The shared future of green H_2 and sustainable bio- & e-fuels

The Future of Biofuels
Copenhagen 24-25 Oct. 2023

Dr. Fernanda Neira D'Angelo
Fernanda.neiradangelo@hycc.com

HyCC

The Hydrogen Chemistry Company

Enabling emission-free industries

Joining forces to create a new leader in green hydrogen

NOBIAN

Leader in essential chemicals with 100+ years experience in electrolysis

MACQUARIE | Green Investment Group

Global investment group focused on accelerating the green transition

50%

50%

HyCC

The Hydrogen Chemistry Company

A leading provider of green hydrogen and circular chemistry solutions with over 1 gigawatt under development.

We bring decades of experience in operating large scale electrolysis plants

- Nobian has 100+ years experience with large-scale chlor-alkali electrolysis
- We excel in safety and our HSE framework was rated “Gold standard” by Arcadis
- E-flex operation: Nobian facilities automatically adjust production to power supply since 2018

Victor Salet

Former Site Director
Now Head of
Technology Team HyCC

Image: Nobian operates Europe’s largest single-line facility, in Rotterdam (200 MW)

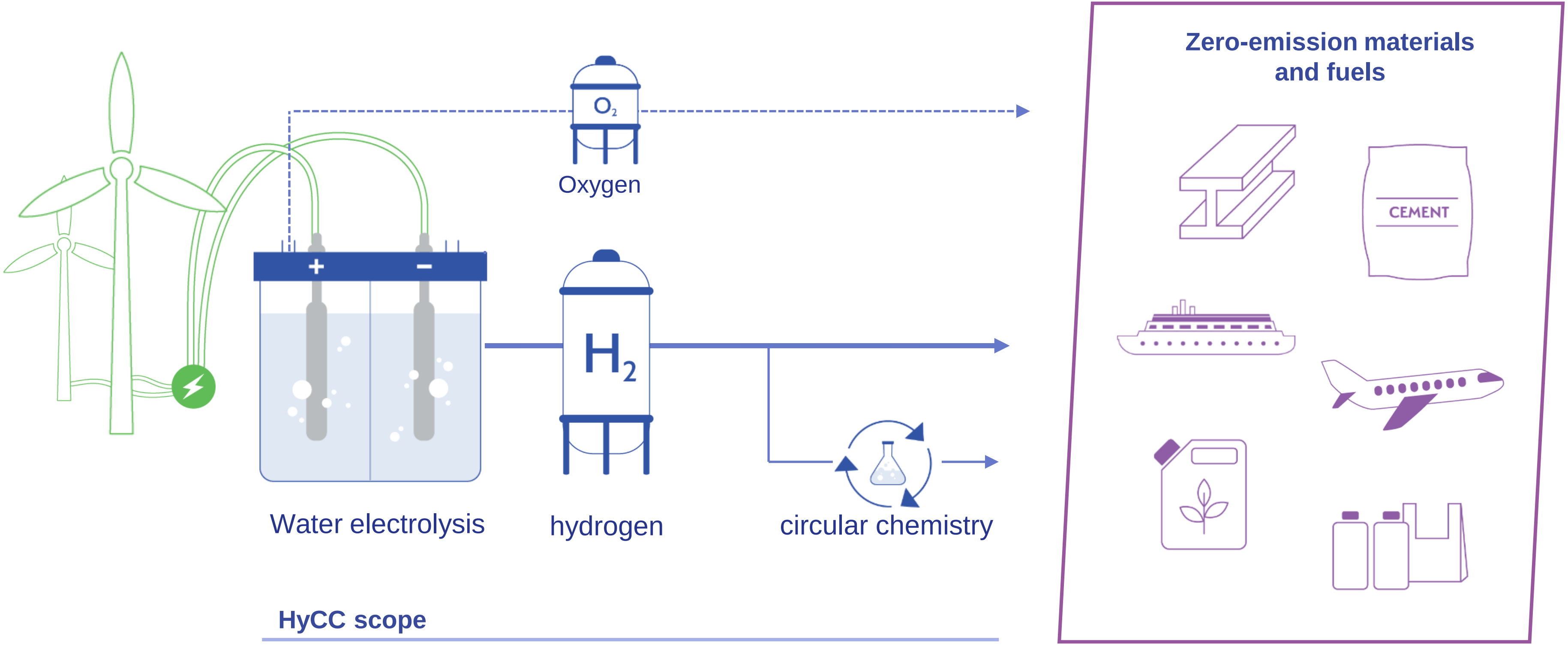
Enabling emission-free industries

Our Vision & Mission

To enable the full **decarbonization of industry** and the transition to a truly circular economy, by supplying safe, reliable and affordable **green hydrogen** supplies and circular **chemistry solutions**

