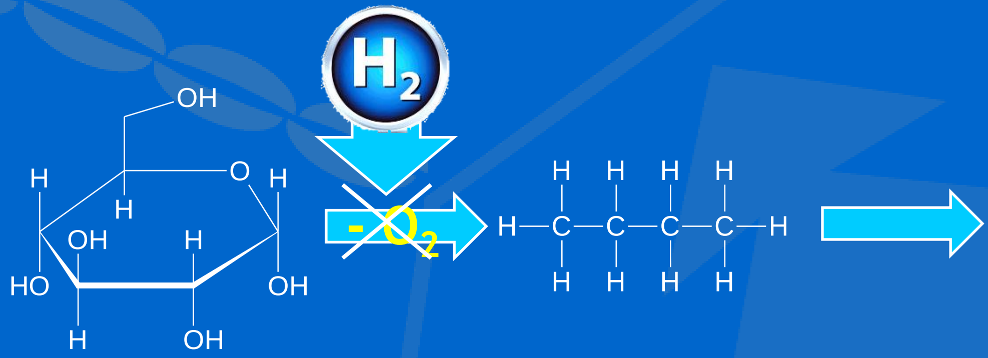
The potential and challenges of "drop in" biofuels



Carbohydrate Hydrocarbon

Sergios Karatzos, Jim McMillan and Jack Saddler
International Energy Agency Bioenergy Task 39 (liquid biofuels)

Forest Products Biotechnology/Bioenergy (FPB/B)

UBC NREL NATIONAL RENEWABLE ENERGY LABORATORY Task 39 IEA Bioenergy

Commissioned Task 39
'drop in' biofuel report

- OVERVIEW
  - Definition
  - Role of Hydrogen in drop in biofuels
  - Role of Hydrogen in petroleum industry

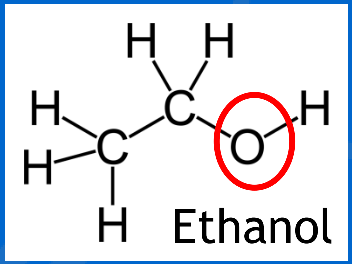
- TECHNOLOGIES

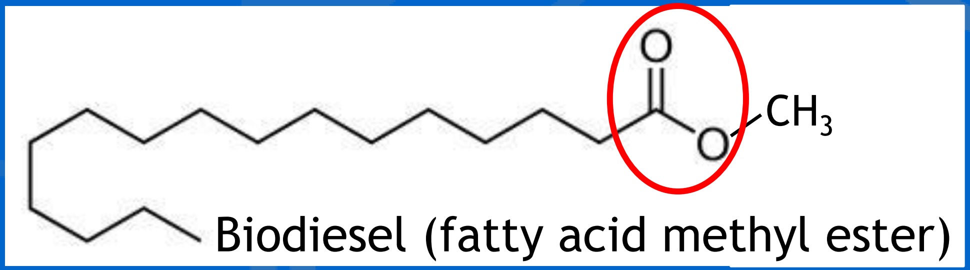
Definition of a "drop-in" biofuel

- Bioethanol: Biogenic ethyl alcohol
- Biodiesel: Fatty acid methyl esters (FAME)
- Drop in Biofuels: Liquid bio-hydrocarbons that are functionally equivalent to petroleum fuels and as such compatible with existing petroleum infrastructure.
- Examples:
  - Hydrotreated Vegetable Oils (HVO)
  - Hydrotreated Pyrolysis Oils (HPO)
  - Fischer Tropsch Liquids (FT liquids)

Oxygen Challenge

- Oxygen is present in biomass in the form of hydroxyls, esters, and ethers
- Can oxidize fuel components, reactors and pipeline metallurgy to cause corrosion
- Oxygen content reduces energy density





