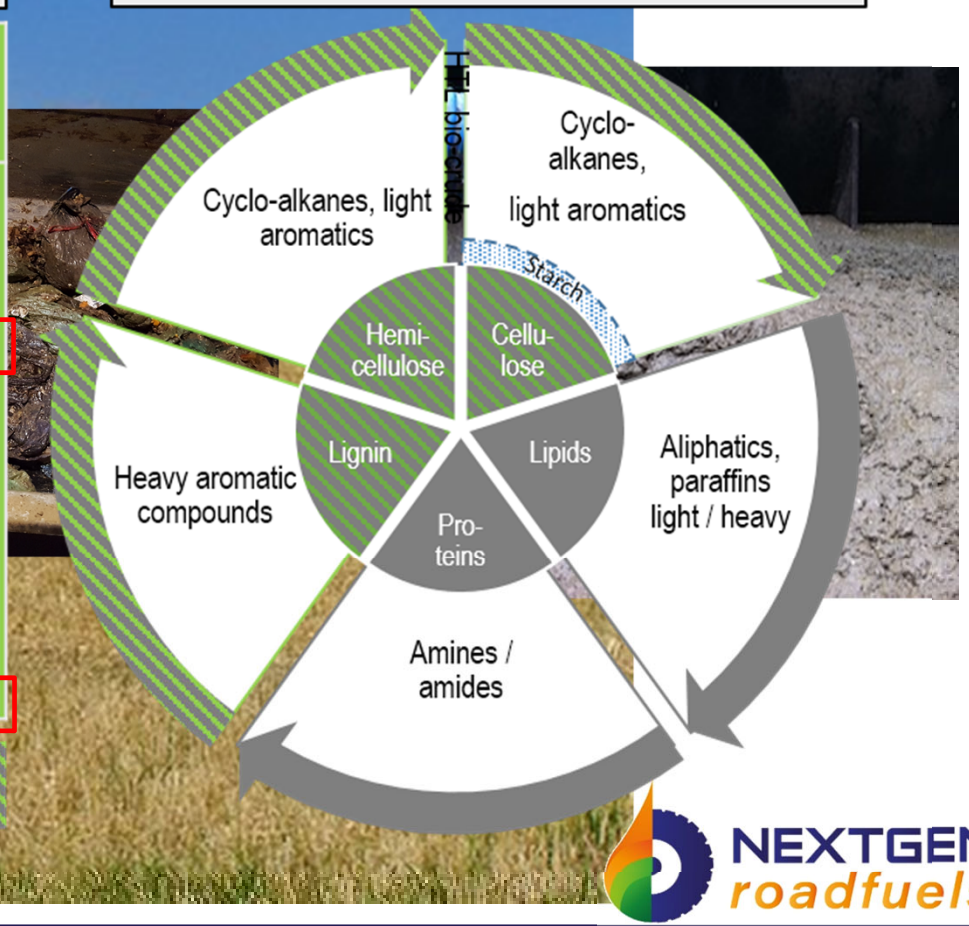
Jensen, CU, Guerrero, JKR, Karatzos, S, Olofsson, G, Iversen, SB 2017. 'Fundamentals of Hydrofaction™: Renewable crude oil from woody biomass.' Biomass Conv.Bioref. 7:495-509, DOI 10.1007/s13399-017-0248-8

Forskellige feedstocks giver forskellig olie – men indenfor et begrænset spektrum

Urban resource chemical composition → Derived HTL bio-crude compounds

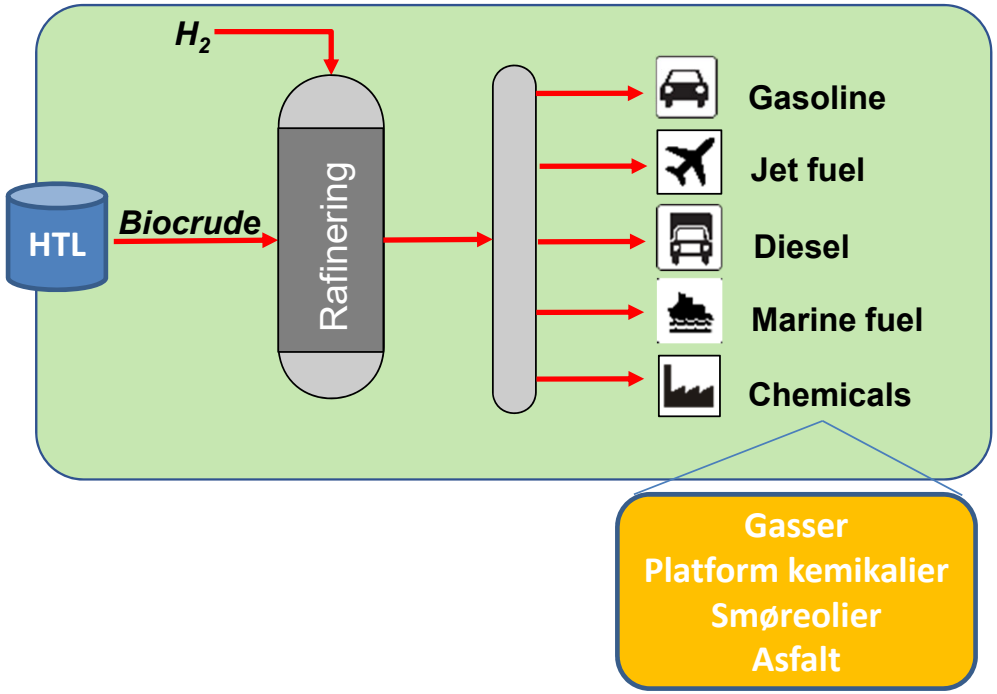
Parameter	Type of sludge			Food waste	Construc-tion wood waste
	Untreated primary sludge	Secon-dary sludge	Digested primary sludge		
Total dry solids (TS - % weight)	2.0-8.0	0.8-1.2	6.0-12.0	12.9-28.9	60-75
Volatile solids (% TS)	60-80	59-88	30-60	29.6-96.1	98
Grease and fats (% TS)	7-35	5-12	n/a	3.6-47.2	-
Protein (% TS)	20-30	32-41	15-20	4.7-26.5	-
Starch (% TS)				30.1-34.7	-
Cellulose (% TS)	8.0-15.0	7-9.7	8-.0-15.0	3.7-10.6	39-46
Hemicellulose (% TS)	-	-	-	1.6-4.7	25-35
Lignin (% TS)	-	-	-	1.5-21.7	23-27
P (% TS)	0.8-2.8	2.8-11.0	1.5-4.0	-	<< 1
N (% TS)	1.5-4	2.4-5.0	1.6-6.0	-	<< 1
K (% TS)	0-1	0.5-0.7	0-30	-	<< 1
S (% TS)	0.3-2.3	0.3-2.3	0.3-2.3	-	<< 1
pH	5.0-8.0	6.5-8.0	6.5-7.5	-	-
Inorganics	Very high	High	High	Low	Low