HyCC

Towards a zero-carbon future



Strong pipeline built on robust customer engagement

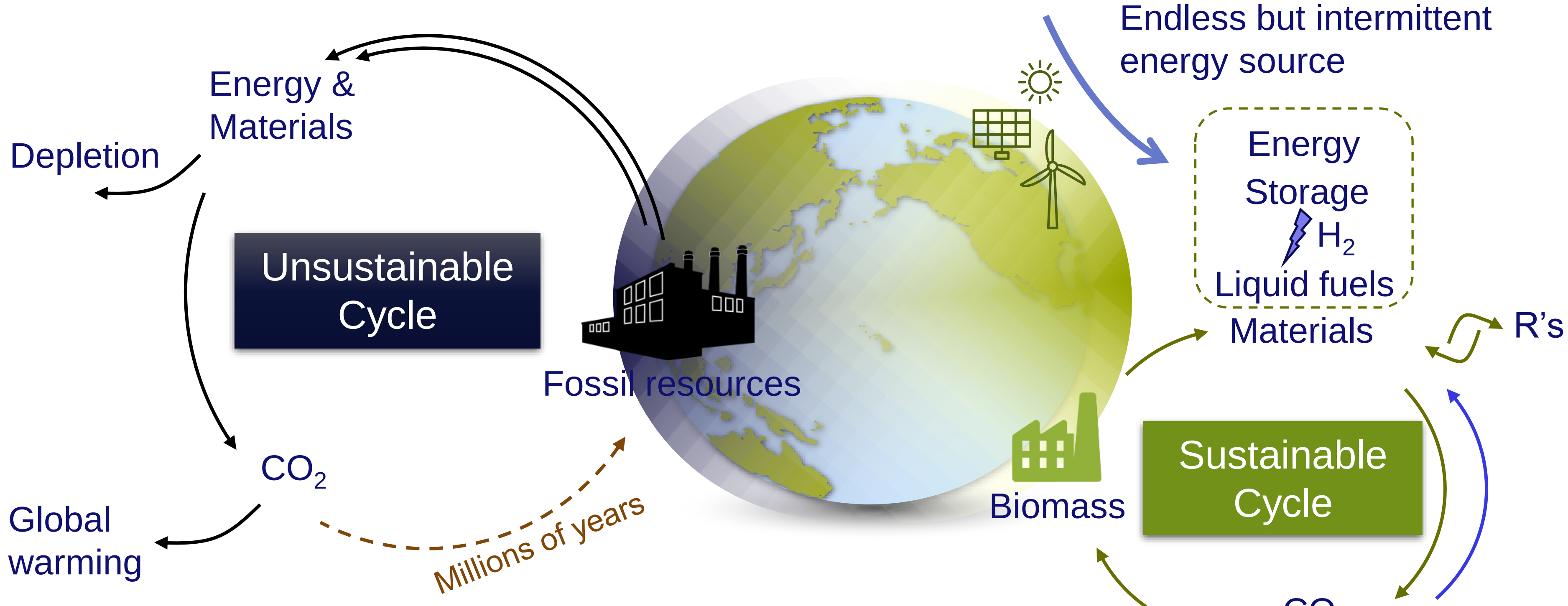
Green hydrogen projects

			IPCEI project	IPCEI project			
ISPT, thyssenkrupp	OCI, Gasunie	KLM, SkyNRG, SHV Energy	Tata Steel, Port of Amsterdam	bp	Port of Amsterdam	VNG	On track to reach **gigawatt scale**
R&D Carbon2Chem MW test center	**20 MW** Djewels	**40 MW** H_2eron	**100 MW** H_2ermes	**250 MW** H2-Fifty	**500 MW** H_2era	GreenRoot	

H_2eron: green hydrogen for Sustainable Aviation Fuels

The Future Energy & Material Transition

HyCC



Biomass: do we have enough?

Fossil consumption per sector

Type of fuel	*Sector*	*Mtoe, EU-27, 2021*[1]
Crude Oil		458
LPG	Chemical	25
Naphtha	Chemical	41
Gasoline	Road	67
Jet/kerosene	Aviation	27*
Diesel/gasoil	Road, maritime	245 (~ 16 maritime)
Fuel oil	Maritime, other	41
Coal	Energy, metal.	145
Natural gas	Energy, industry.	329

* Aviation fuel decreased after COVID. Pre-COVID ~ 45 Mtoe per year

"Conservative" estimate
~ 65 Mtoe biomass for chemicals
~ 85 Mtoe biomass for biofuels

Projected availability of <u>non-food sustainable</u> biomass in EU by 2030-2050 in Mtoa per year

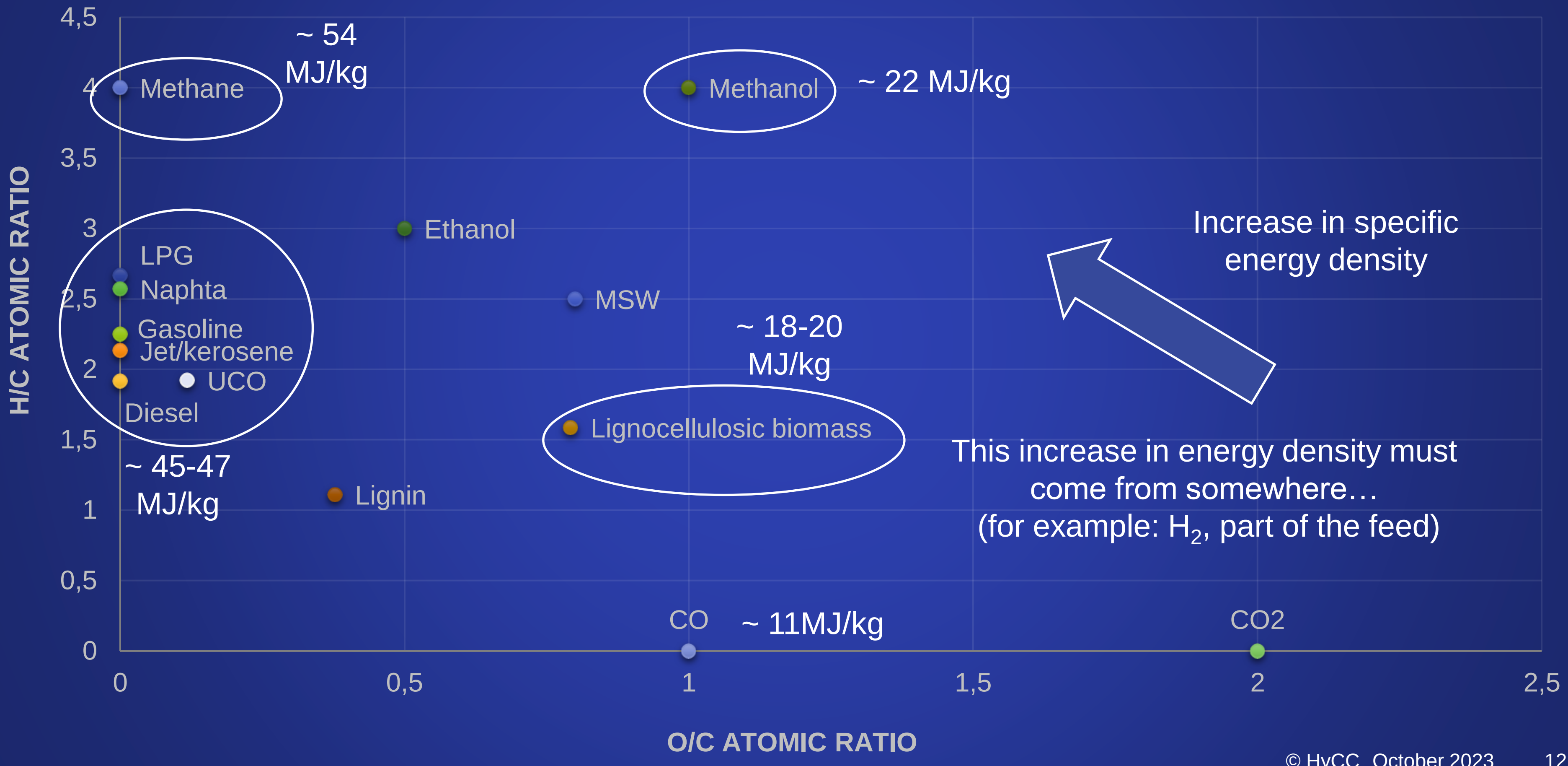
Used Cooking Oil (UCO)	Non-edible animal fat	Lignocellulose (Agro & forestry wastes & bio-MSW)	Non-bio MSW
			
