Developments in Liquefaction routes to Marine biofuels and other renewable fuels

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Duncan Akporiaye
SINTEF, Vice President Research

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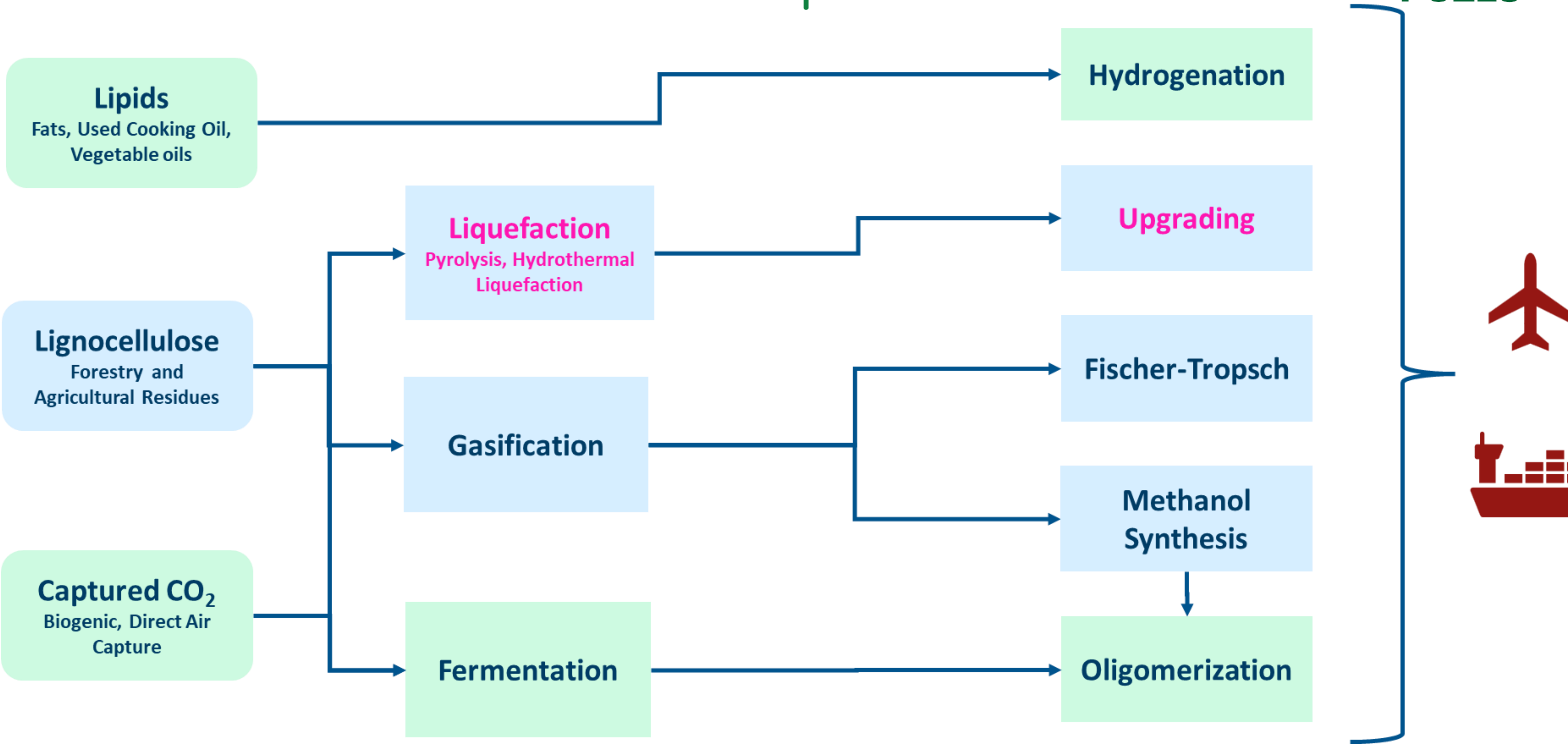
Norwegian Centre for Environmentfriendly Energy Research

Forestry dominates sustainable biomass resources in Norway

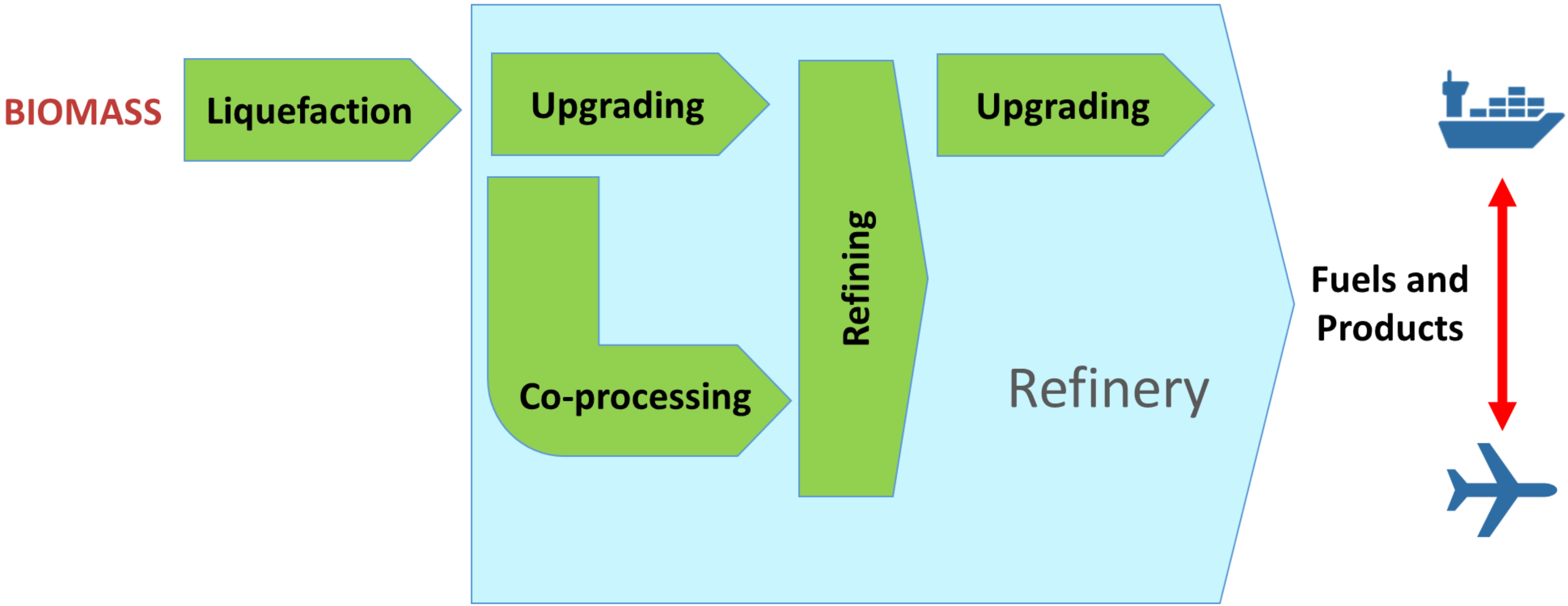
78% of the 33 TWh of theoretical available biomass for energy applications in 2024

