The potential and challenges of drop-in biofuels production
2018 update

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Forest Products Biotechnology/Bioenergy Group

International Energy Agency Bioenergy Task 39 (Liquid biofuels)

Task 39
IEA Bioenergy

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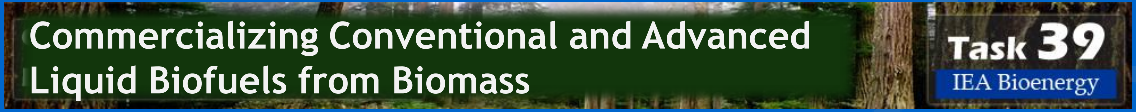

Commercializing Conventional and Advanced Liquid Biofuels from Biomass

Task 39
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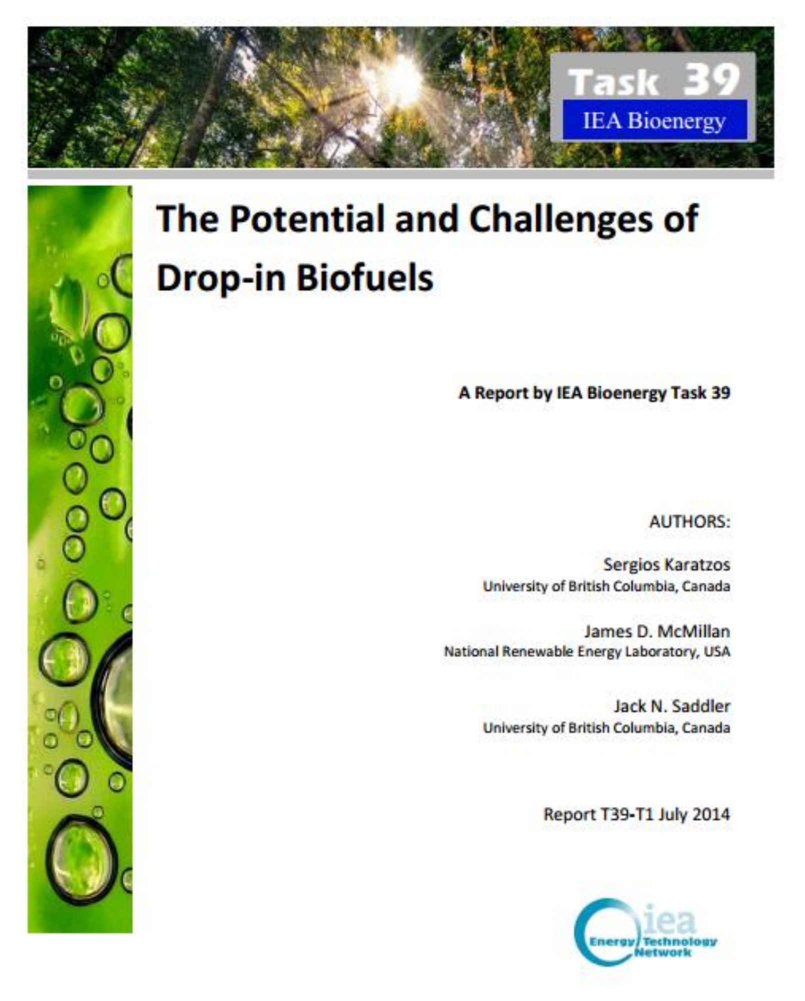