~ 3-7[2]	< 1[3]	~270-295[2]	~ 45

(Without considering losses during chemical conversion)

We need to focus on lignocellulosic feedstocks

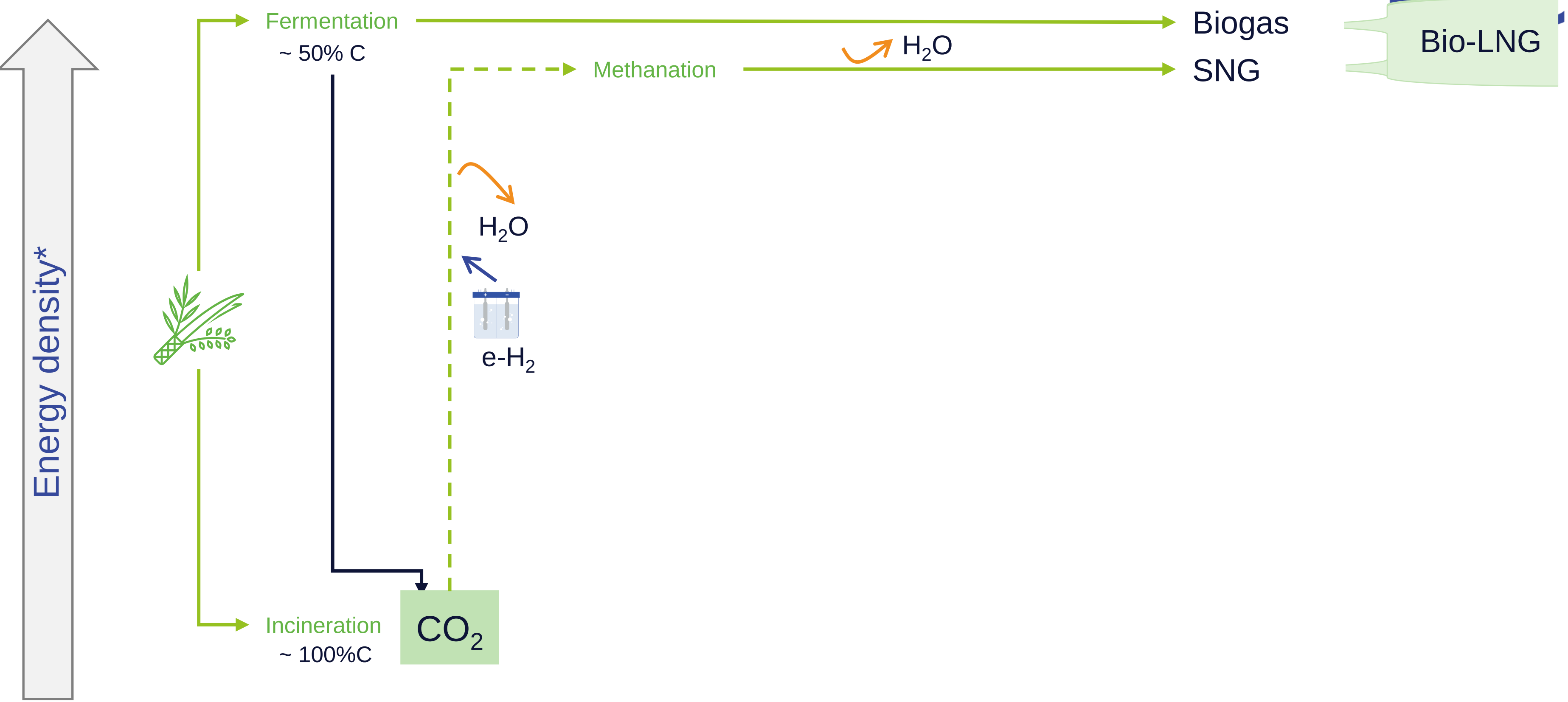
[2] Concawe, 2021 [3] Cerulorogy, 2023

From biomass to fuels: increasing energy density



This increase in energy density must come from somewhere…
(for example: H_2, part of the feed)