Present in sewage sludge/food waste | Starch in food waste | Present in both

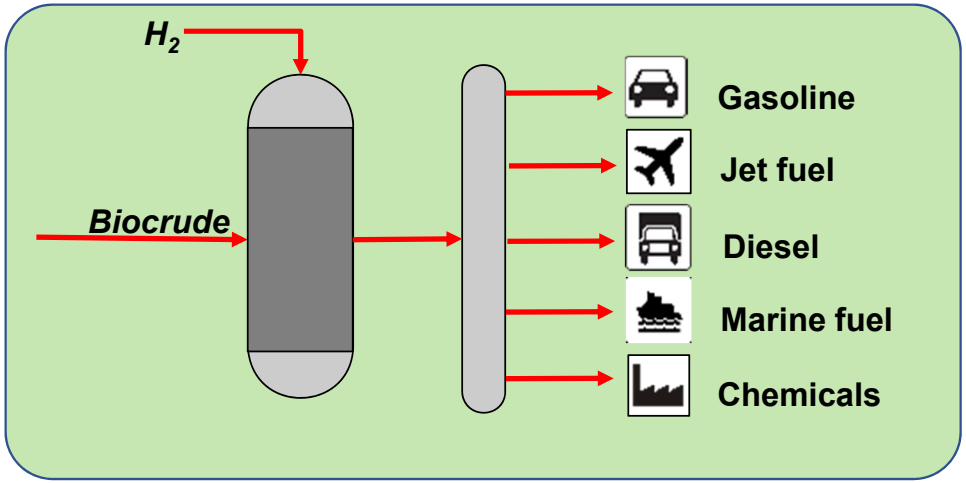


NEXTGEN roadfuels

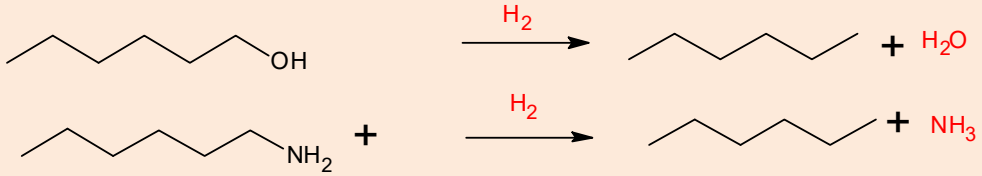
HTL – grøn feedstock til raffinaderier



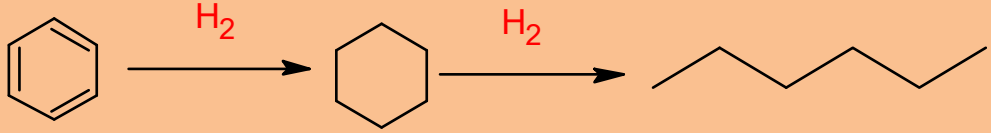
Raffinering er – næsten – kendt teknologi