The Potential and Challenges of Drop-in Biofuels

A Report by IEA Bioenergy Task 39

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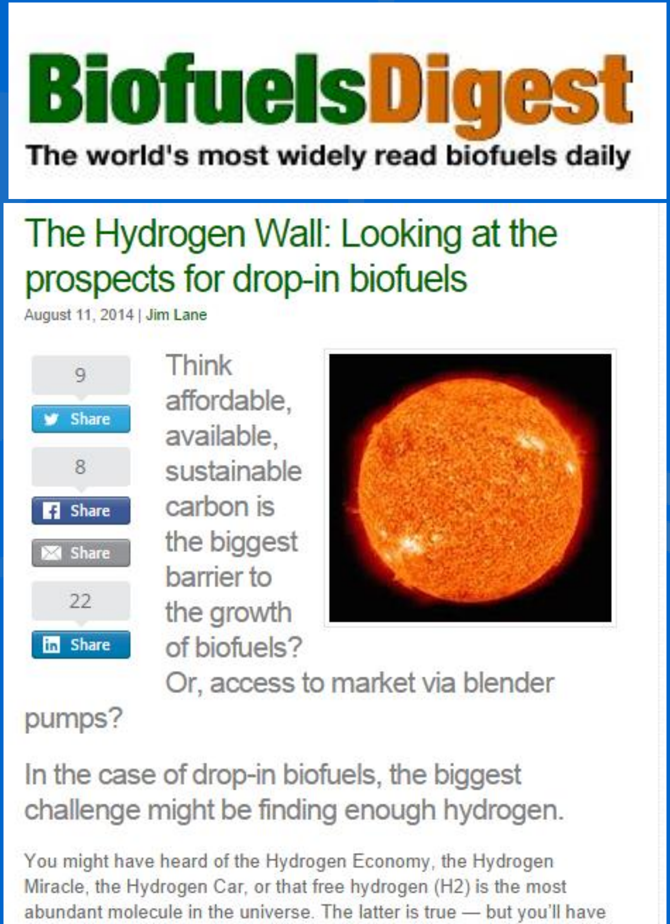


BiofuelsDigest
The world's most widely read biofuels daily

The Hydrogen Wall: Looking at the prospects for drop-in biofuels

August 11, 2014 | Jim Lane

Think affordable, available, sustainable carbon is the biggest barrier to the growth of biofuels?
Or, access to market via blender pumps?

In the case of drop-in biofuels, the biggest challenge might be finding enough hydrogen.

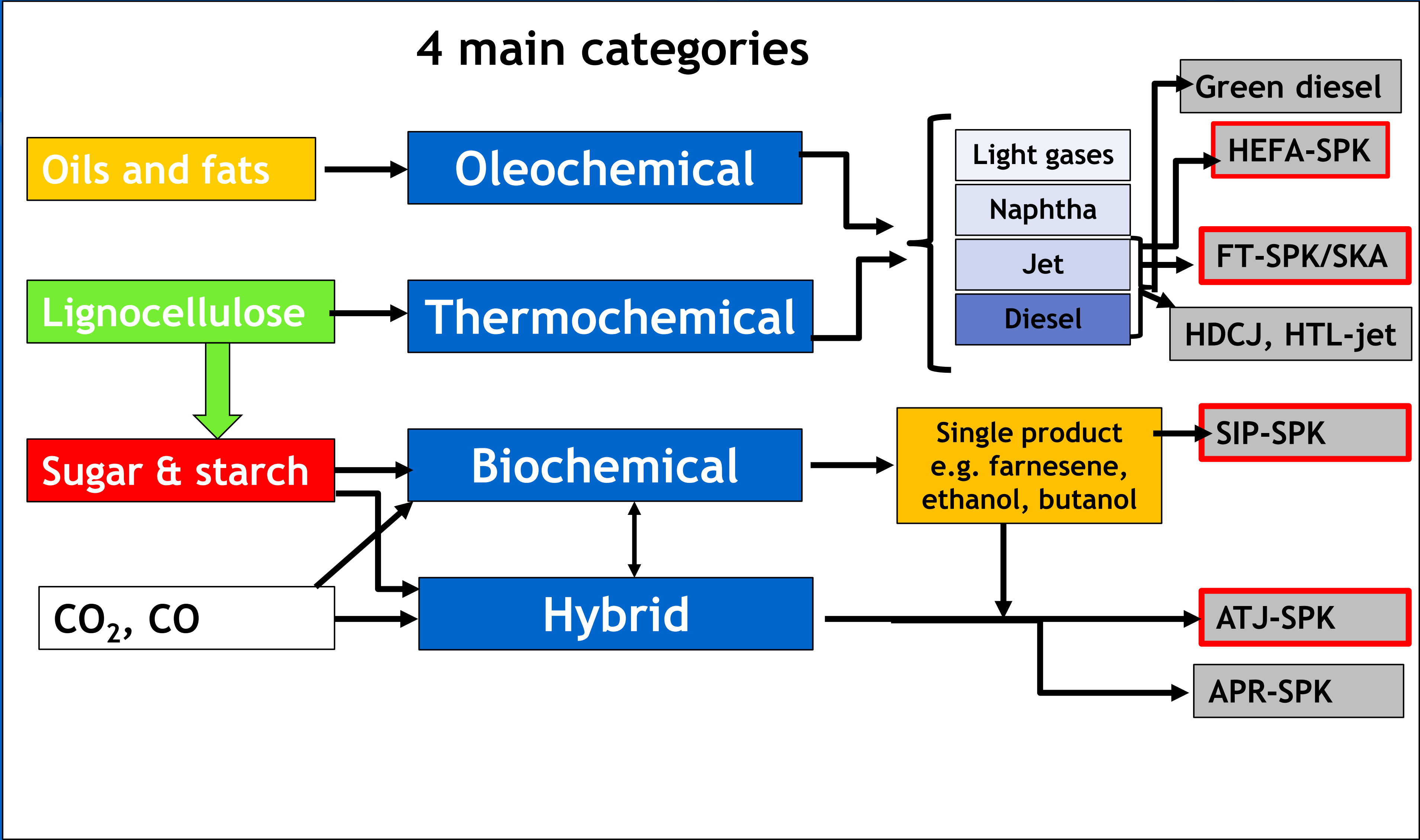
You might have heard of the Hydrogen Economy, the Hydrogen Miracle, the Hydrogen Car, or that free hydrogen (H2) is the most abundant molecule in the universe. The latter is true — but you'll have