Advanced bio & e-fuel technologies



C “loss” to CO_2

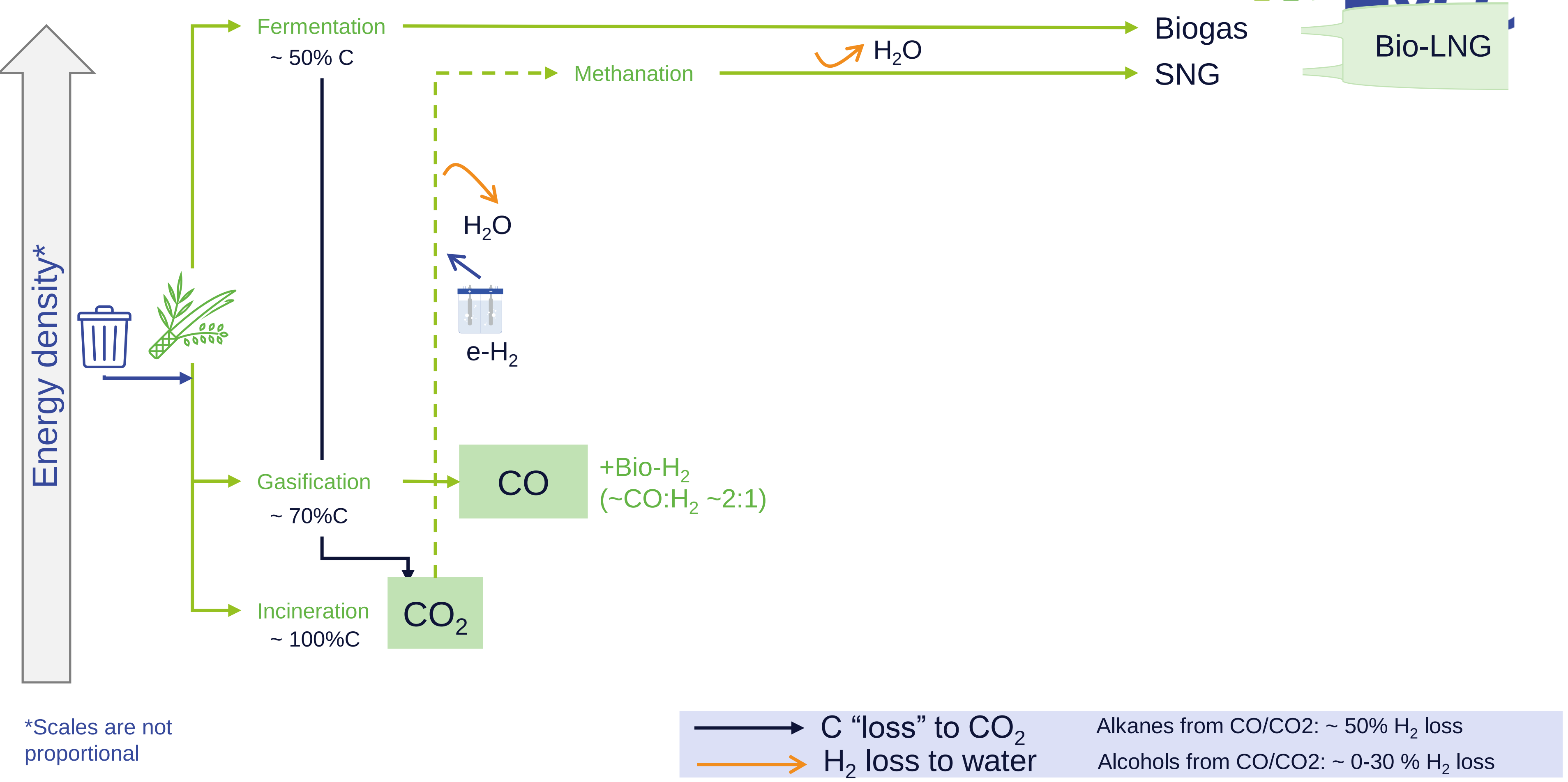
H_2 loss to water

Alkanes from CO/CO2: ~ 50% H_2 loss

Alcohols from CO/CO2: ~ 0-30 % H_2 loss

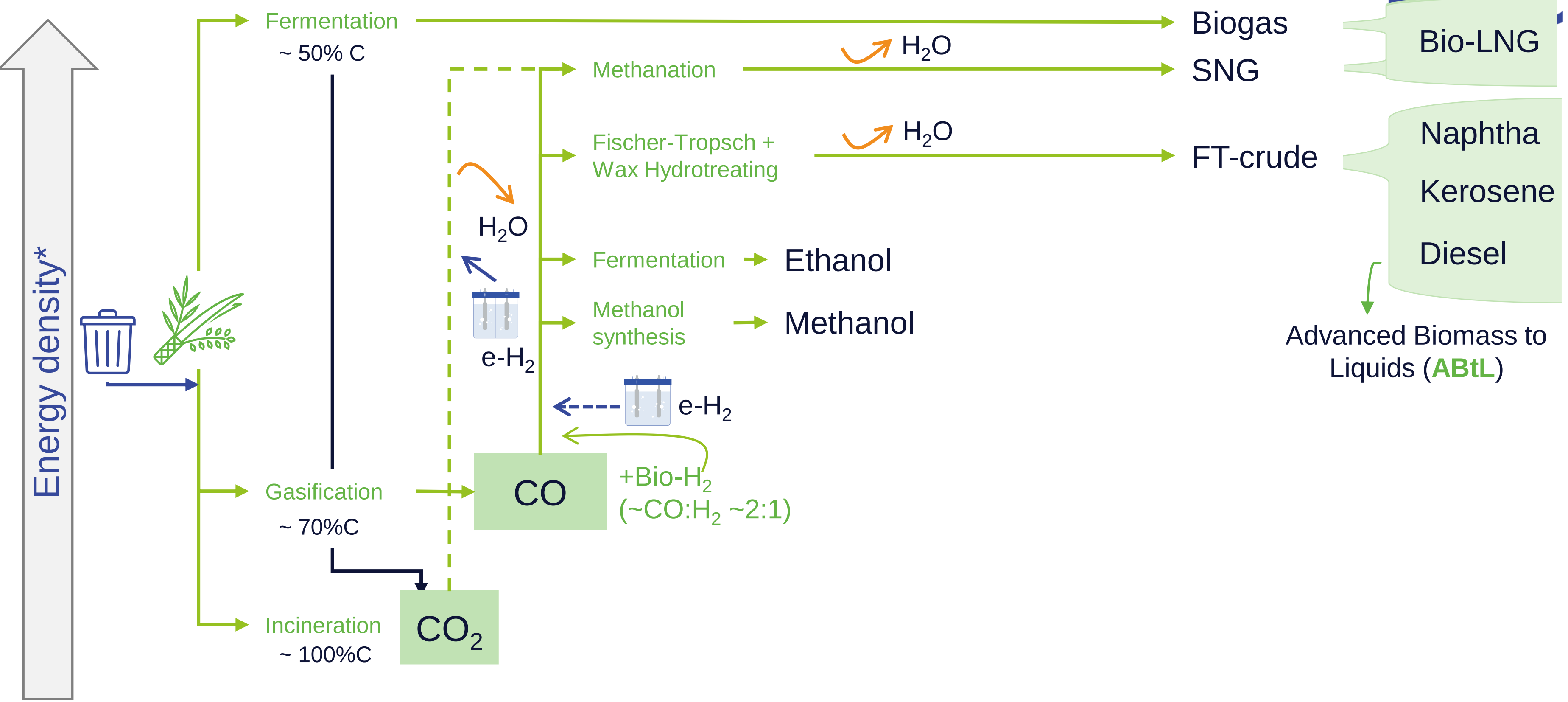
*Scales are not proportional

Advanced bio & e-fuel technologies



*Scales are not proportional

Advanced bio & e-fuel technologies



*Scales are not proportional

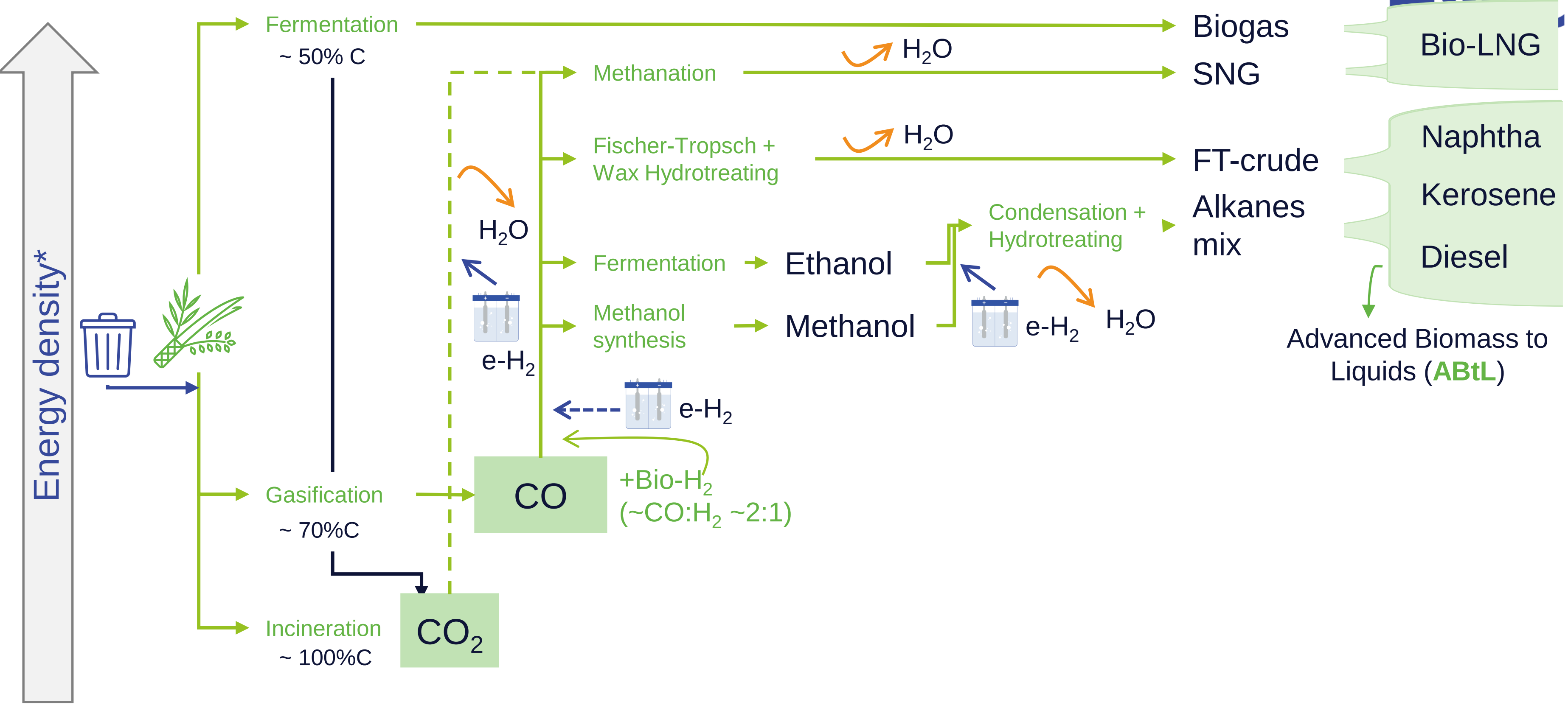
C "loss" to CO_2

H_2 loss to water

Alkanes from CO/CO2: ~ 50% H_2 loss