https://www.enova.no/nb/bedrift/industri/hvor-mye-baerekraftig-biomasse-har-vi-i-norge-til-energiformal

Selected routes to Sustainable Transport Fuels



Liquefaction routes with refinery integration



Multiple Processes relevant for Integration of bio-liquids in refinery

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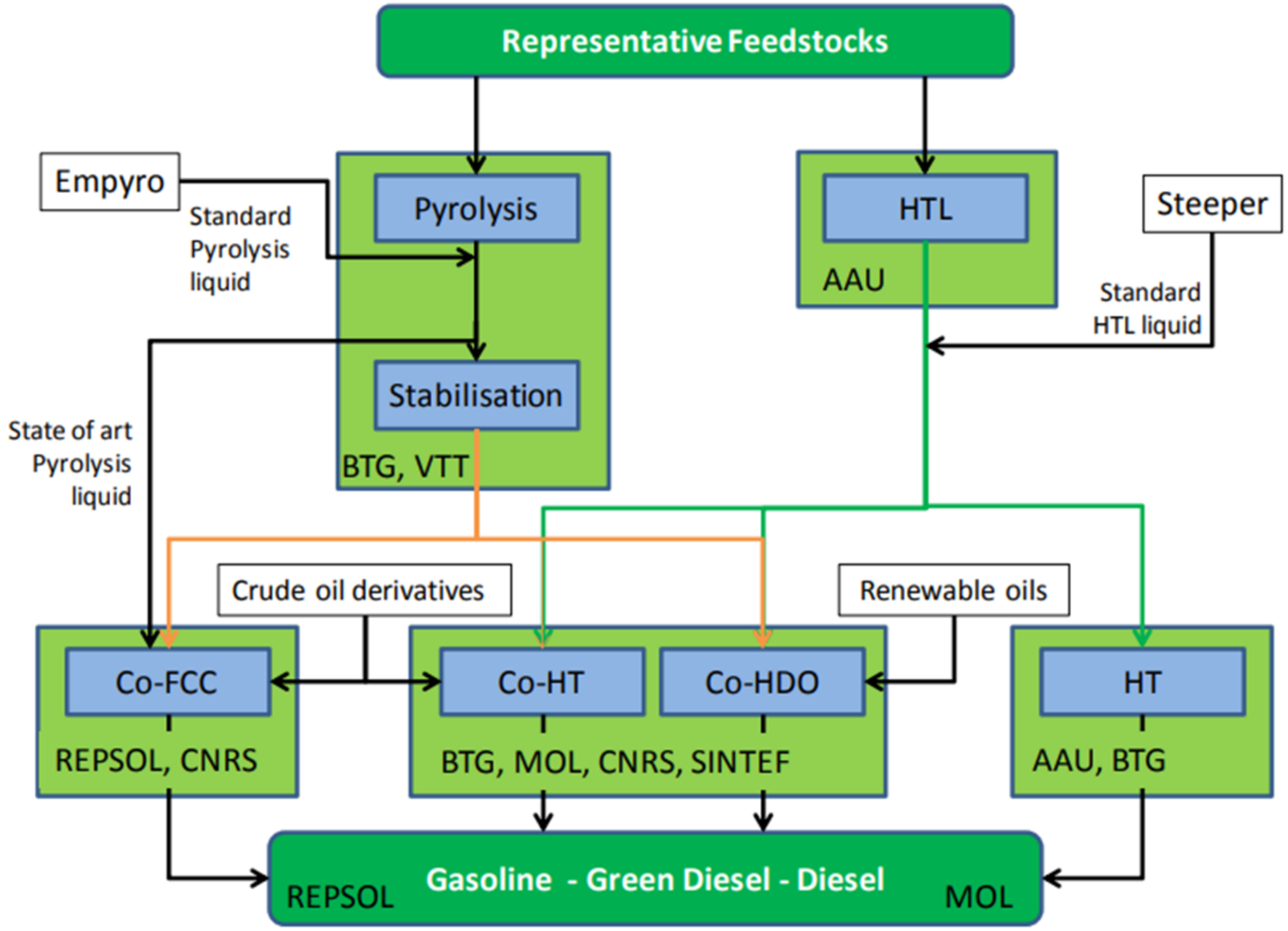
- Two primary conversion processes of biomass
  - Pyrolysis
  - HTL
- Four refining processes to upgrade the bio-liquids
  - Co-FCC
  - Co-HT
  - Co-HDO
  - HT
- Final products
  - Gasoline
  - Diesel
  - LPG