Definition of “drop-in” biofuels

- Drop-in biofuels: are “liquid bio-hydrocarbons that are:
    - functionally equivalent to petroleum fuels and
    - fully compatible with existing petroleum infrastructure”

- Definition still applicable – does not mean that the drop-in biofuel on its own will meet all the specifications for a specific fuel product. Sometimes blending required

Technologies for drop-in biofuel production



4 main categories

Oleochemical drop-in biofuel platform

- Main source of commercial drop-in biofuels (~5 BL)
  - Renewable diesel
  - HEFA biojet fuel (AltAir)
- Key trends
  - Conversion of existing refineries into HEFA biorefineries
    - AltAir (USA), ENI (Italy), Total (France), Andeavour (USA)
  - Move towards more sustainable feedstocks (waste & other) – increase in trade of UCO & tallow
  - Co-processing of lipids (ASTM approved for biojet)
- Key drivers & challenges
  - Policy e.g. low carbon fuel standards (California, BC)
  - Demand from aviation industry for biojet
  - Feedstock cost and availability

Thermochemical technologies

- Gasification based technologies
- Key trends
  - Plasma gasification – key projects cancelled e.g. Solena (technology too expensive although cleanest syngas)
  - Entrained (for slurries) or fluidized bed technologies
  - Municipal solid waste as cheap feedstock is a key trend
    - Enerkem commercial for methanol/ethanol production
    - Fulcrum Bioenergy (under construction - 2020) – FT liquids still need processing
  - Wood as feedstock – Kaidi (Finland), Red Rock Biofuels (USA)
- Key drivers & challenges
  - Policy
  - Aviation industry demand
  - Feedstock cost & supply chains

Thermochemical technologies

- Thermochemical liquefaction – pyrolysis, hydrothermal liquefaction
- Key trends
  - Fast pyrolysis, BTG, Ensyn – stabilization of bio-oil; progress in co-processing; multi-product focus (char & bio-oil)
  - Catalytic pyrolysis – KiOR closure; low yields; economics challenging
  - Hydrothermal liquefaction – slow progress towards commercialization (Steeper, Licella) – but co-processing of liquid products emerging as a key strategy
  - Plastics & waste as a feedstock
- Key drivers and challenges
  - Incorporation of co-processing under policies (California, BC)

Biochemical & hybrid technology platforms

- Key trends
    - Most companies move away from biofuels towards biochemicals and bioplastic building blocks
    - Except alcohol to jet pathways – Gevo (isobutanol to jet) & Lanzatech (ethanol to jet) – both pathways received ASTM certification for biojet
    - Power to Liquids (PtL) becoming a key focus in Europe

- Key drivers
    - Aviation sector and shortage of biojet fuels
    - ASTM certification created instant access to biojet market
    - PtL driven by 100% decarbonization in transport

Commercial volumes of drop-in biofuel through oleochemical platform

Neste Oil facility, Rotterdam

Company	Feedstock	Billion L/y
Neste (4 facilities)	mixed	2.37
Diamond Green Diesel	tallow	0.49
REG Geismar	tallow	0.27
Preem Petroleum	Tall oil	0.02
UPM biofuels	Tall oil	0.12
ENI (Italy)	Soy & other oils	0.59
Cepsa (Spain 2 demo facilities)	unknown	0.12
AltAir Fuels	mixed	0.14
World Total		4.12

Co-processing as a key strategy to expand drop-in biofuel production?