Alcohols from CO/CO2: ~ 0-30 % H_2 loss

Advanced bio & e-fuel technologies



C "loss" to CO_2

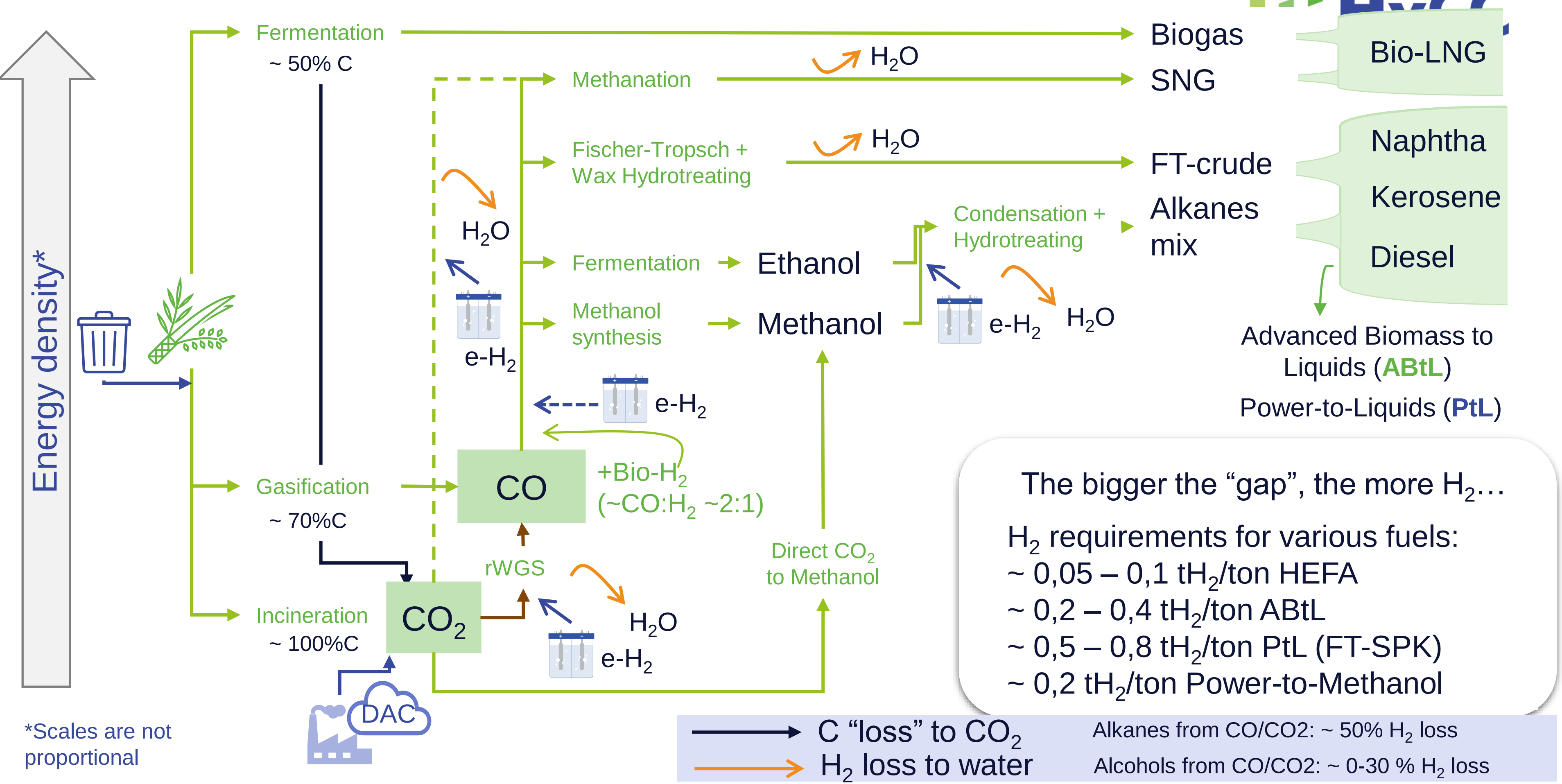
H_2 loss to water

Alkanes from CO/CO2: ~ 50% H_2 loss

Alcohols from CO/CO2: ~ 0-30 % H_2 loss

*Scales are not proportional

Advanced bio & e-fuel technologies



The bigger the "gap", the more H_2…

H_2 requirements for various fuels:
- ~ 0,05 – 0,1 tH_2/ton HEFA
- ~ 0,2 – 0,4 tH_2/ton ABtL
- ~ 0,5 – 0,8 tH_2/ton PtL (FT-SPK)
- ~ 0,2 tH_2/ton Power-to-Methanol