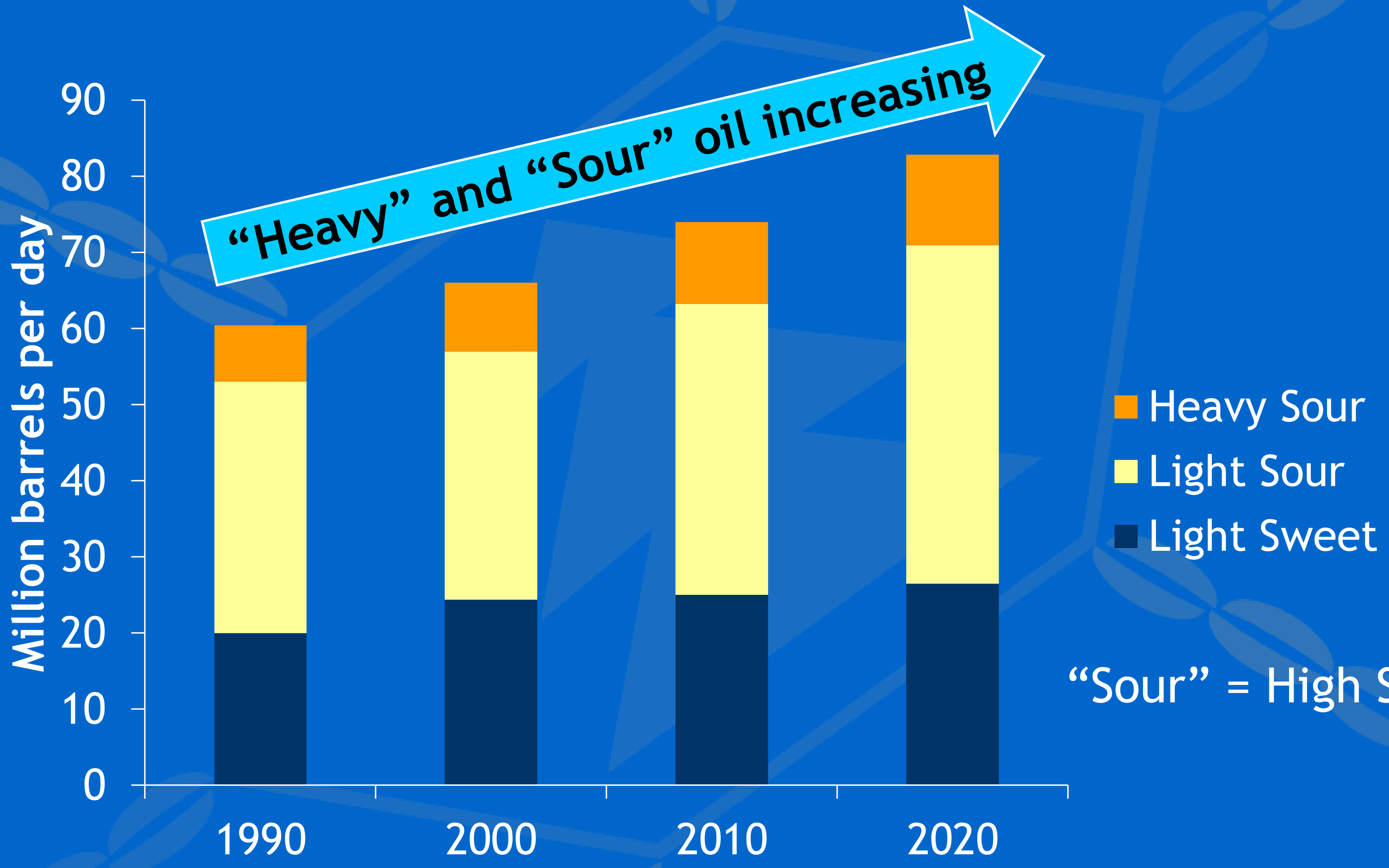
The Hydrogen-Oxygen dilemma

- "Drop-in biofuels" is a loose term referring to liquid biofuels containing low or no oxygen content
- Deoxygenation requires hydrogen inputs or "oxidizing/burning" of feedstock carbon
- High H/C_{eff} ratio feedstocks such as lipids are well suited for drop-in biofuel production

What will determine the success of “drop in biofuels”?

- Drop-in biofuel technologies complexity and hydrogen demand
- Commercialization challenges such as capital, yield and refinery insertion
- Crude oil is becoming increasingly hydrogen deficient (‘heavier’ and ‘sourer’)

Crude oil quality declining…



"Sour" = High Sulfur

Purvin & Gertz forecast for world crude oil quality (Source: data from EIA)