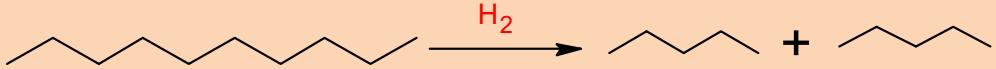
Heteroatoms removal



Hydrogenation

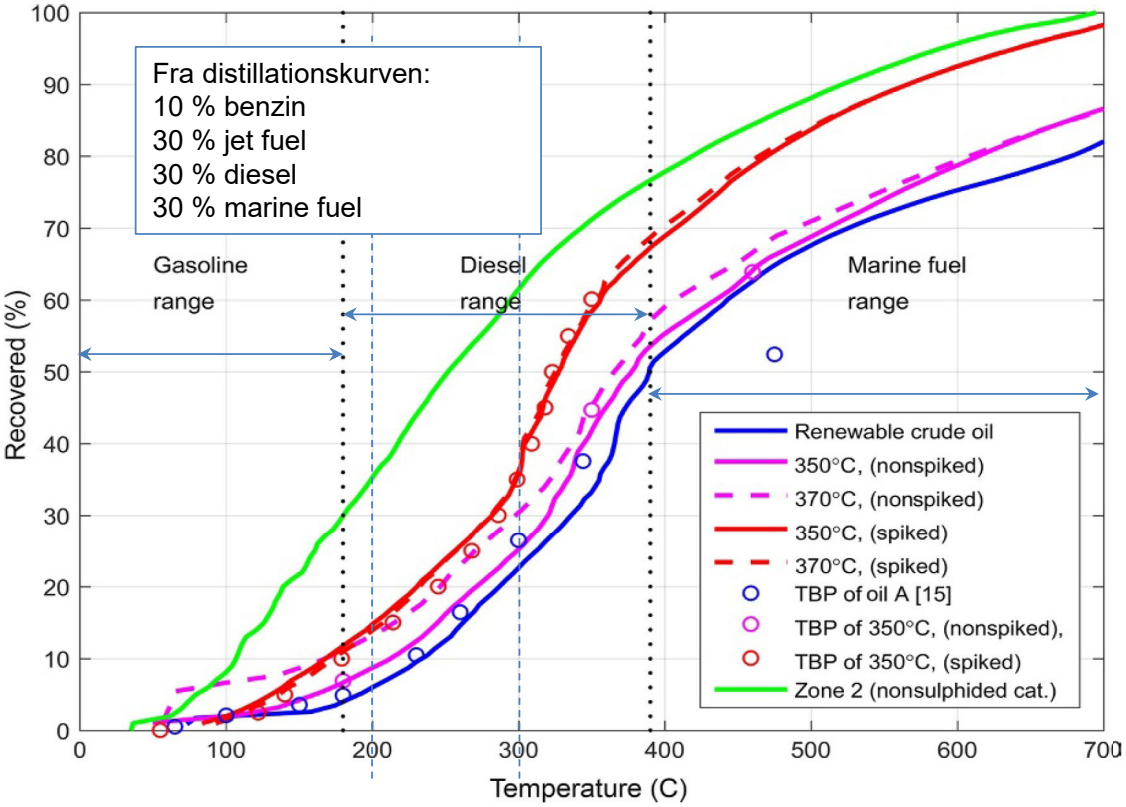


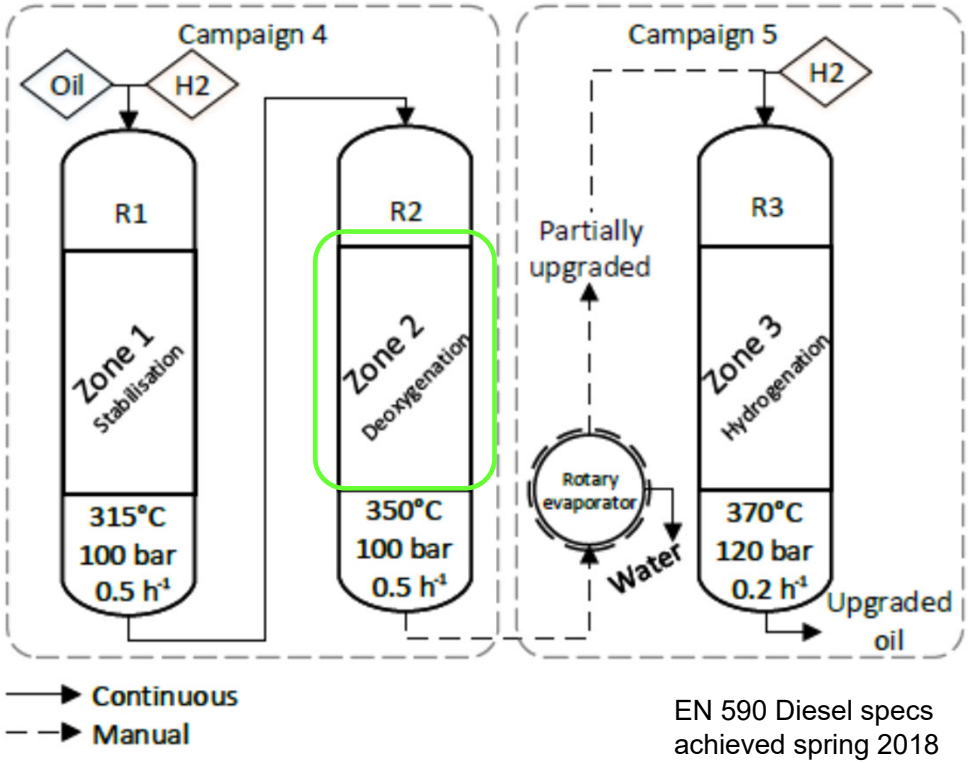
Hydrocracking



Standard NiMo hydrotreating catalysts

Lignocellulosic-based HTL biocrude and upgraded product





EN 590 Diesel specs achieved spring 2018

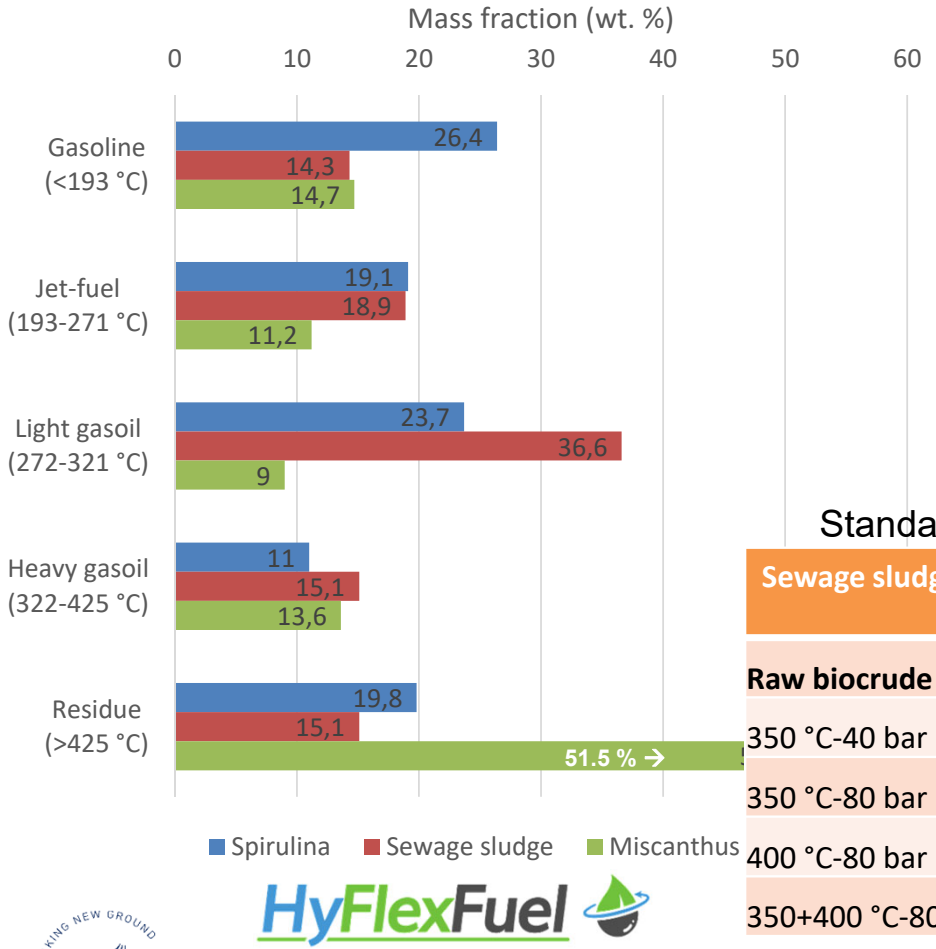
steeper ENERGY Hydrofaction™

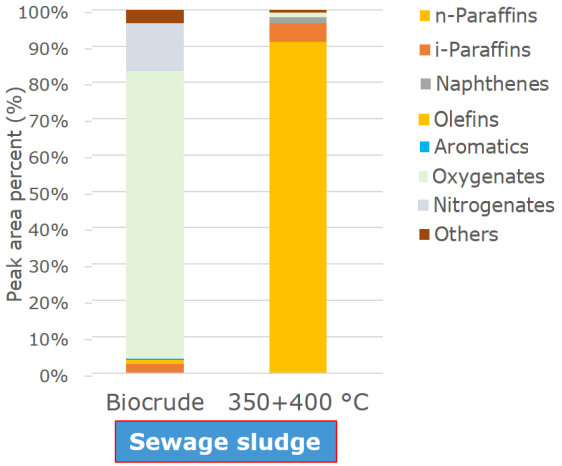
Standard NiMo hydrotreating catalysts

Jensen et al, Hydrofaction™ of Forestry Residues to Drop-in Renewable Transportation Fuels. In *Direct Thermochemical Liquefaction for Energy Applications* edited by L. Rosendahl, ISBN: 9780081010259, pp. 319-345, 2018.