Drop in fuels



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Exhaustive evaluation of all potential pathways into refinery
Process and Techno-Economic models

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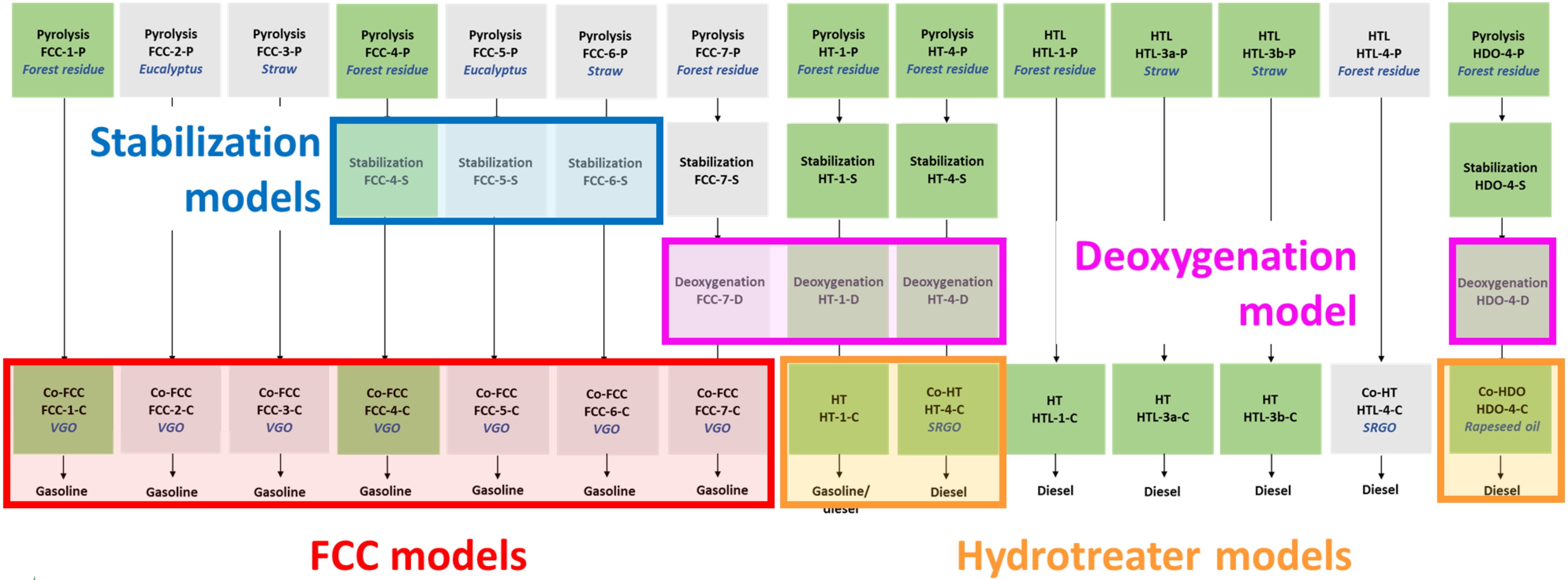
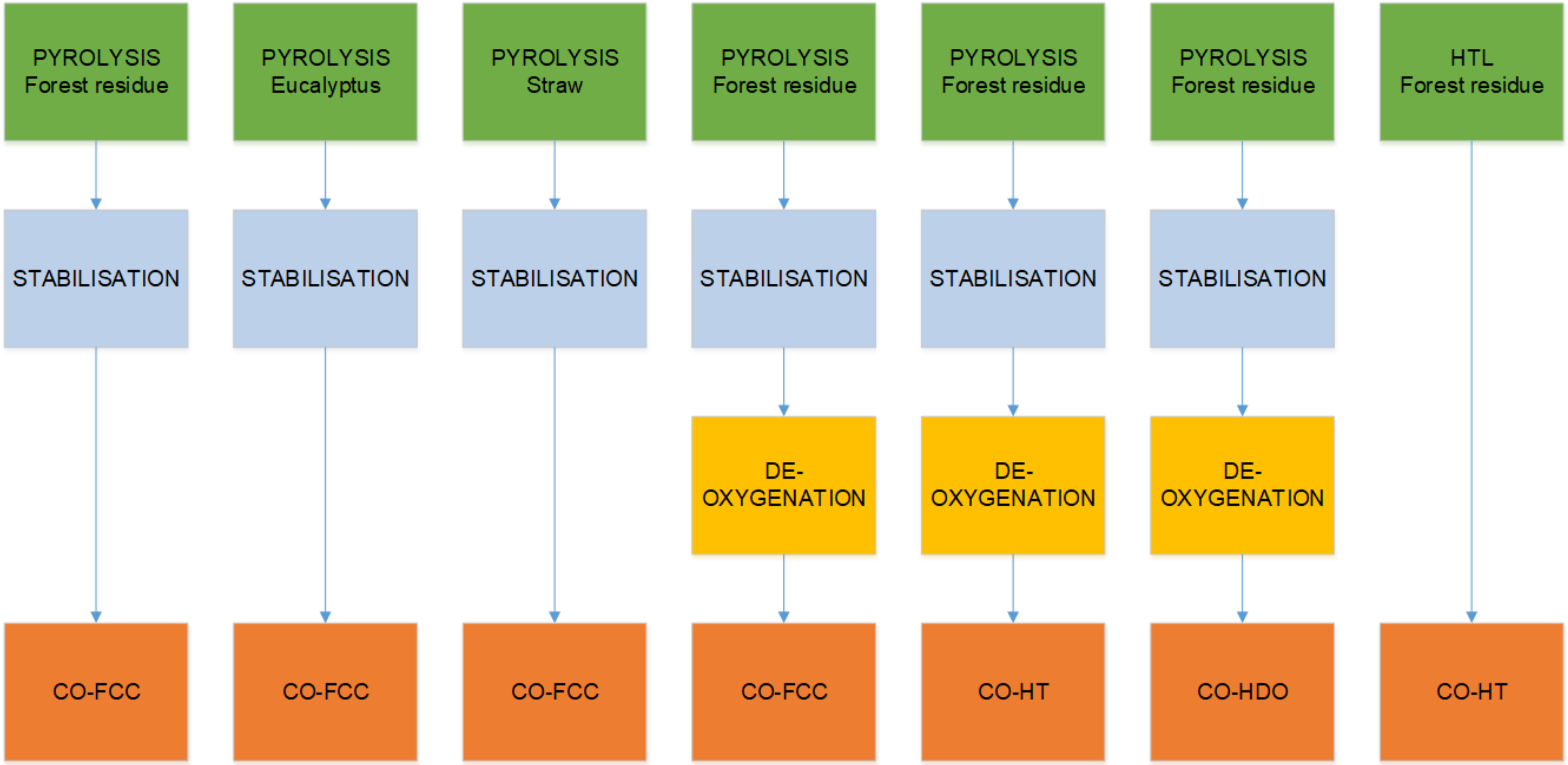