*Scales are not proportional

Some intermediate conclusions

HyCC

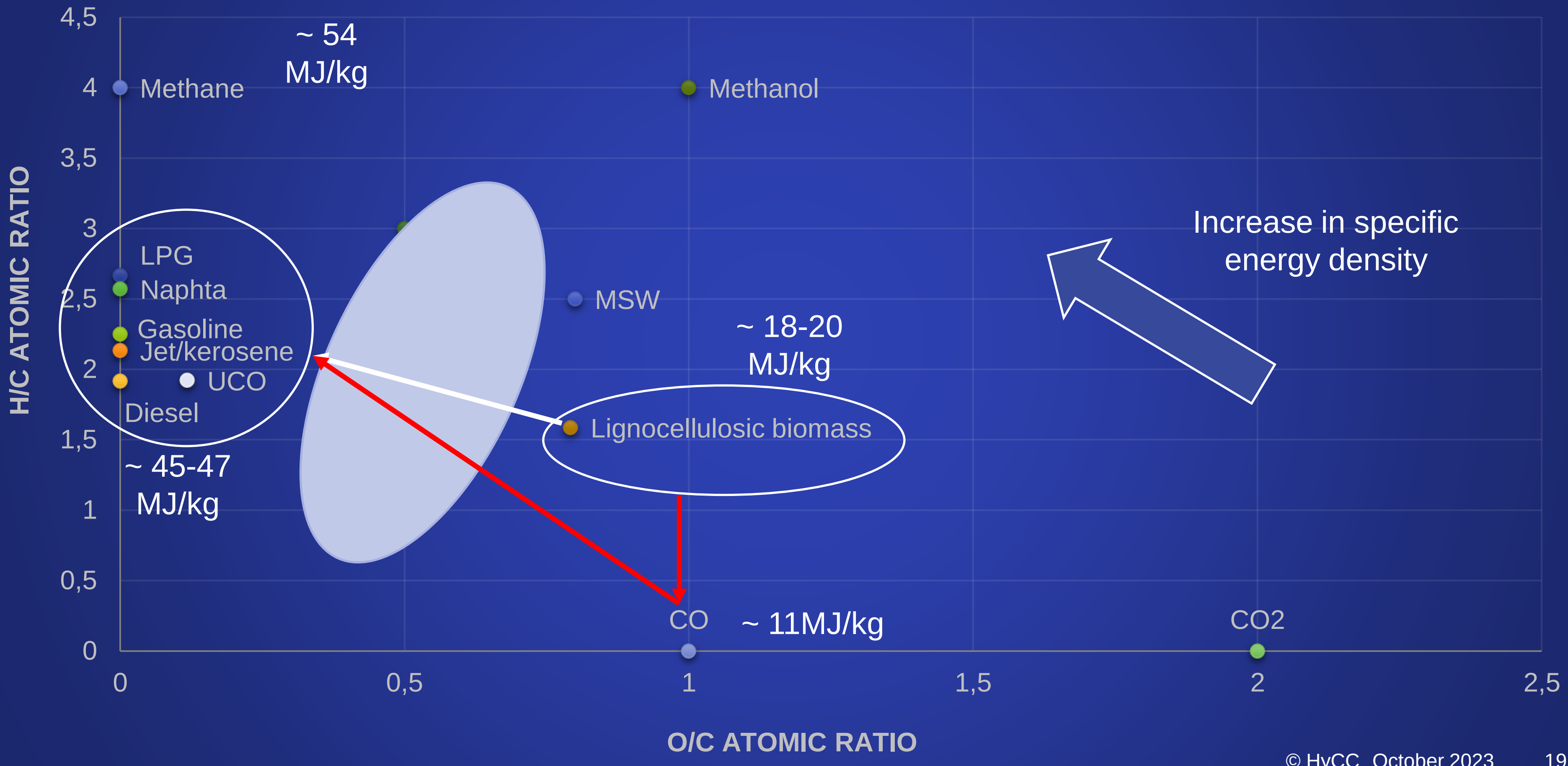
Stating the obvious: Not a single solution

- HEFA feedstocks ideal, but scarce.
- ABtL and PtL key for future energy mix, but *inevitably* more energy intensive to produce (~4-5x and 10x more H_2 than HEFA) and lower technology maturity.
- PtL is energy intensive, but no feed constrains & improved carbon efficiency
- PtL to alcohols may be a good start for near future.

The bigger the energy "gap", the more H_2 is required:
~ 0,05 – 0,1 tH_2/ton HEFA
~ 0,2 – 0,4 tH_2/ton ABtL
~ 0,5 – 0,8 tH_2/ton PtL (FT-SPK)
~ 0,2 tH_2/ton Power-to-Methanol