- Build stand-alone infrastructure
- Co-location (hydrogen)
- Repurpose existing infrastructure (e.g. AltAir in California)
- Co-processing of biobased intermediates in existing refineries to produce fossil fuels with renewable content (lower carbon intensity)

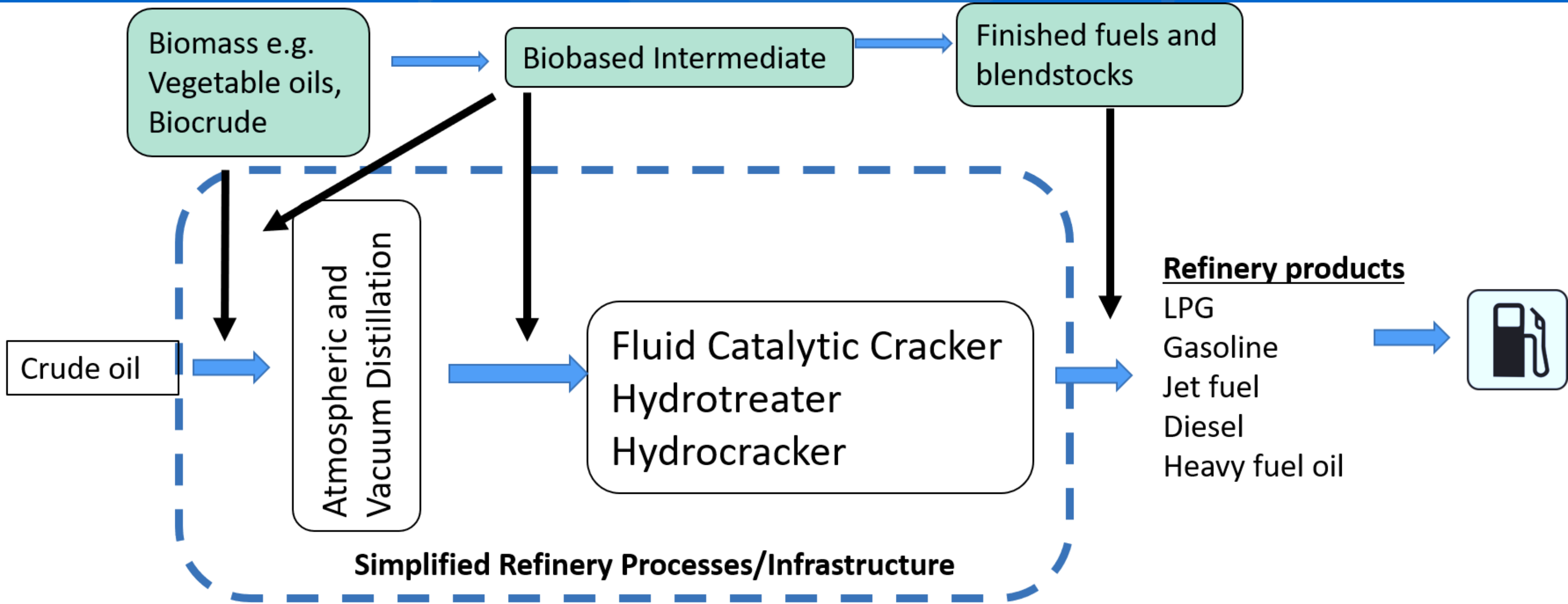
Risk **Capital**

Decarbonisation through co-processing

Refinery participation is the key!

Potential insertion points of biobased intermediates

1. Atmospheric distillation – highest risk of contamination
2. Processing/finishing steps – FCC, hydroprocessing
3. Blending stage – Lowest risk