Prioritization of feedstock from different locations

- **Forest residue:**
  - Northern Europe
  - Baltics
- **Eucalyptus:**
  - Southwestern Europe (Spain)
- **Straw:**
  - Central Europe
  - Denmark



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Evaluating Business Cases

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Business Case	Raw Material	De-centralised Pre-processing	Refinery Processing	Product
FCC-1	Forest Residue	Fast Pyrolysis N plant(s)	FCC	Gasoline
HTL-1	Forest Residue		HTL 1 plant → HT	Diesel
HT-1	Forest Residue	Fast Pyrolysis N plant(s)	UPGR 1 plant → HT	Diesel

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Developing the most promising Business Cases

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Business Case	Raw Material	De-centralised Pre-processing	Refinery Processing	Product
FCC-1	Forest Residue	Fast Pyrolysis N plant(s)	FCC	REFOLUTION Unlocking the potential of biofuels
HTL-1	Forest Residue		HTL 1 plant → HT	Diesel
HT-1	Forest Residue	Fast Pyrolysis N plant(s)	UPGR 1 plant → HT	FuelUp

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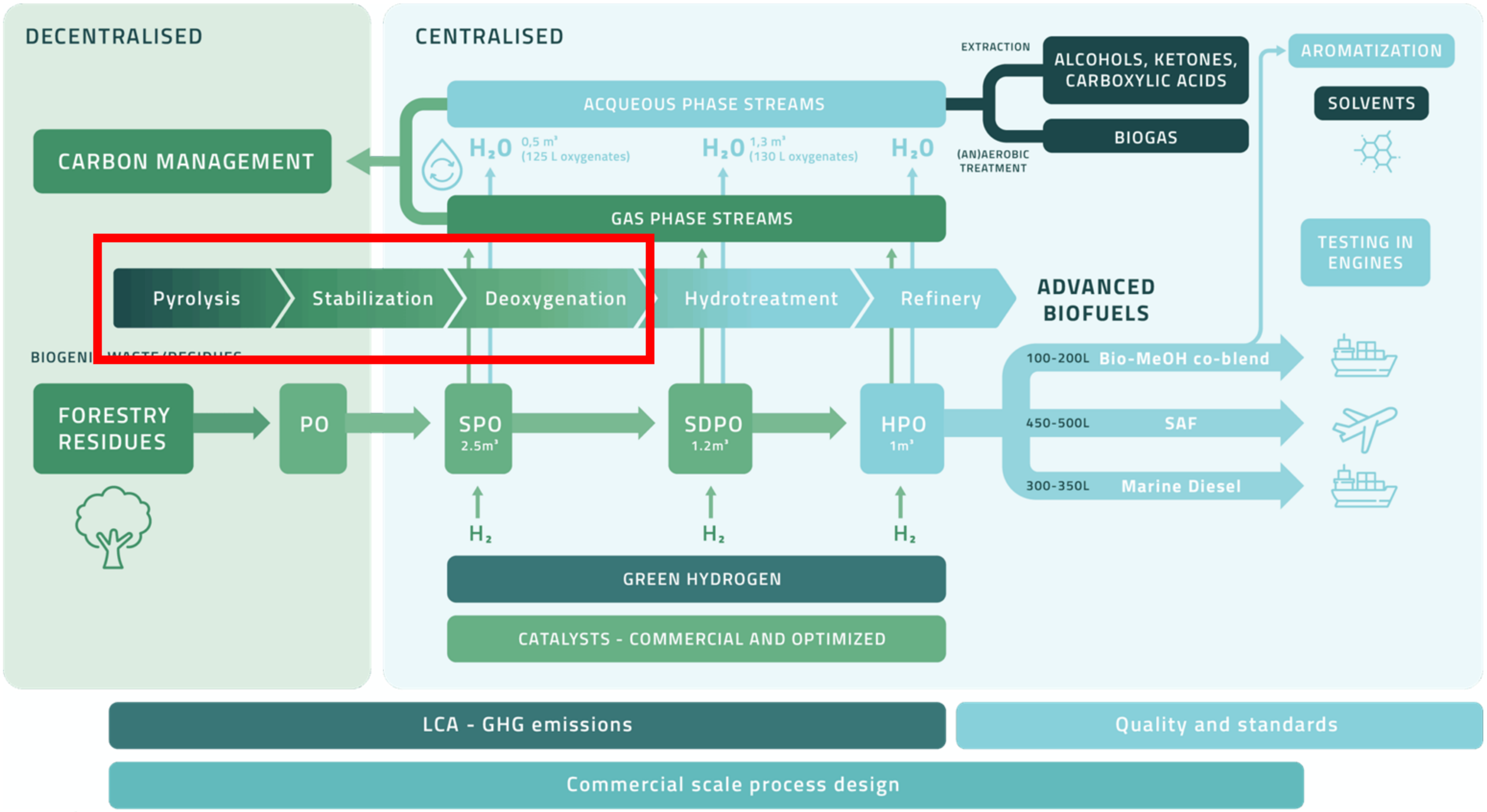
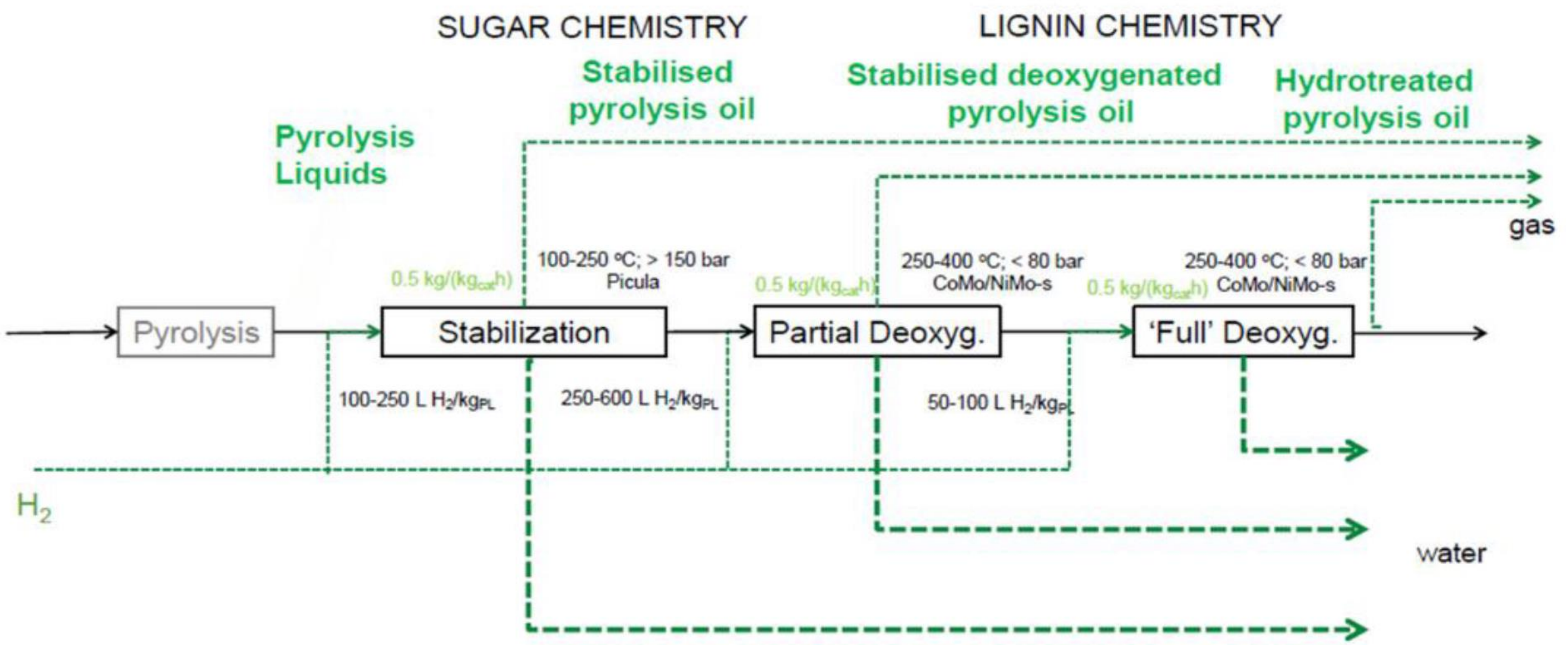
Total Concept for the Value Chain

Fuel Up



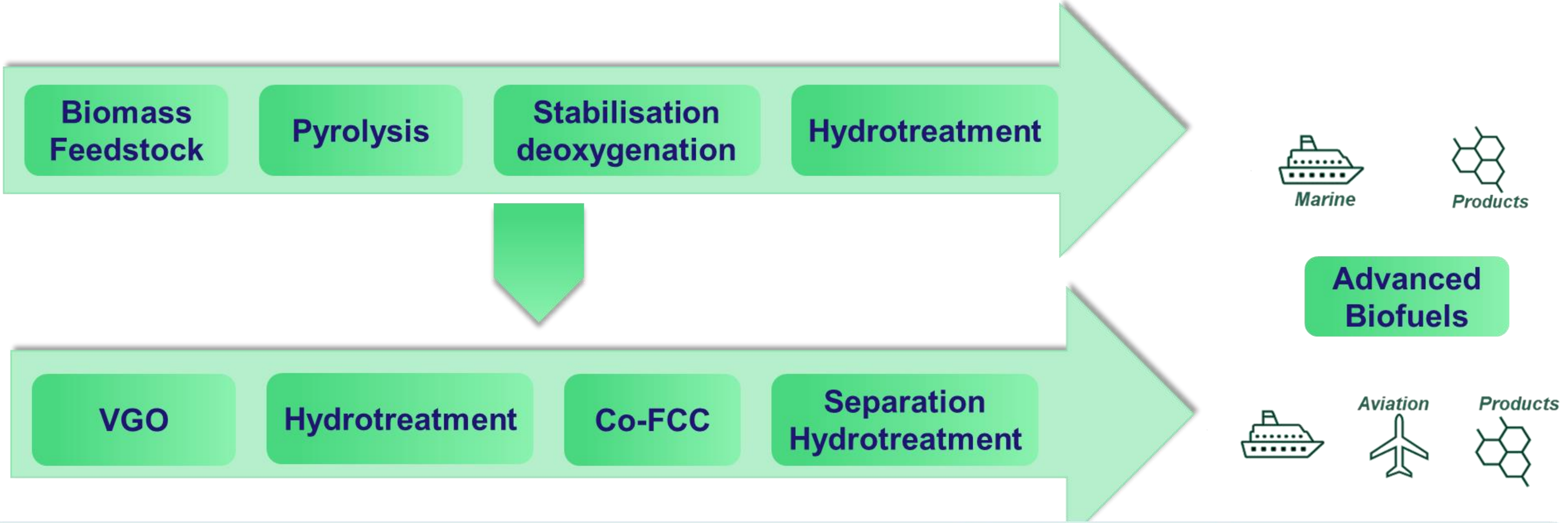
btg · btg-neXt advanced pyrolysis biofuel · Ranido · Tüpraş · DLR · Avecom Bioproducts & Apps · AristEng Greenergize your process! · eta · LIST · Ketjen · SINTEF