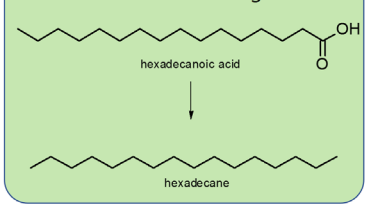
Production of fuel fractions from different feedstocks@subcrit HTL

Castello et al (2019). Renewable Energy





- Large part of the sewage sludge biocrude is constituted by fatty acids. especially in the range C12-C18
- The upgrading converts fatty acids into straight-chain alkanes
- High potential in the jet-fuel and diesel range

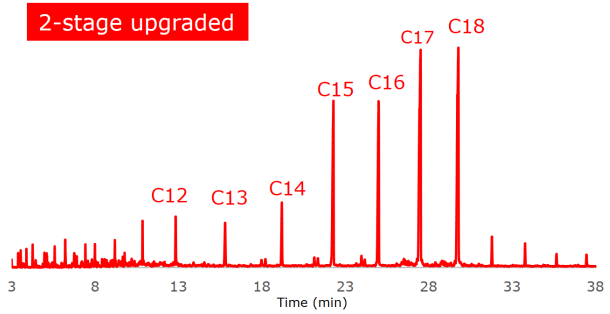


Standard NiMo hydrotreating catalysts

Sewage sludge	C (wt. %)	H (wt. %)	N (wt. %)	O* (wt. %)
Raw biocrude	74.5	10.6	3.9	11.0
350 °C-40 bar	83.1	12.1	3.6	1.2
350 °C-80 bar	84.1	13.4	2.5	0.0
400 °C-80 bar	85.3	13.8	0.9	0.0
350+400 °C-80bar	85.2	14.5	0.3	0.0