Future competition for Hydrogen inputs…

- Heavy oil processing

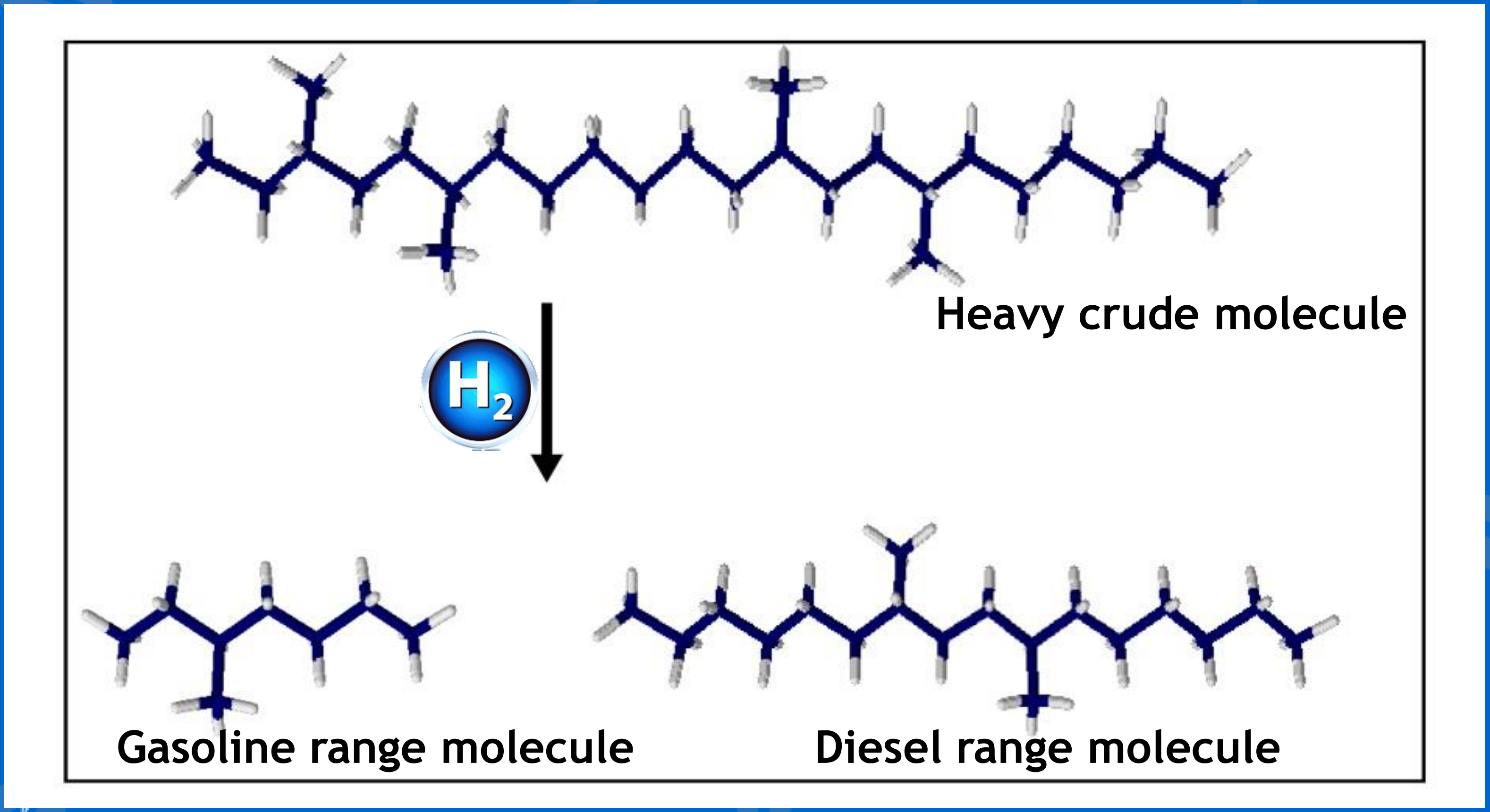
e.g.

Venezuela and Alberta

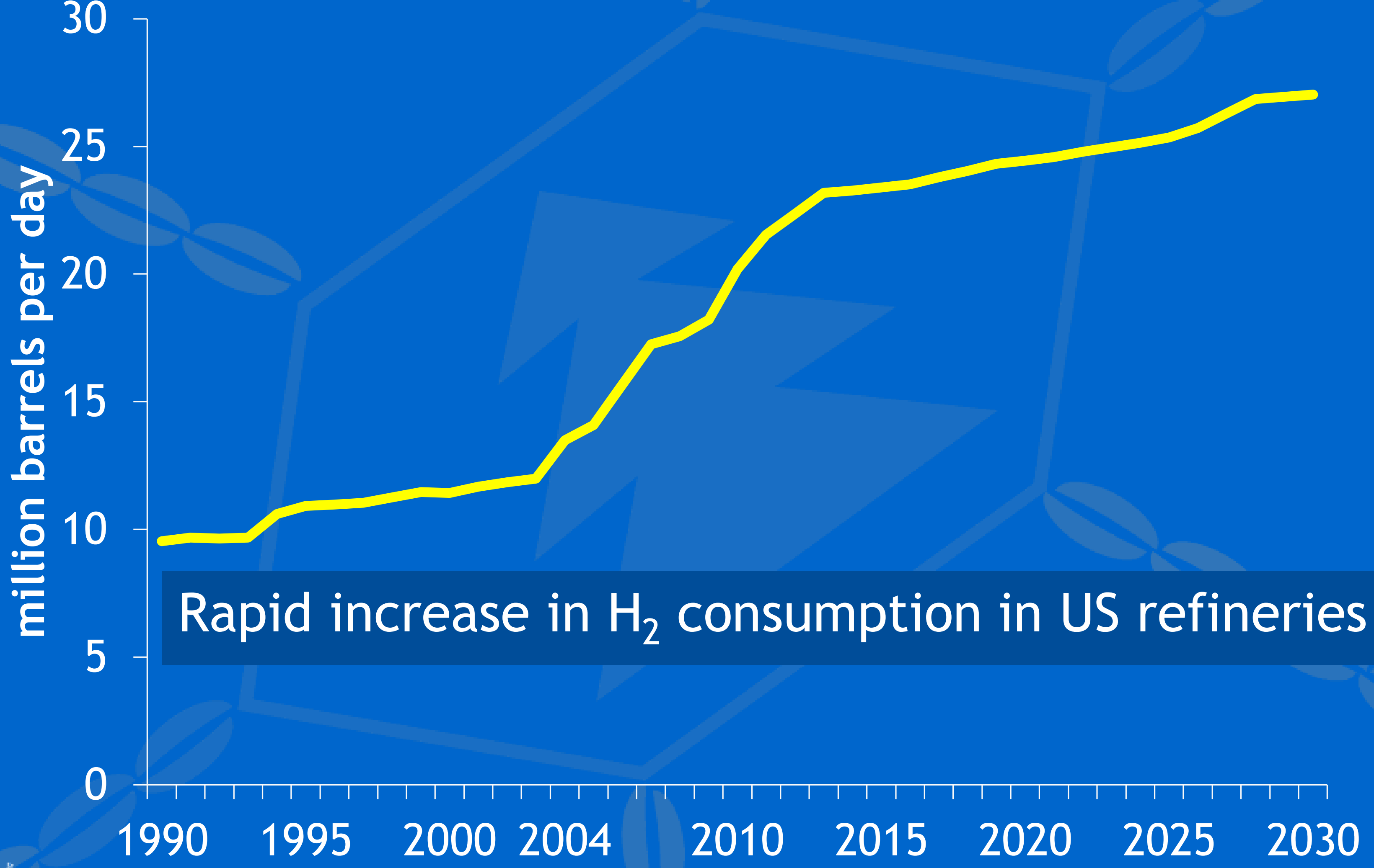
- Ammonia industry
- Drop-in biofuels?