Understanding the Chemistry in the Process Steps



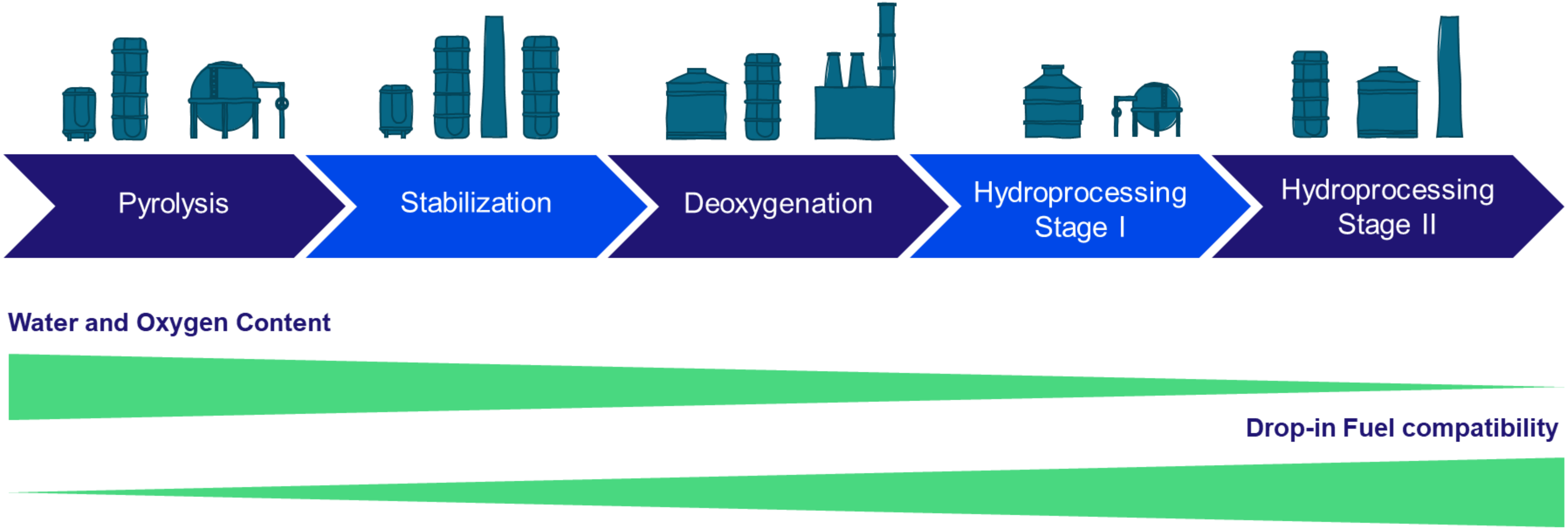
Alternatives of co-processing

REFOLUTION
Unlocking the potential of biofuels



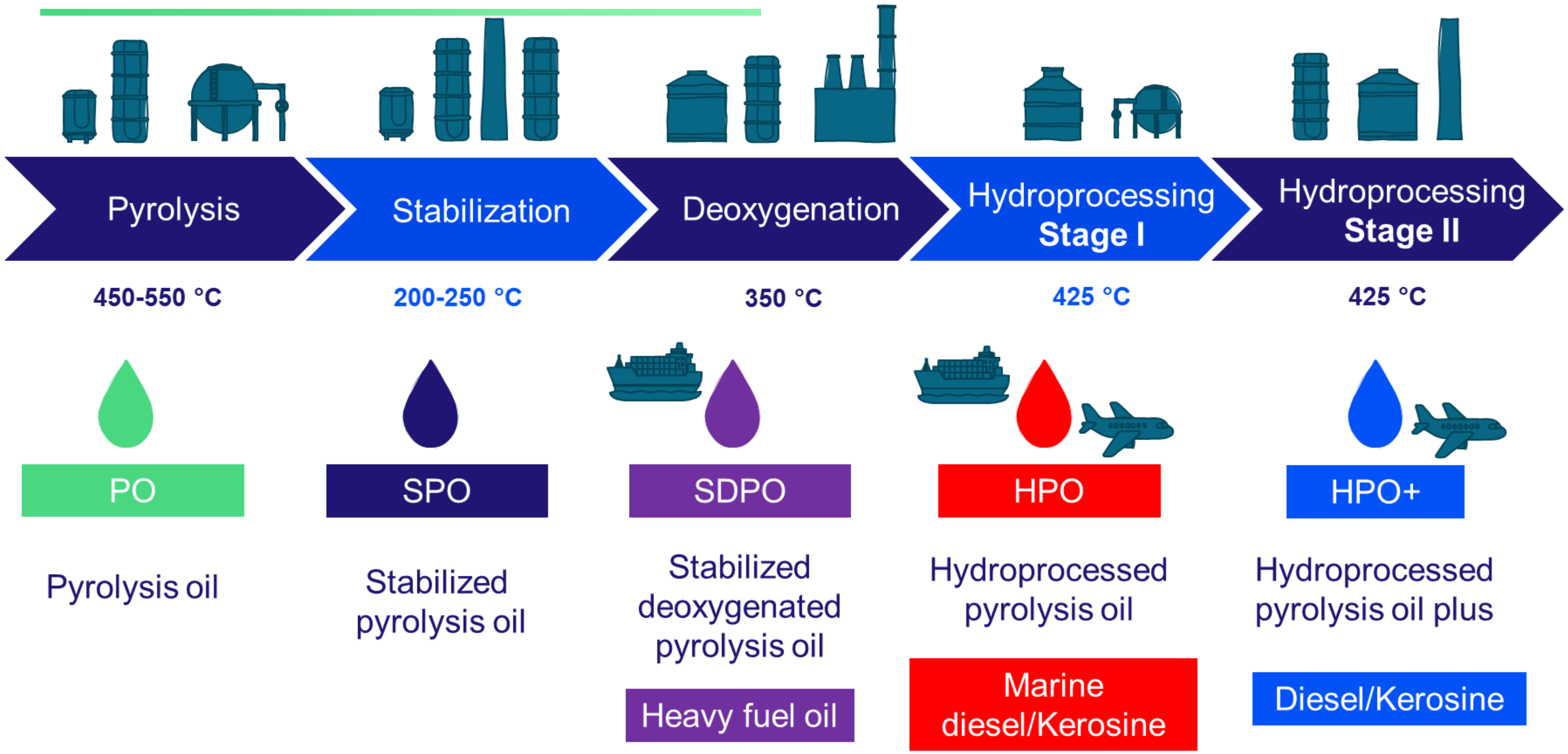
SINTEF · btg · NESTE · Universität Rostock · OMV · cnrs · etaflorence renewableenergies