Biocrude

2-stage upgraded



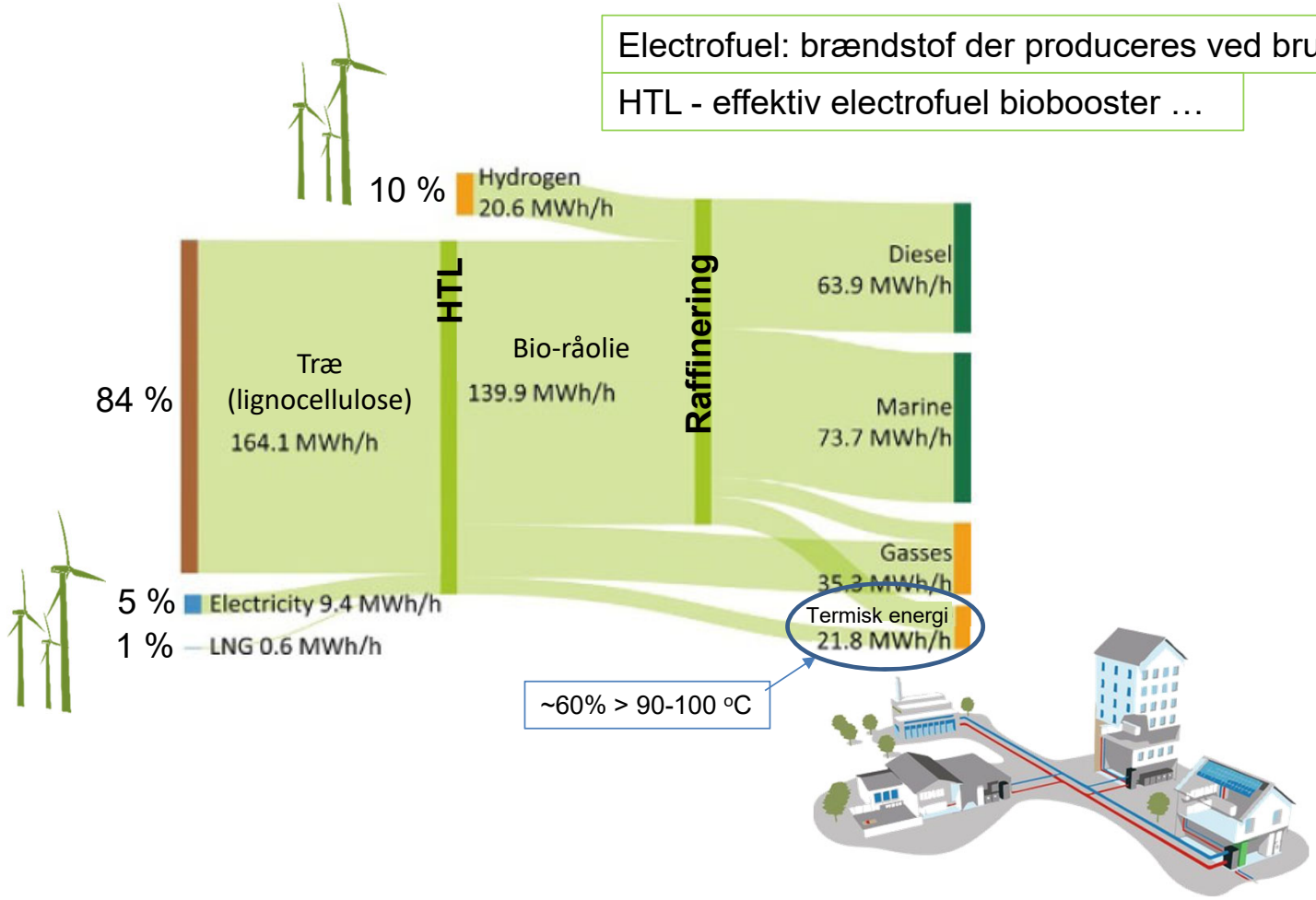
HyFlexFuel

* *Oxygen by difference*

HTL – energieffektivitet og electrofuel 1

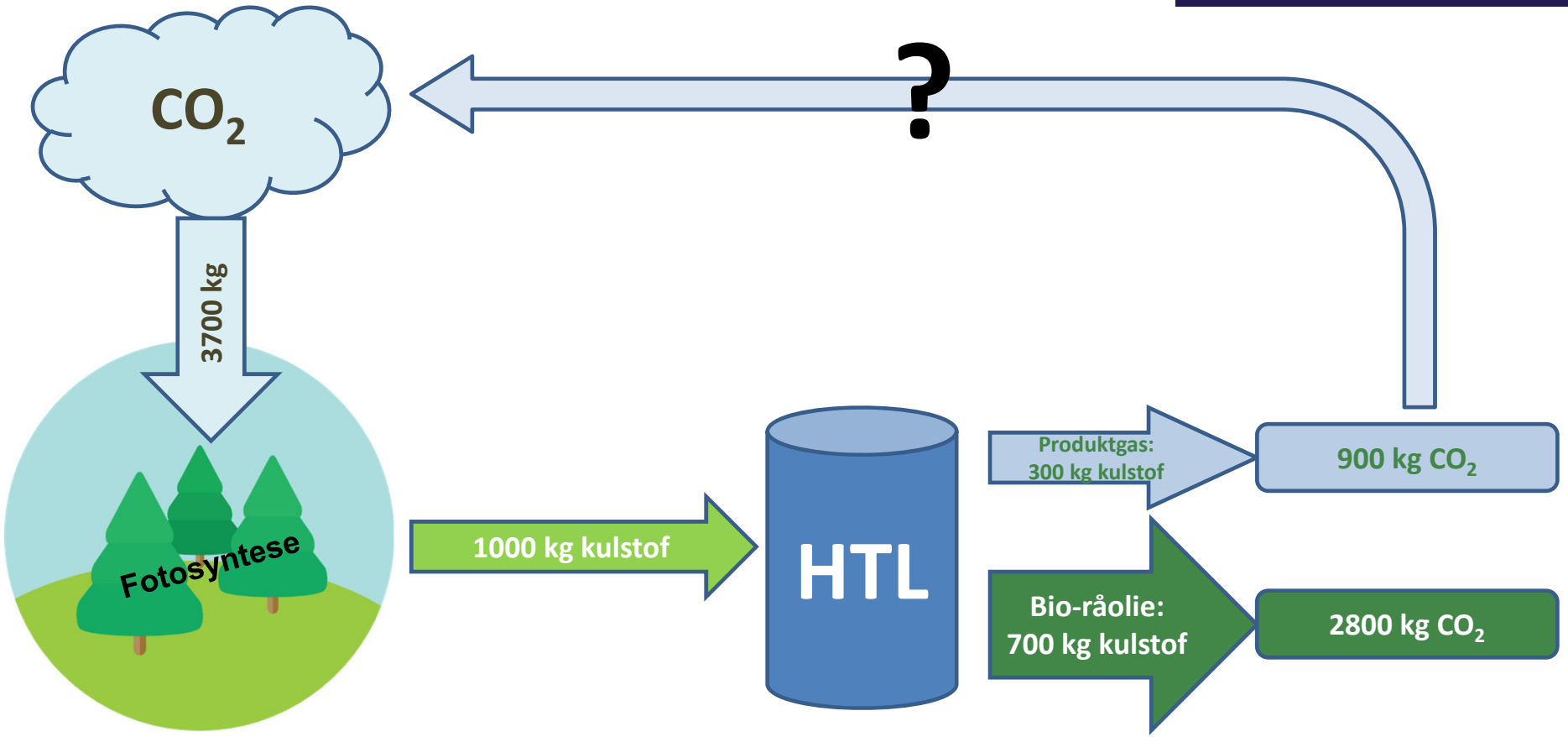
Electrofuel: brændstof der produceres ved brug af el

HTL - effektiv electrofuel biobooster …

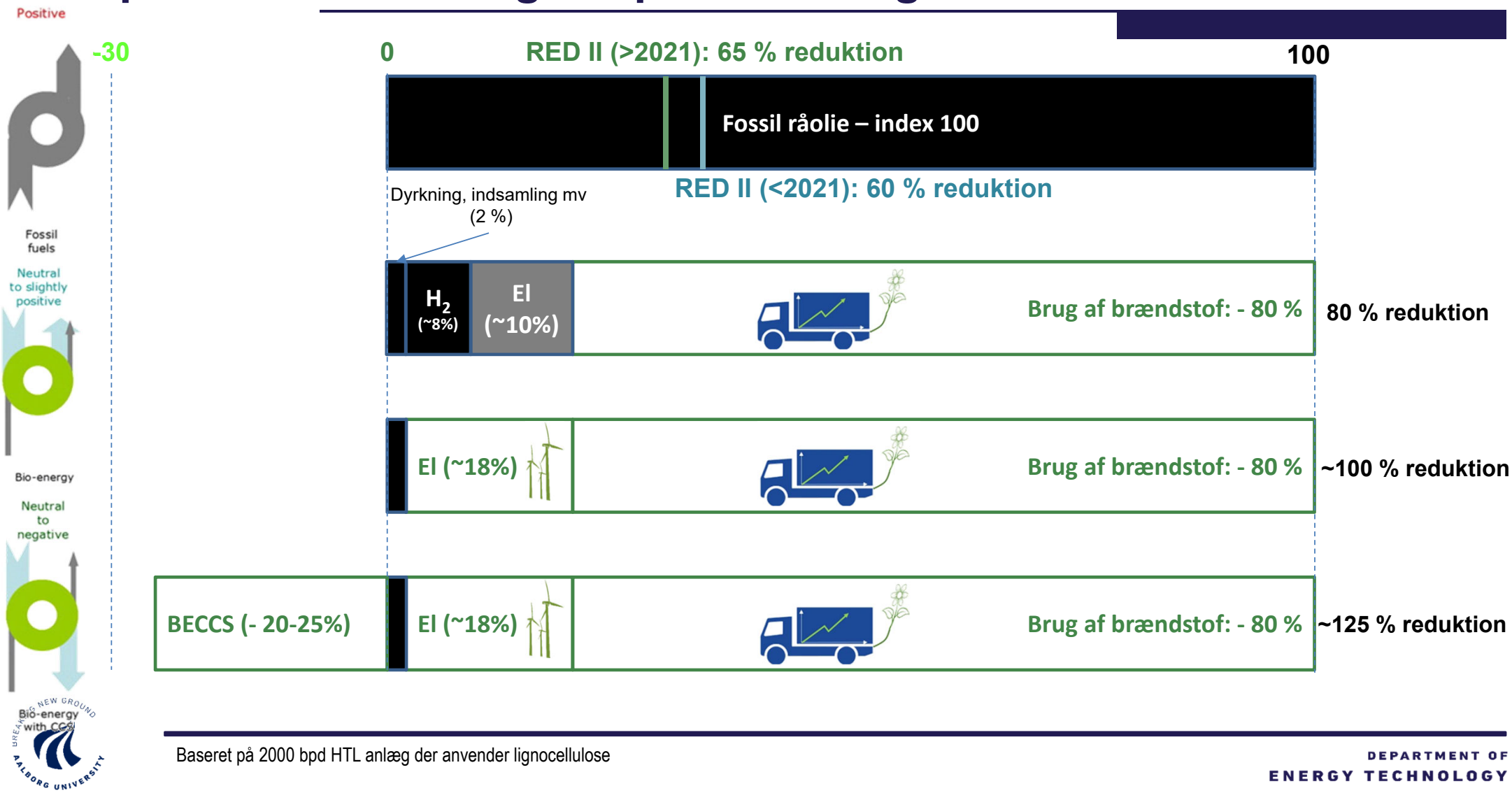


Baseret på **Jensen et al,** Hydrofaction™ of Forestry Residues to Drop-in Renewable Transportation Fuels. In *Direct Thermochemical Liquefaction for Energy Applications* edited by L. Rosendahl, ISBN: 9780081010259, pp. 319-345, 2018.