Hydrotreating and Hydrocracking

- Hydrotreating (Removes sulfur impurities as H_2S)
- Hydrocracking (breaks heavy oil to lighter molecules)



US Hydrotreating capacity 1990-2030



Source EIA, Annual Energy Outlook 2006

Natural gas: Where H_2 comes from

- 90 % of commercial H_2 comes from <u>steam reforming natural gas</u>

ENERGY INTENSIVE PROCESS!!

Role of H_2 in upgrading petroleum and drop-in biofuels

Petroleum

- Increasing Sulfur content
- Increasing heavy oil needs cracking

Drop-in Biofuels

- No Sulfur
- High Oxygen content of feedstock needs hydrogenation

Both require Hydrogen for upgrading to finished fuels

Hydrogen will likely come from Natural Gas

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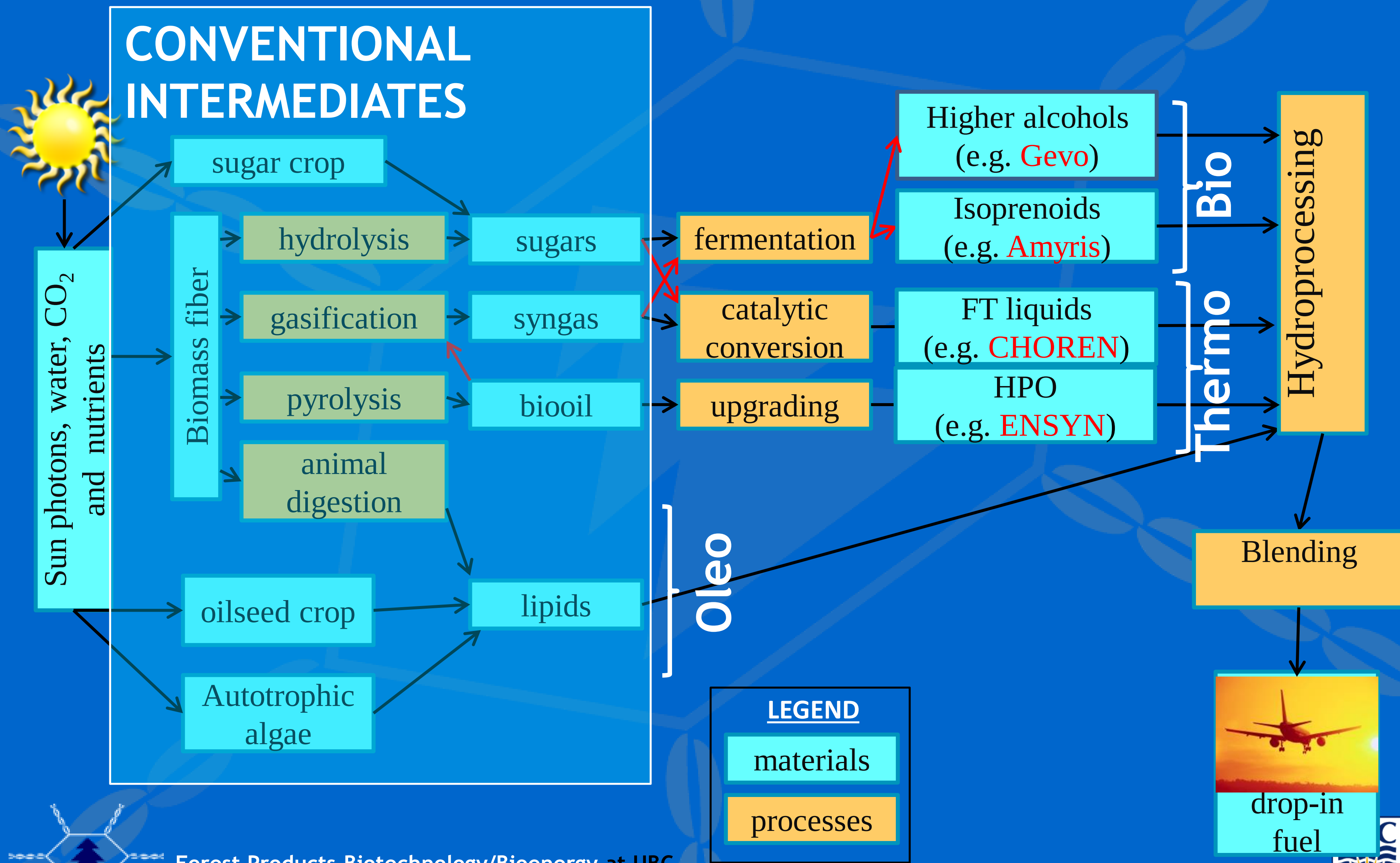
The commercialization potential of Drop in Biofuel platforms and their H_2 dependence