Biomass e.g. Vegetable oils, Biocrude

Biobased Intermediate

Finished fuels and blendstocks

Crude oil

Atmospheric and Vacuum Distillation

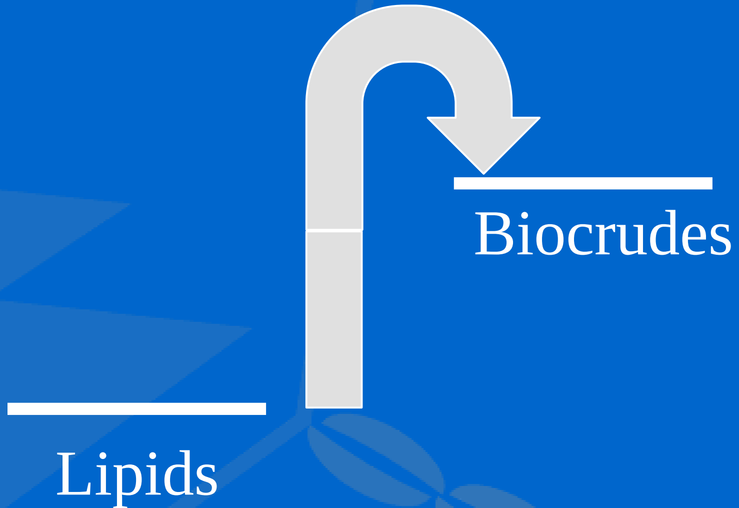
Fluid Catalytic Cracker
Hydrotreater
Hydrocracker

Refinery products
LPG
Gasoline
Jet fuel
Diesel
Heavy fuel oil

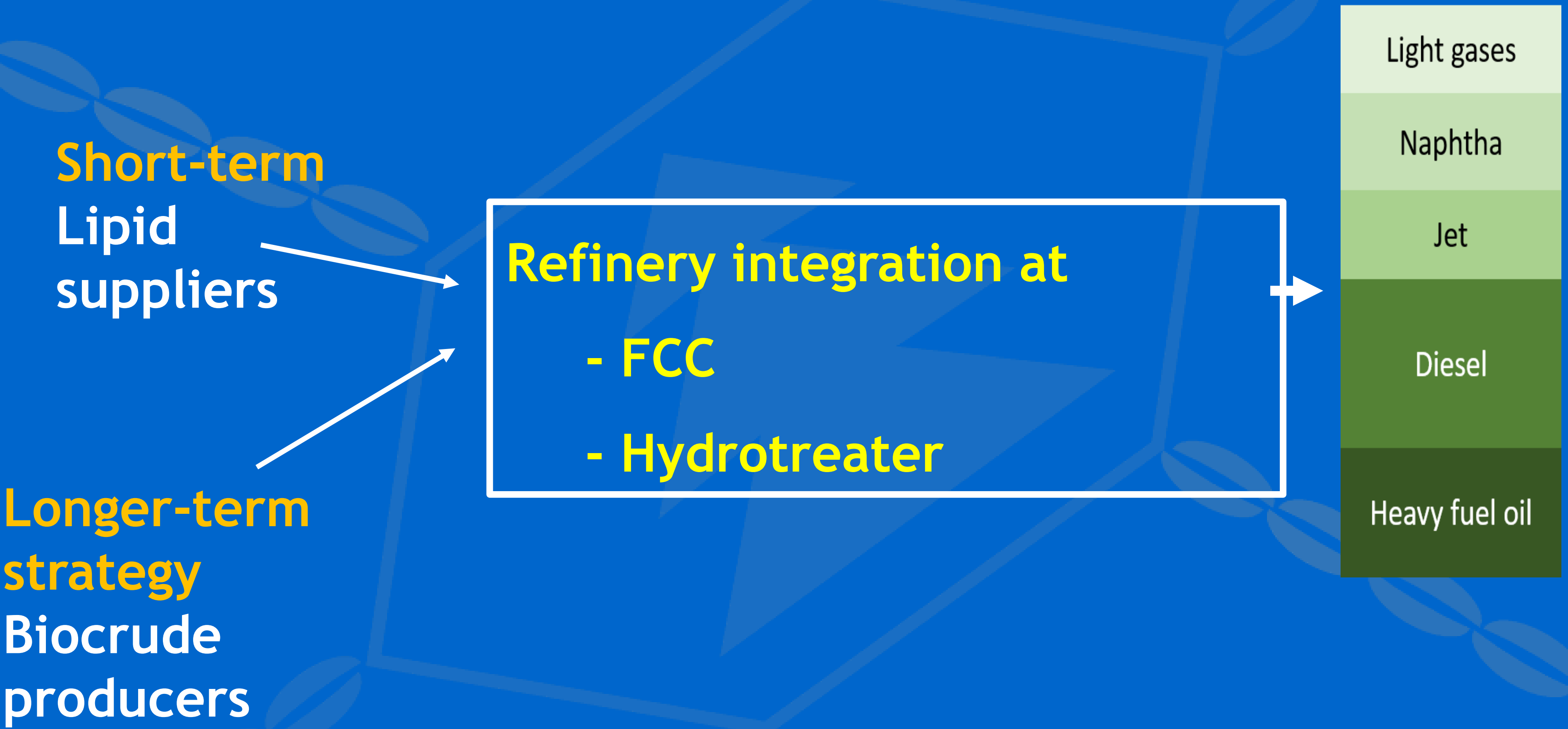
Simplified Refinery Processes/Infrastructure