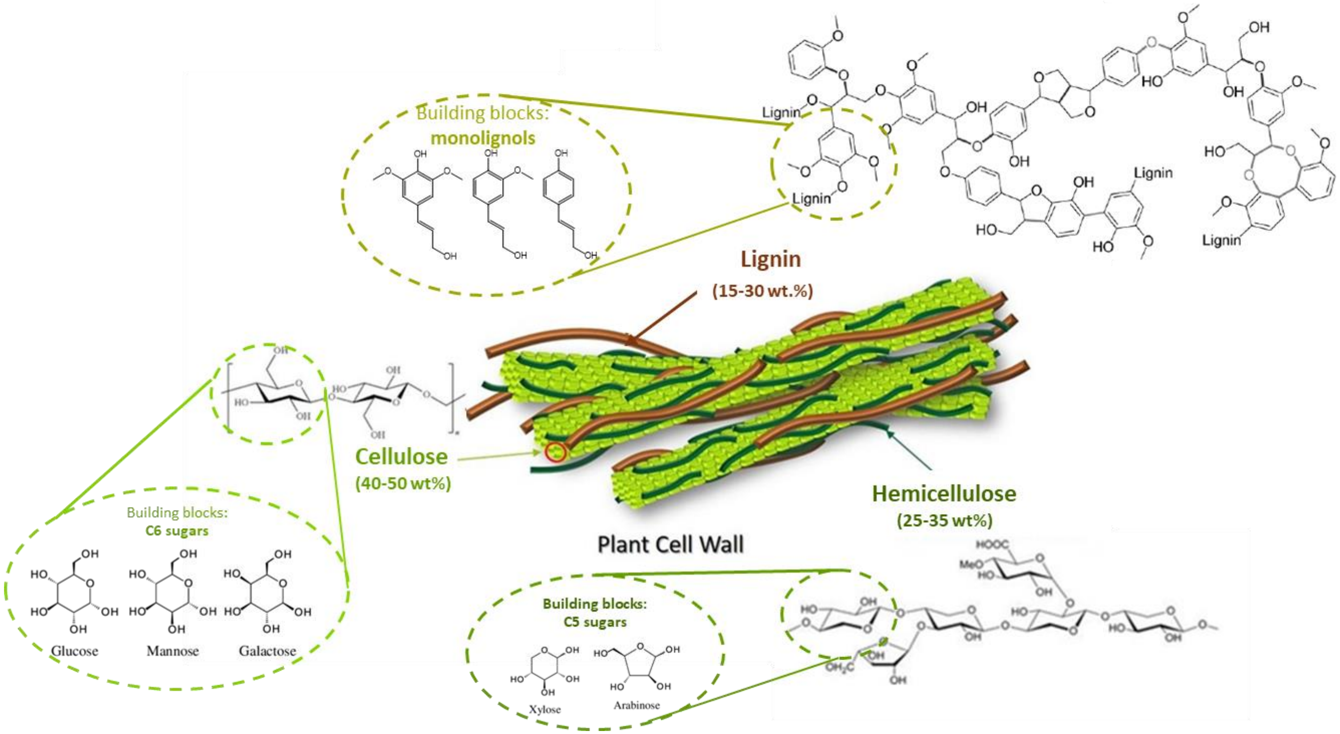
Can ABtL technologies become more (energy/carbon) efficient through RD&I?

Mind the gap

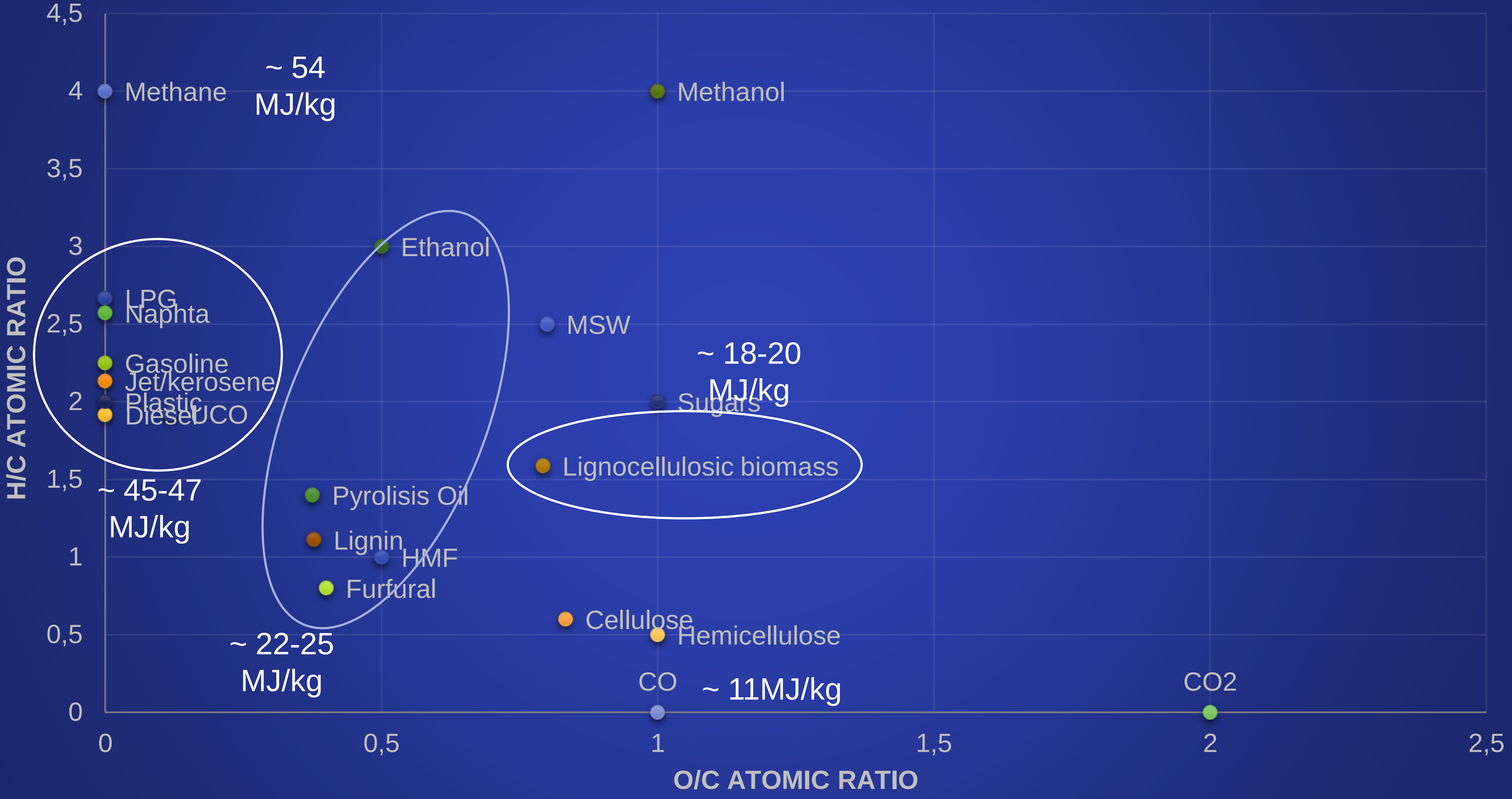


H/C ATOMIC RATIO
O/C ATOMIC RATIO
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
0
0,5
1
1,5
2
2,5
~ 54 MJ/kg
Methane
Methanol
LPG
Naphta
Gasoline
Jet/kerosene
UCO
Diesel
MSW
~ 18-20 MJ/kg
Lignocellulosic biomass
~ 45-47 MJ/kg
CO
~ 11MJ/kg
CO2
Increase in specific energy density