- Oleochemical (HVO, algae)
- Thermochemical (Pyrolysis - HPO, Gasification FT-liquids)
- Biochemical (Advanced Fermentation)
- Hybrid platforms (e.g. Virent, Zeachem, Lanzatech)

Technology pathways to “drop-in”



Commercial drop-in biofuel companies

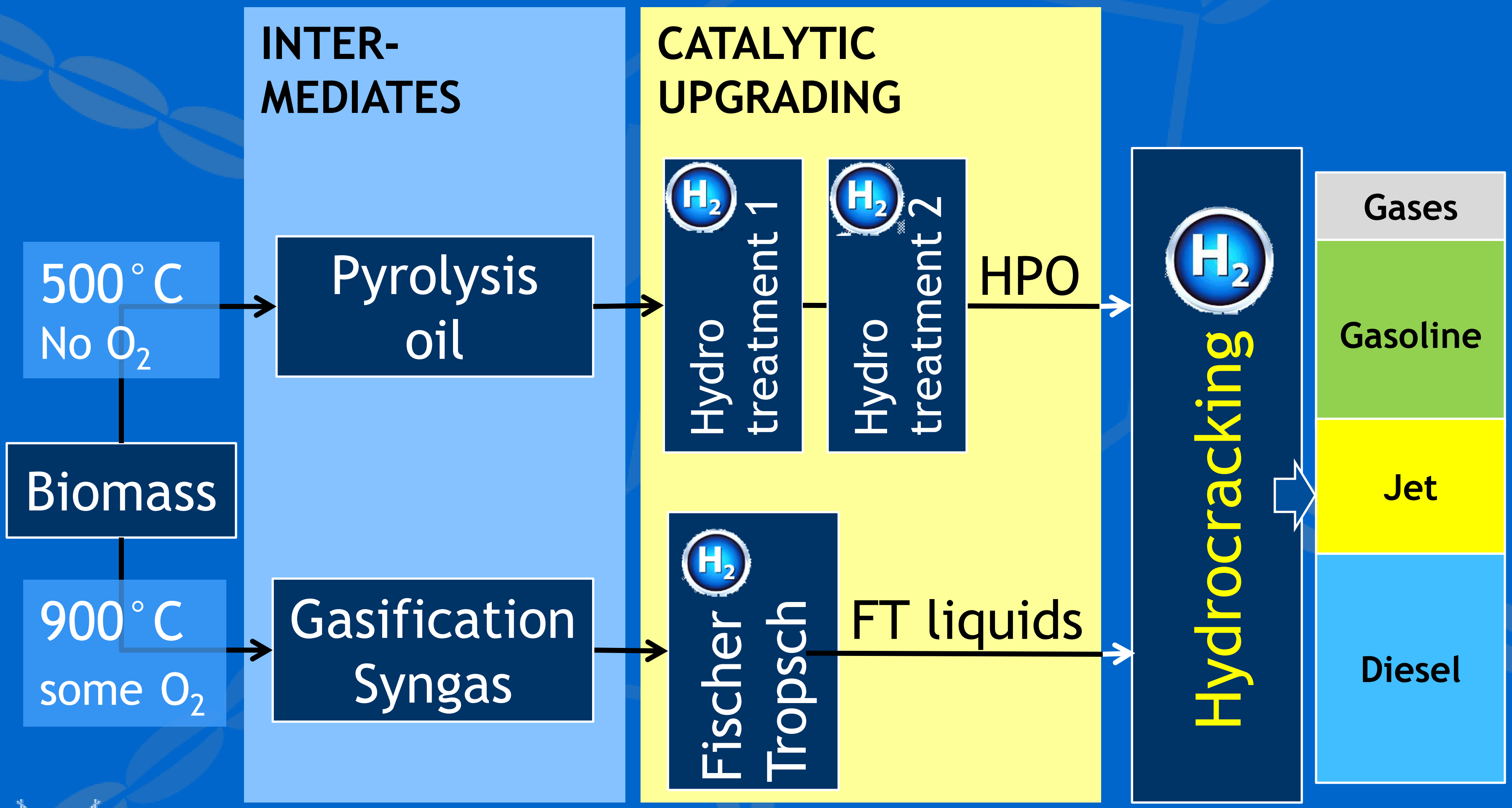
Neste Oil facility, Rotterdam

- All based on oleochemical
  - Neste Oil: 630,000,000 gallons diesel from palm oil
  - Dynamic Fuels: 75,000,000 gallons diesel from animal fat

