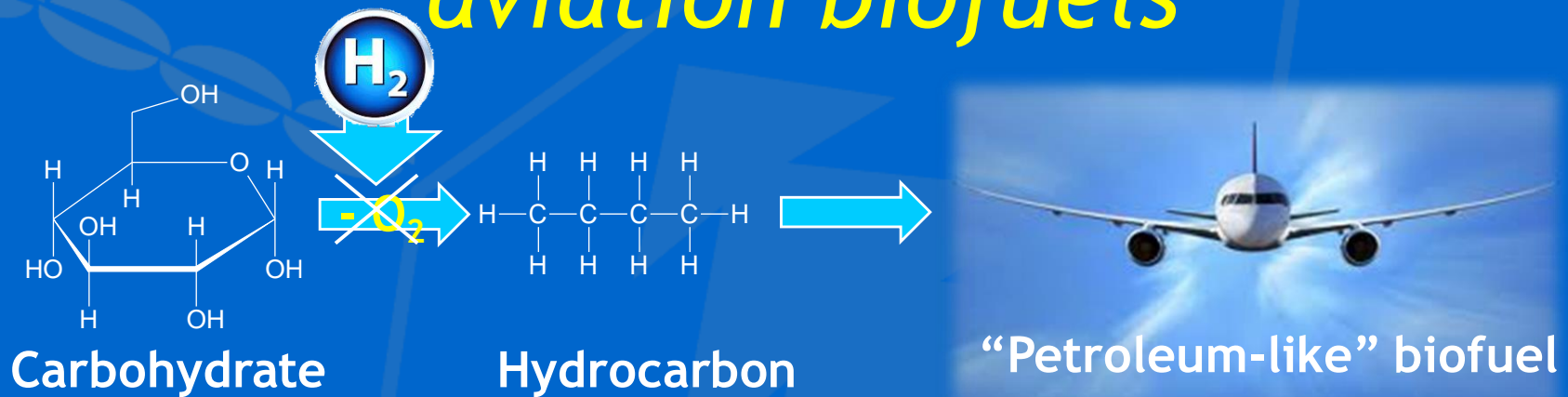


# Pathways and companies involved in drop-in biofuels for marine and aviation biofuels



Jack Saddler, Jim McMillan and Susan van Dyk  
International Energy Agency Bioenergy Task 39 (liquid biofuels)

# Commissioned report published by IEA Bioenergy Task 39 (2014) {2 years work}

Commercializing Conventional and Advanced  
Liquid Biofuels from Biomass

Task 39  
IEA Bioenergy

[www.Task39.org](http://www.Task39.org)



## The Potential and Challenges of Drop-in Biofuels

A Report by IEA Bioenergy Task 39

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Report T39-T1 July 2014



## 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

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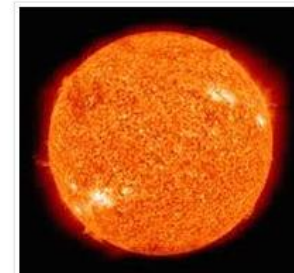
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Think affordable, available, sustainable carbon is the biggest barrier to the growth of biofuels?



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 (H<sub>2</sub>) is the most abundant molecule in the universe. The latter is true — but you'll have

# Definition of a “drop-in” biofuel

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

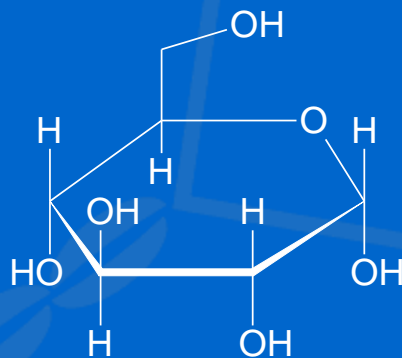


# Effective hydrogen to carbon ratio ( $H/C_{\text{eff}}$ )

- A high Effective Hydrogen to Carbon ratio is desired for drop-in biofuels

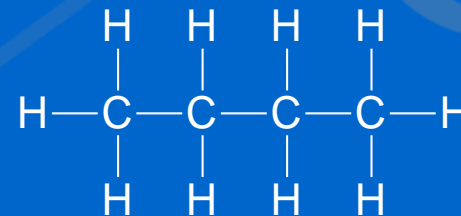
- $$H/C_{\text{eff}} = \frac{n(H) - 2n(O)}{n(C)}$$