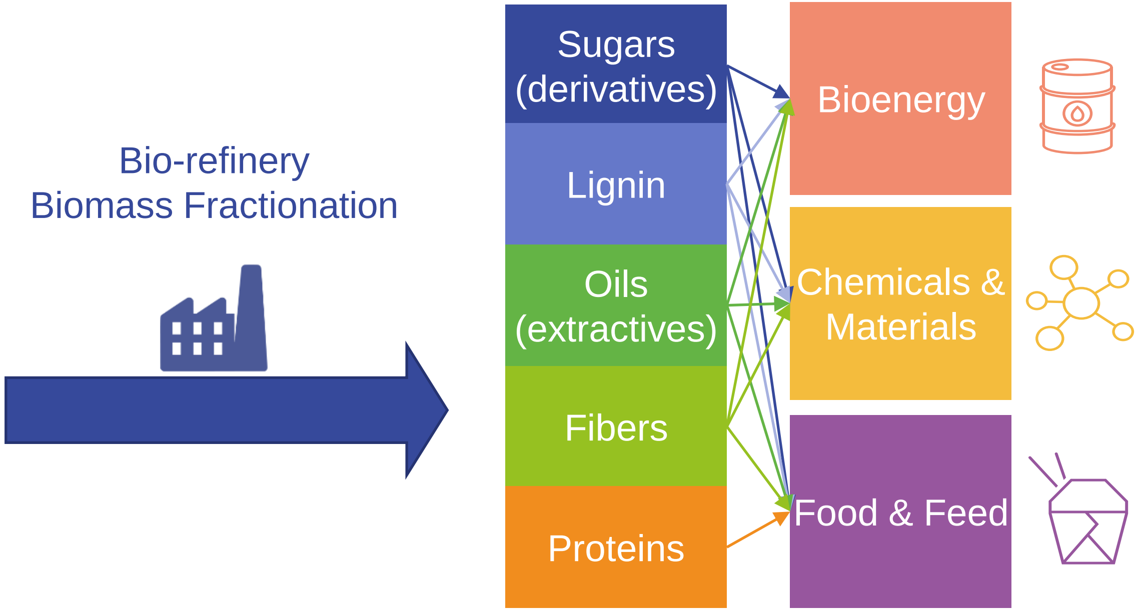
Lignocellulosic biomass: biopolymers made from a handful of “building blocks”



Mind the gap


4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
H/C ATOMIC RATIO
0
0,5
1
1,5
2
2,5
O/C ATOMIC RATIO
Methane
~ 54 MJ/kg
Methanol
Ethanol
LPG
Naphta
Gasoline
Jet/kerosene
Plastic
Diesel
UCO
~ 45-47 MJ/kg
MSW
~ 18-20 MJ/kg
Sugars
Lignocellulosic biomass
Pyrolisis Oil
Lignin
HMF
Furfural
Cellulose
Hemicellulose
~ 22-25 MJ/kg
CO
~ 11MJ/kg
CO2

Bio-refining *via* high value "building blocks"



- Sustainable supply of biomass
- Feedstock flexibility

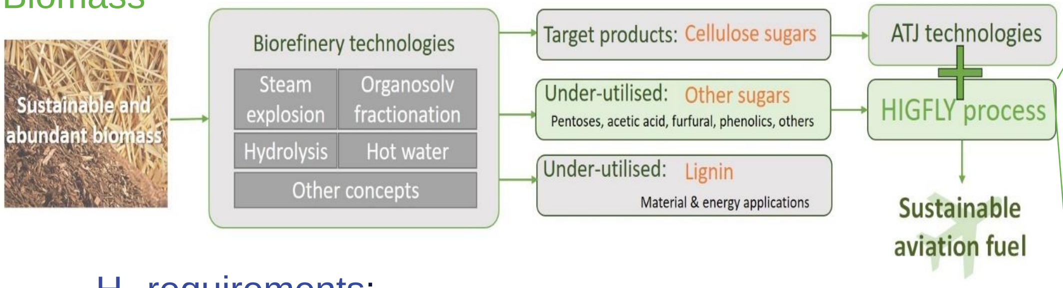
- Low temperature, liquid phase processes
- Use of (bio)catalysis

- Co-production of fuels, chemicals and food/feed

Example: Furanics-to-Jet

Advanced Biomass

Synergy with bio-refineries



H_2 requirements:

~ 0,2 – 0,4 tH_2/ton ABtL – thermochemical

< 0,2 tH_2/ton ABtL – via furanics

Carbon efficiencies (with respect to feed):

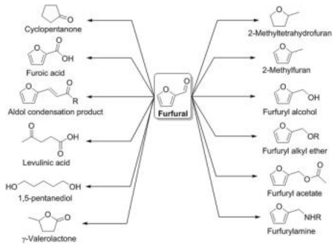
~ 30 - 50% ABtL –thermochemical

~ 60 – 70 % ABtL – via furanics

C5 biorefinery streams

1. Synthesis of jet fuel precursors (Catalytic Route)
2. Synthesis of jet fuels (Condensation + Hydrotreating)

Drop-in grade jet fuel



Low TRL!

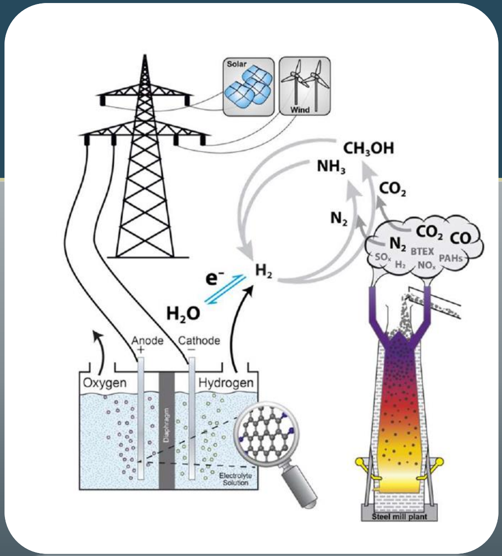
Coordinated by

www.higfly.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°101006618

Power-to-Liquids to Decarbonize Industry: Carbon2Chem®

Based on the Thyssenkrupp's Steel Mill in Duisburg (Germany)



Carbon2Chem®

HyCC
NOBIAN
thyssenkrupp
CLARIANT
Fraunhofer
Bundesministerium für Bildung und Forschung

Take-home messages

HyCC

- Advanced Biofuels and Power-to-Liquids will be needed to cover energy needs
- Efforts to increase energy efficiency / cost-competitiveness: RD&I on new/more efficient routes, process integration / synergies across value chain
- Green hydrogen and (advanced) biofuel technologies go hand in hand. We should walk together that path to develop together an *overall* more efficient and more sustainable future.

Thank you