Many examples of commercial biofuel flights

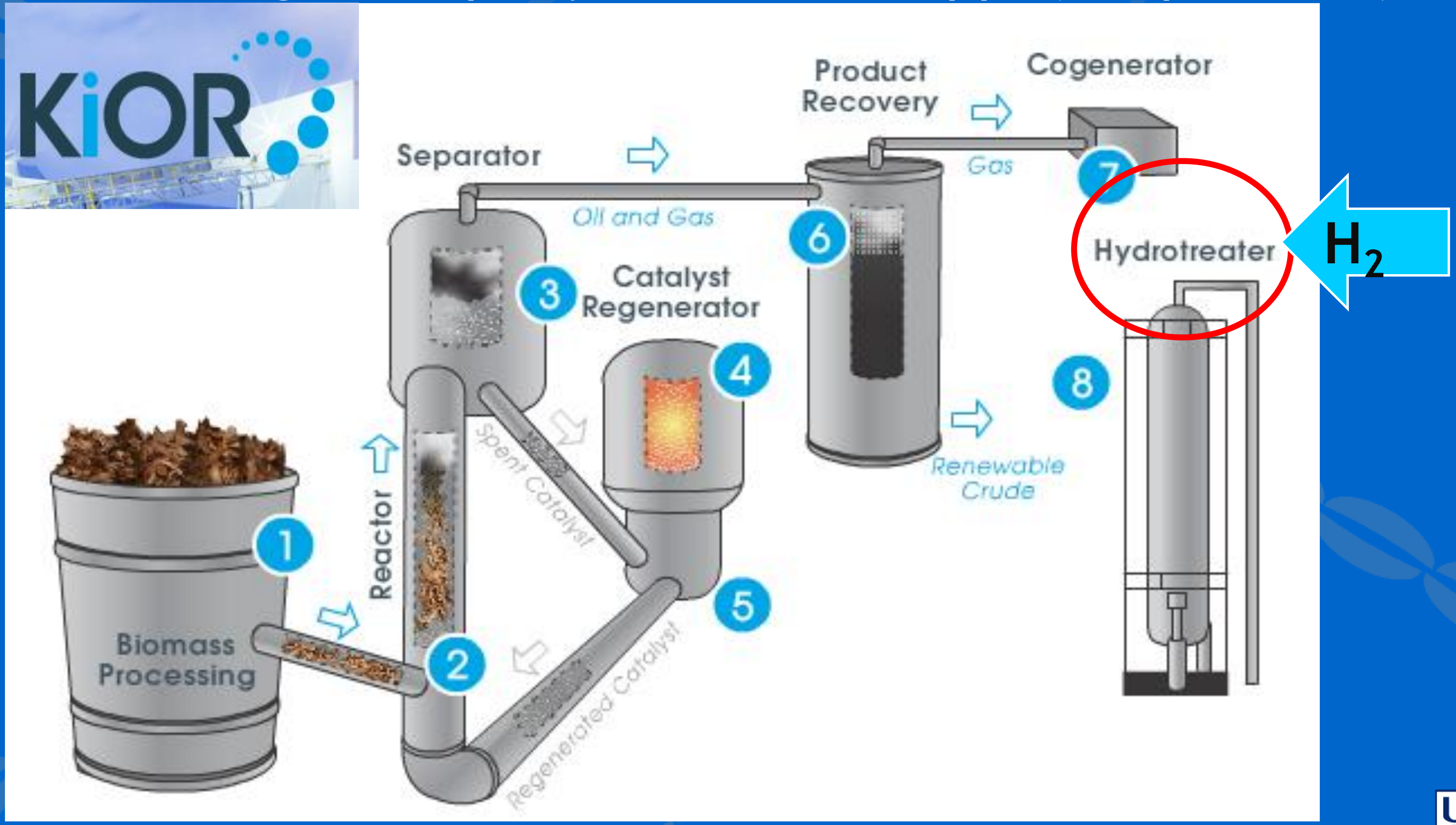
- Virtually all based on oleochemical
  - US Navy: Sept 2011 Solazyme algae oil and palm oil
  - Continental Airlines: Nov 2011 Solazyme algae oil
  - Alaska Airlines: Jan 2012 tallow and algae
  - Lufthansa: July 2011 Jatropha, Camelina
  - Finnair: July 2011 Used Cooking Oils
  - Many more