VTT · btg bioliquids · btg-neXt advanced pyrolysis biofuel · moeve · DLR · GRACE · university of groningen

Attaining specifications for drop-in fuels

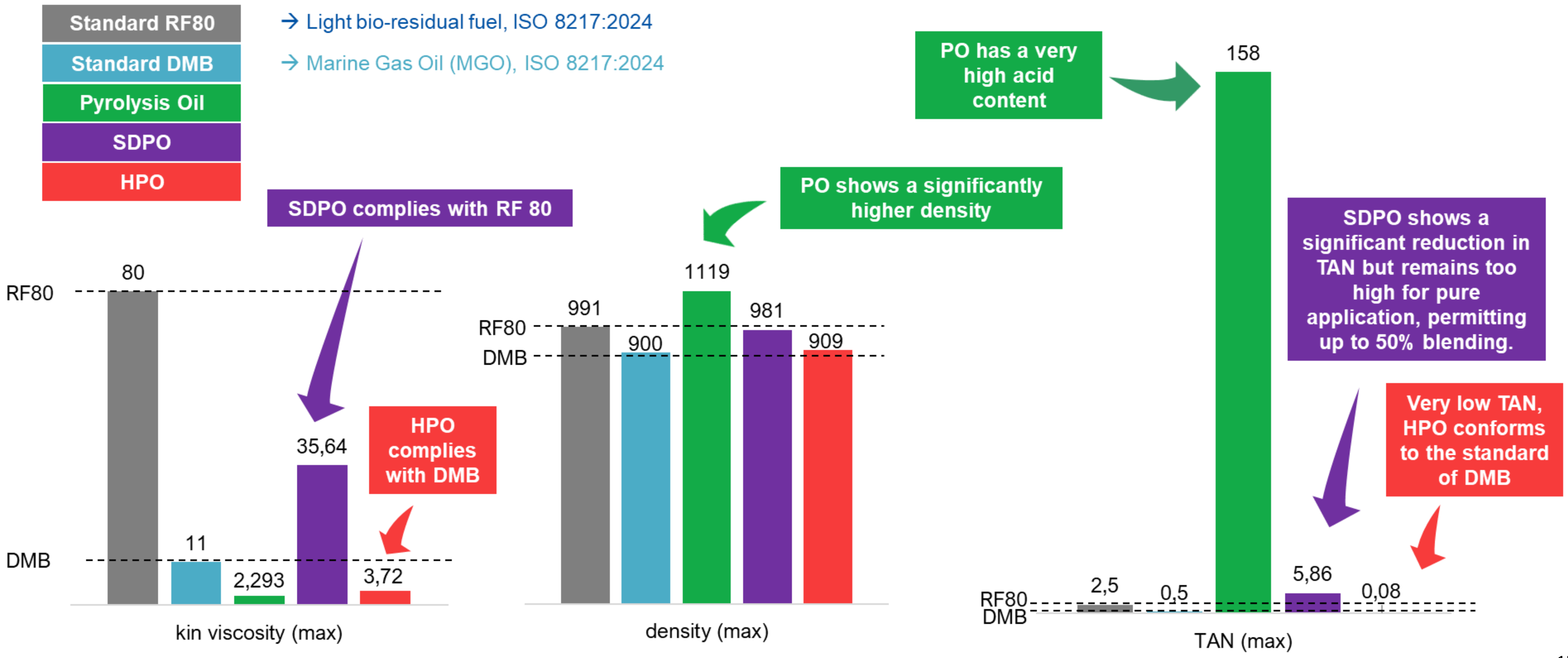


- Efficient **upgrading** is essential to **reduce oxygen content** and enhance fuel quality
- Oxygen content strongly influences **fuel stability**, **miscibility**, and **drop-in compatibility**