Lipids will be the initial biobased intermediate inserted into the refinery, followed by biocrudes

- Lipids easier to upgrade
- Lipids readily available (although expensive)
- Experience and derisking with a simpler feedstock to create familiarity with biobased intermediates until cheaper biocrudes become available in high volumes



Facilitating Refinery integration and co-processing



Short-term
Lipid suppliers

Longer-term strategy
Biocrude producers

Refinery integration at

- FCC
- Hydrotreater

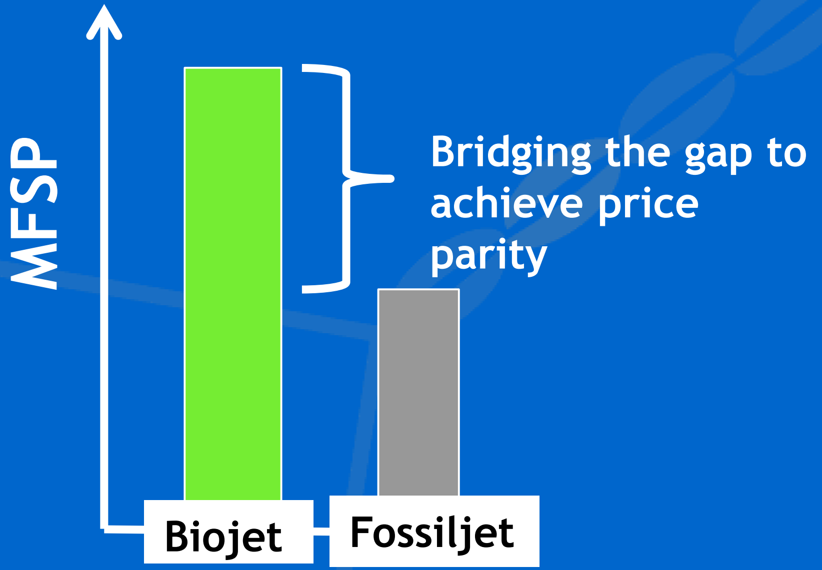
Light gases
Naphtha
Jet
Diesel
Heavy fuel oil

Tracking renewable content during co-processing

- C14 isotopic method
- Potential mass balance approach
  - Total mass balance method
  - **Mass balance based on observed yields**
  - **Carbon mass balance method**

(CARB, 2017)

Role of policy



- Policy has been essential for development of conventional biofuels
- Blending mandates, Subsidies, Tax credits, market based measures (carbon tax, low carbon fuel standards)

- Drop-in biofuels will find it challenging to compete at current oil prices
- Policy to assist in bridging this price gap
- Specific policy support for drop-in fuels

Some conclusions

- Important role of policy to drive development

- Co-processing and refinery integration
  - Drop-in biofuel production more similar to oil refining
  - Multiple products
  - Similar upgrading

- Search for cheaper and more sustainable feedstock

- Demand for biojet fuels playing an important role in driving drop-in biofuel development

Future Work: co-processing of "oleochemicals /biocrudes" in petroleum refineries

- Refinery configuration and potential co-processing insertion points
- Types of biobased intermediates, commercial availability and volumes
- Development of technical standards for biobased intermediates based on different refinery insertion points
- Technical challenges of co-processing based on different insertion points, including the Fluid Catalytic Cracker and Hydrotreater
- Tracking the renewable content of biogenic carbon into solid, liquid and gaseous fractions
- Specific policies to accommodate and incentivize refinery co-processing
- Life cycle assessment and analysis of co-processing and benefits;
- Techno-economic analysis of co-processing

Future Work: Low-carbon drop-in biofuels for long distance transport sectors

- Build on the knowledge developed by IEA bioenergy Task 39 on the potential and challenges of drop-in biofuels
- Develop and refine decarbonisation strategies based on greater use of low carbon drop-in biofuels for long distance transport sectors including aviation, marine, rail and trucking
- Assess the technology readiness, supporting policies and sustainability of low carbon biofuels and to identify the challenges and opportunities to produce commercial volumes of these biofuels in a sustainable and cost-efficient manner