Thermochemical drop-in biofuel platforms



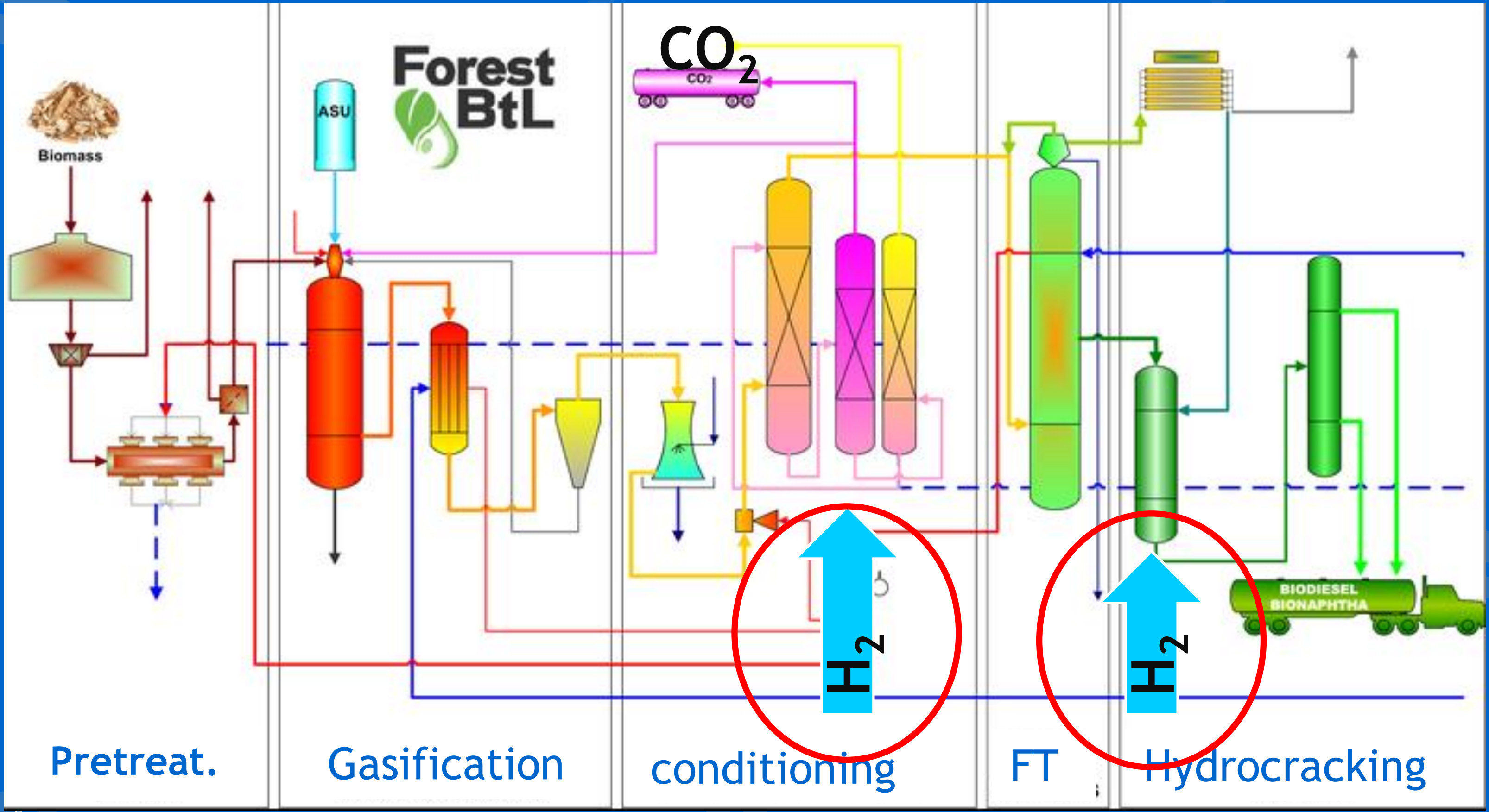
Example of pyrolysis drop in facility: KiOR

- 13,000,000 gallons per year in Mississippi (in operation)