CO2 strømmen ind og ud af HTL

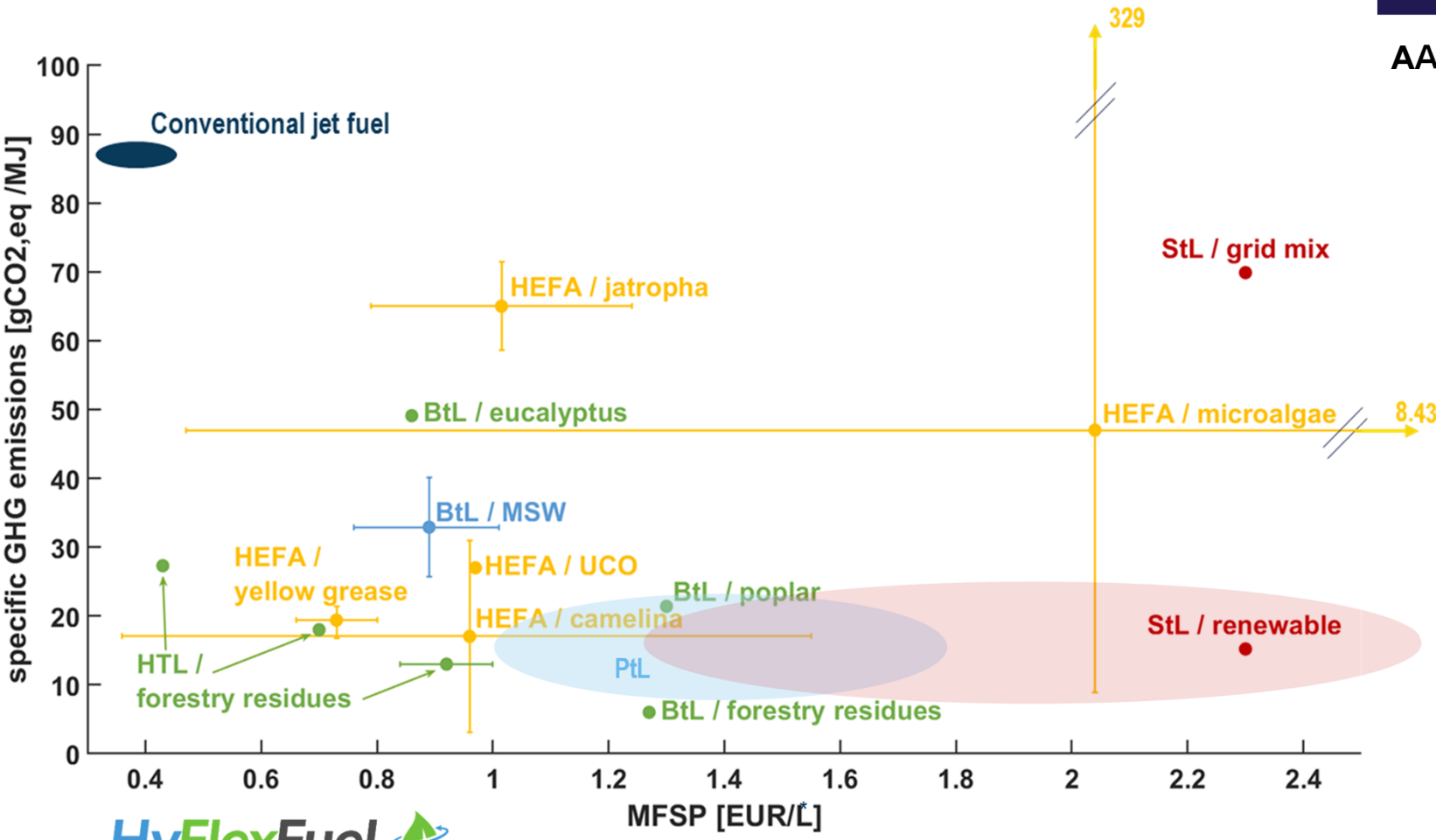


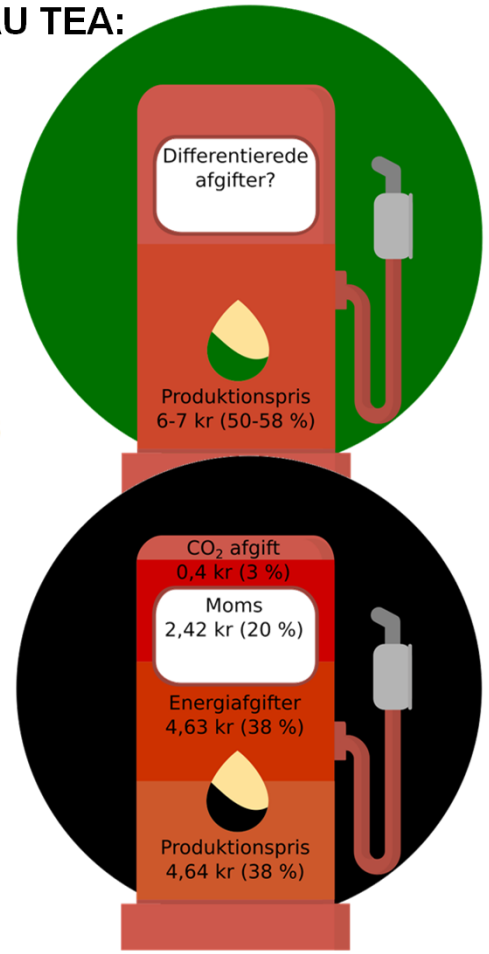
CO2 profil ved forskellige implementeringer af HTL