Upgrading steps



Benchmarking of Fuel Parameters



Optimisation of Fuel Parameters

HPO

Parameters	Unit	Standard DIN EN ISO 8217 DMB	REF0010 (distilled at flashpoint)	REF0011 (distilled at flashpoint)	REF0021 (distilled at flashpoint)	(distilled at flashpoint)
Density (max)	kg/m^3	900	900.0	878.7	891.4	908.9
Kin. Viscosity at 40°C	mm^2/s	-	4.12	4.33	3.99	4.72
Kin. Viscosity at 50°C (min/max)	mm^2/s	2.0-11.0	3.29	3.44	3.26	3.72
Water content (max)	ppm	30,000	31	16	24	28
Total acid number (max)	mg KOH/g	0.5	0.06	0.05	0.05	0.08
Oxidation stability	h	-	-	7.04	>48	-
Flash Point (min)	°C	60	78	82	61	75.6
Cloud Point	°C		-21.4	-21.7	-34.5	-31.3
Pour Point (max)	°C	6	-21	-21	-36	-33
Sulphur content	ppm	0.1 (SECA)	<1	<1	<1	<1

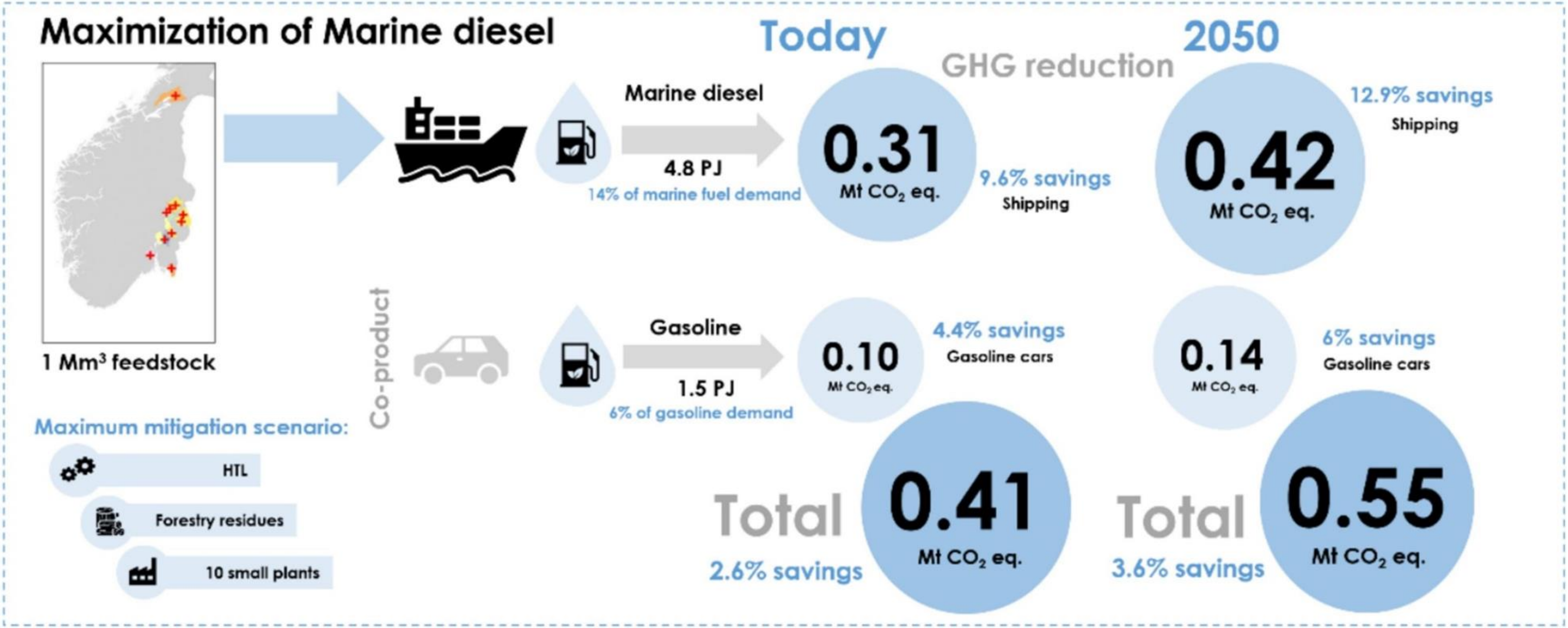
HPO: Fully compliant with ISO 8217 (DMB); excellent drop-in compatibility with marine diesel and FAME.

SDPO

Parameters	Unit	Standard DIN EN ISO 8217 RF80	BTG 2024-2956, REF0070 (distilled at flashpoint)
Density	kg/m^3	991	981
Kin. Viscosity at 40°C	mm^2/s	-	64.3
Kin. Viscosity at 50°C	mm^2/s	20.0-80.0	35.6
Water content	ppm	50,000	108.5
Total acid number	mg KOH/g	2.5	5.86
Flash Point	°C	60	80.6

SDPO: Meets new ISO 8217 (RF80) criteria; slightly elevated acid number, but blending up to 50 % would be possible.

Full value chain assessment of climate impact in Norway for liquefaction value chain



Vedant Ballal[a,*], Marcos Djun Barbosa Watanabe[a], Matteo Gilardi[b], Eirik Ogner Jåstad[c], Per Kristian Rørstad[c], Bo Huang[a], Marvin Werra[a], Filippo Bisotti[b], Bernd Wittgens[b], Francesco Cherubini[a]

Energy Conversion and Management, 327 (2025) 119586

Summary

Liquefaction routes produce drop-in fuels with promising results for optimisation for Marine fuels and Marine fuel blends

Integration with existing refinery processes provides options for using existing infrastructure with potential for achieving production at scale

Acknowledgements

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Horizon Europe Grant agreement no. 101075503.

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REFOLUTION Unlocking the potential of biofuels

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FuelUp


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