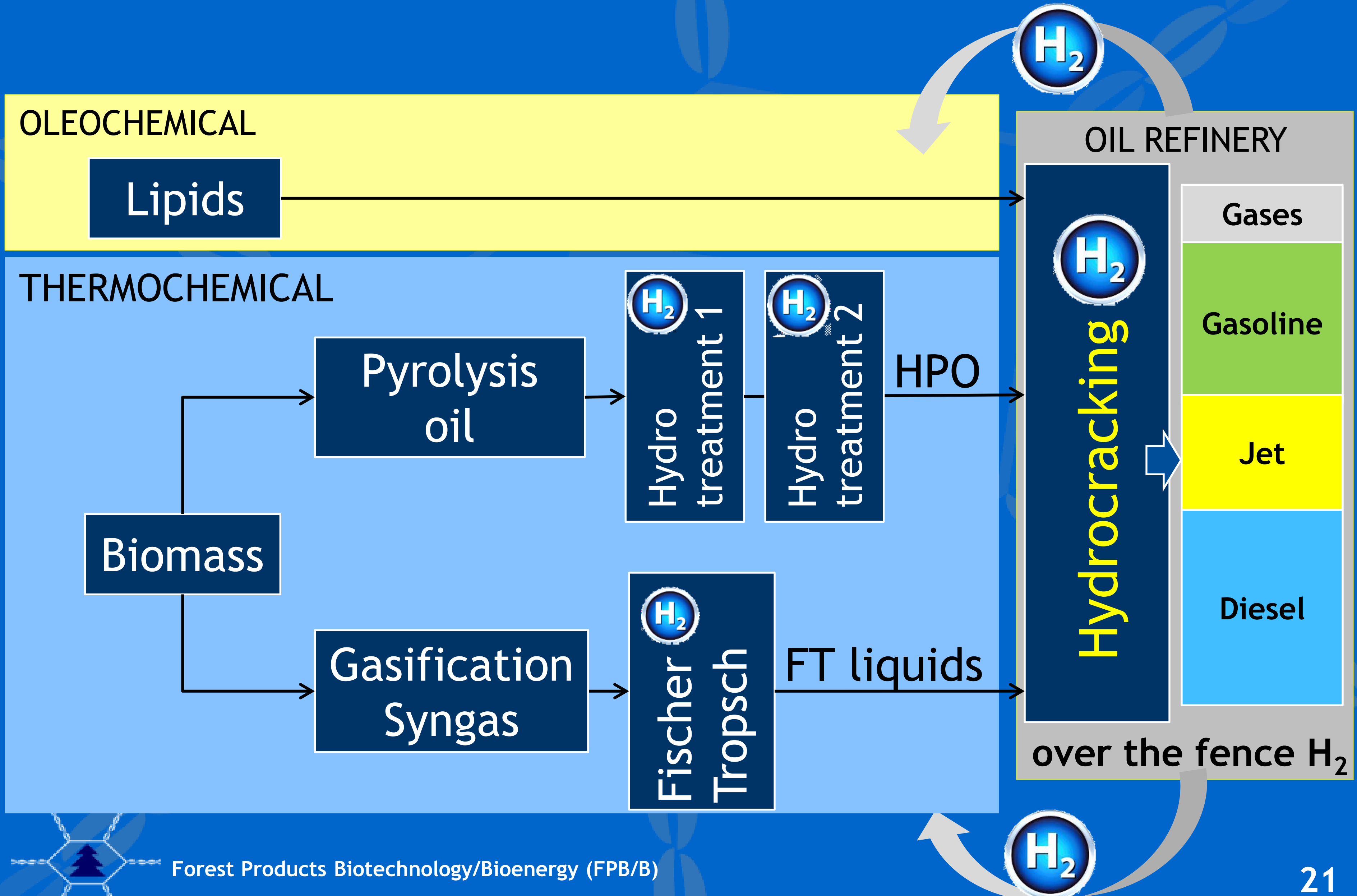
Forest BtL Oy and Choren's Carbo-V

- 34,000,000 gallons per year of Gasification FT liquids by 2016 (Finland)



Sundrop biofuels 50 MGPY

Drop in biofuels leveraging on Oil refineries



Challenges of hydrocracking biofeed:
The Haldor Topsoe experience

HALDOR TOPSØE
CATALYSING YOUR BUSINESS

- Higher Hydrogen consumption
  - requirements more than doubled when just 5% of feed was replaced with biofeed!
- Presence of oxygenated gases such as CO and H_2O
- Heterogeneity of feedstock (Catalyst design challenges)

Source: Haldor Topsoe, 2009

Major upscaling challenges for each platform

- Pyrolysis
  - Hydrogen
  - Hydrotreating catalyst
- Gasification
  - Capital / scale
  - Feedstock /yields
- HVO oleochemical
  - Feedstock
- Refinery insertion challenges

Sources: Jones et al. 2009; Swanson et al. 2010; Pearlson et al. 2011

Biochemical: Sugar fermentation to drop-in

SUGAR → FERMENTATION (Modified algae, bacteria or yeast) → Target molecule (Long alcohols, Aliphatic chains)

- Major advantages
  - Pure and “functionalized” product streams suitable for value added markets

- Major challenges
  - Volumetric productivity about 10x lower than ethanol
  - Recovery challenges: e.g. recovery from fermentation broth and intracellular expression
  - Sugar feedstock highly oxidized (H/C = 0)

Summary

- Oleochemical: commercial now and less H_2-dependent with considerable potential for growth (feedstock challenges?)

- Thermochemical well suited for long term drop-in biofuels
  - H_2 and catalyst challenges (Pyrolysis), Scale challenges (Gasification)
  - Leveraging on oil refineries: more challenging than expected

- Biochemical “drop-in” products more valuable in rapidly growing chemicals markets

- Accessing cheap/renewable Hydrogen will be a key challenge for both drop-in biofuels and crude oil of decreasing quality

ACKNOWLEDGEMENTS

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