Baseret på 2000 bpd HTL anlæg der anvender lignocellulose

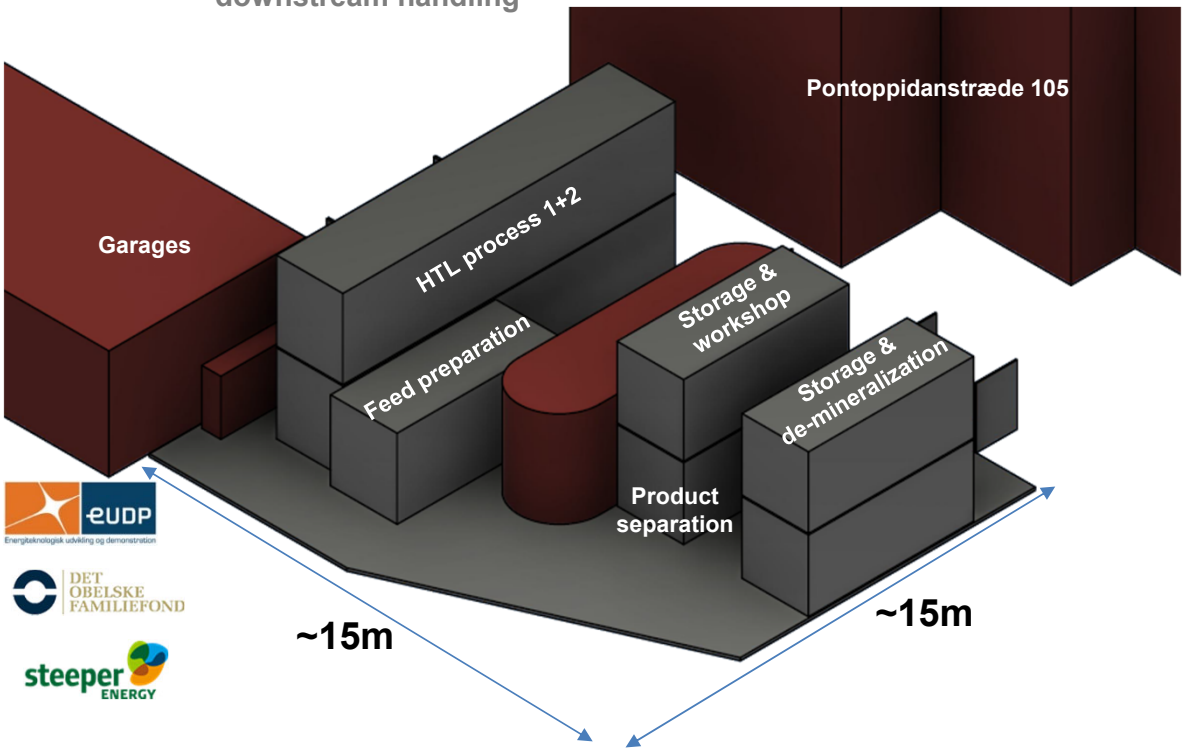
Samlet vurdering af økonomi for HTL





Pilot scale HTL facility – CBS1

- Continuous Hydrothermal Liquefaction (HTL) facility (CBS-1)
- 25-50 kg/h feed, processing conditions up to 500 °C, 350 bar
- Oil production capacity: 1-5 kg/h (0.3 bpd)
- Designed in collaboration with and constructed by Steeper Energy
- Commissioned 2013, recommissioned 2018 with improved up- and downstream handling



Silva Green Fuel – første større demonstrationsanlæg i Europa

steeper ENERGY
The Renewable Oil Company ™

Internationale udviklinger …

Licella

Australia

Cat-HTR™ process

Pulp/paper, plastics

10,000 ton/y

MURADEL

Australia

Green2black™ process

Tires, algae

168 L/h

Genifuel

U.S.A.

HTP™ process

Sewage sludge (Vancouver, California)

Første demonstrationsanlæg i Europa på vej

steeper ENERGY
The Renewable Oil Company™

Silva Green Fuel

SÖDRA Statkraft

Demo plant for **2ND GENERATION BIO FUEL**

Made from **FOREST FEEDSTOCK**

TOFTE in Norway

Test period **2019 - 2020**

OWNERSHIP Statkraft 51% Södra 49%

Can produce **4000 LITER** of bio fuel per day

Investering:
EUR 50 Mill.

Research activity overview - >20 mio EU

HyFlexFuel

Bauhaus Luftfahrt
Neue Wege.

HTL→ fuels

IFD Sino-DK 2019: 5 mio DKK for HTL valorization and disposal of sewage sludge, incl phosphorous

Innovationsfonden
FORSKNING, TEKNOLOGI & VÆKST I DANMARK

steeper ENERGY

HTL & py… …s

Energy system

ENSY… …y of

EUDP 2019: 10 mio DKK for pre-study and hardware upgrades for HTL on organic waste and sludge from Aalborg Kommune

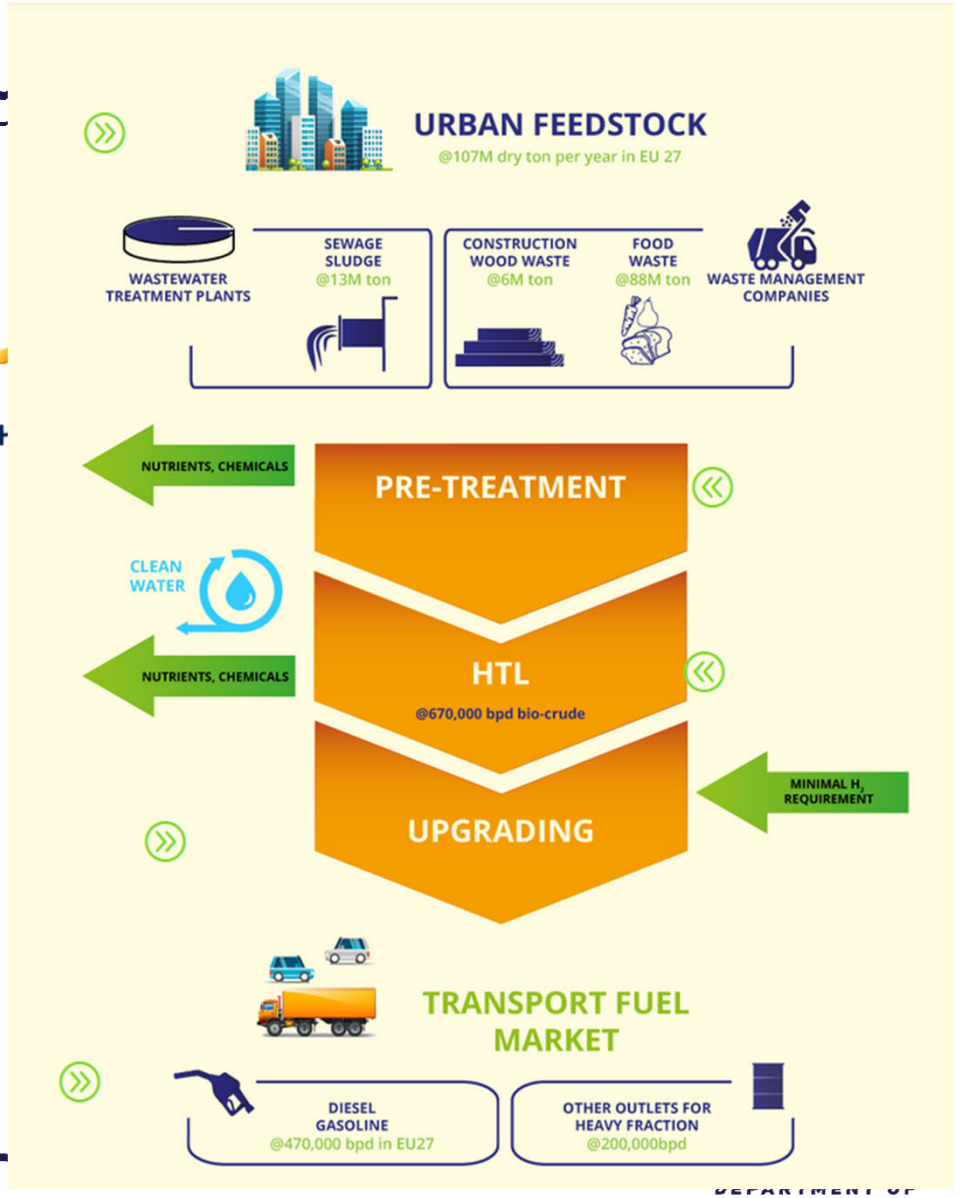
EUDP
Energiteknologisk udvikling og demonstration

steeper ENERGY

roadfuels

AALBORG UNIVERSITET

HTL → road transport fuels



AALBORG UNIVERSITY
BREAKING NEW GROUND

DEPARTMENT OF ENERGY TECHNOLOGY

Aalborg projektet

HTL bio-olie

– et af fremtidens grønne brændstoffer

Aalborg inviterer
til samarbejde med
globale perspektiver

plus

Lastbiler skal køre på lort og madrester

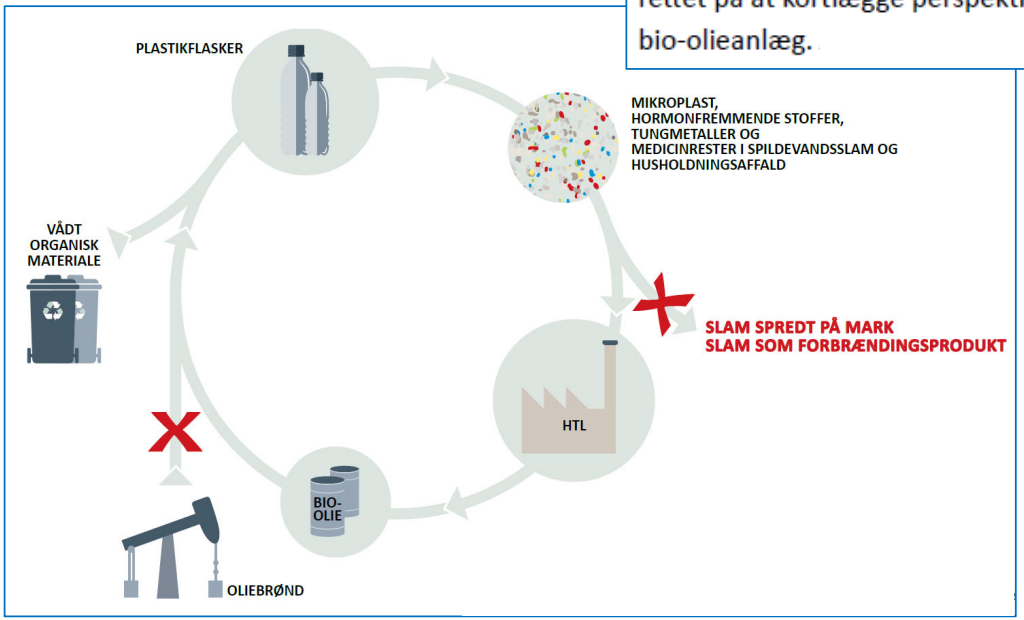
Ny metode skal gøre spildevandslam, træaffald og madrester til bæredygtigt brændstof

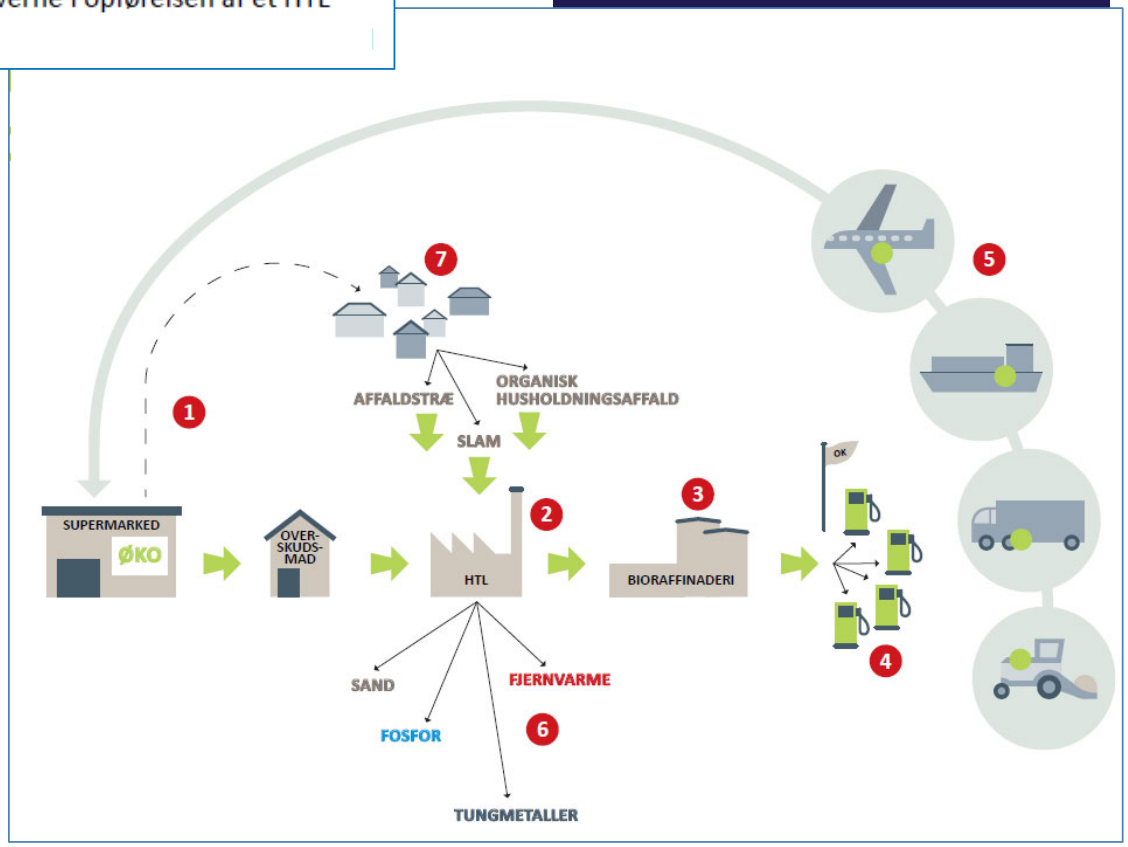
Arkivfoto: Claus Søndberg

ERHVERV 23. november 2018 09:21 - Opdateret 23. november 2018 09:21
Af: Anders Andersen

Aalborg projektet

Med udgangspunkt i Aalborg arbejder initiativtagerne mål-rettet på at kortlægge perspektiverne i opførelsen af et HTL bio-olieanlæg.





Partnerne:	Steeper Energy ApS
Aalborg Kommune	Aalborg Universitet
Aalborg Forsynings vanddivision	Krüger A/S
Aalborg Forsynings renovationsdivision	DCC & Shell Aviation Danmark A/S
Aalborg Forsynings energidivision	COOP Invest A/S
Aalborg Havn A/S	A2Energy ApS
Aalborg Lufthavn a.m.b.a.	
I/S Reno-Nord	
Region Nordjylland	

Advanced Biofuels Research programme

WWW.ADVANCEDBIOFUELS.ET.AAU.DK

EUBIA

IEA Bioenergy
Task 34

eUDP
Energiteknologisk udvikling og demonstration

AALBORG UNIVERSITY
DENMARK

Innovationsfonden
FORSKNING, TEKNOLOGI & VÆKST I DANMARK

EERA
European Energy Research Alliance
BIOENERGY