$H/C_{\text{eff}} = 0$



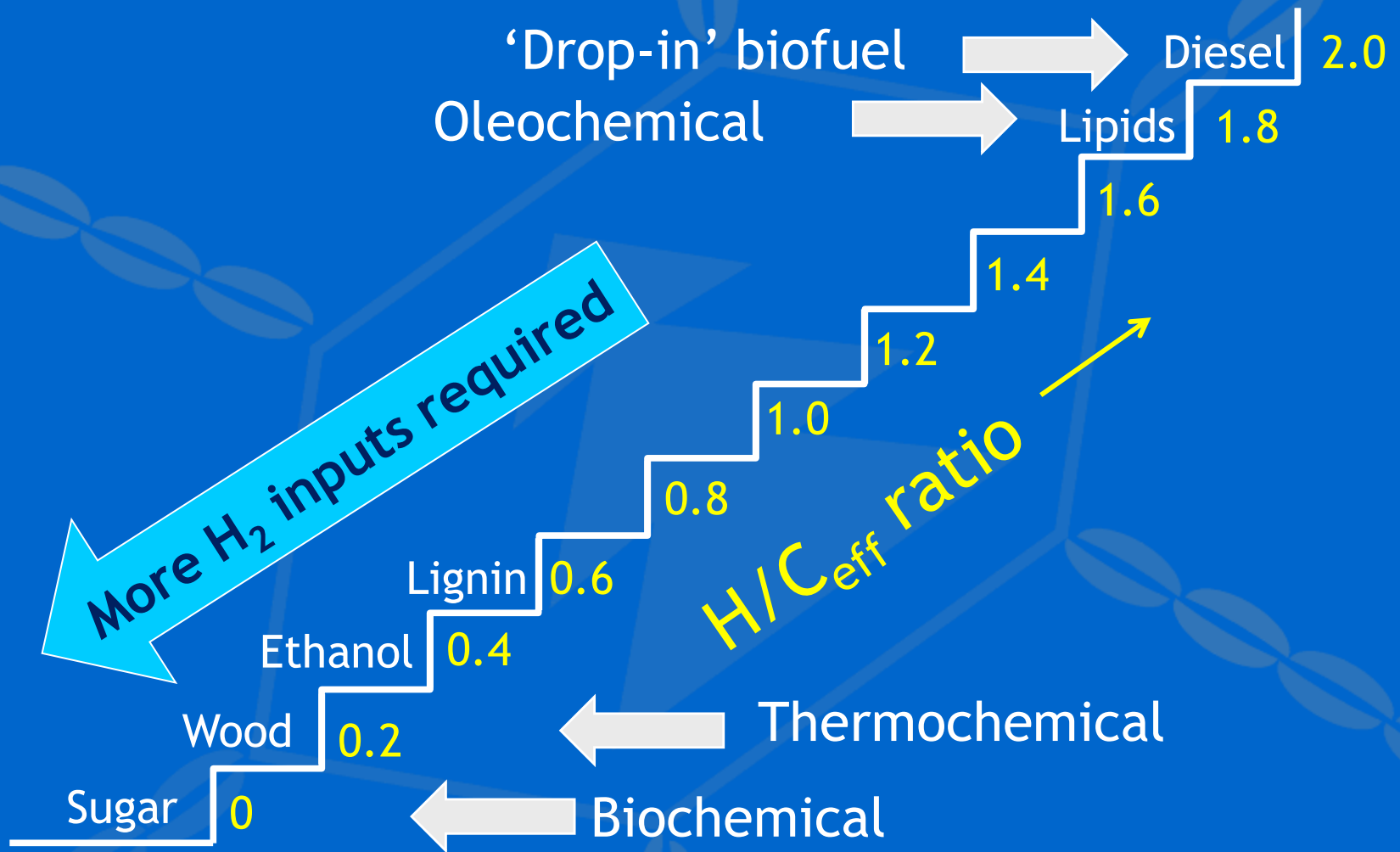
**Carbohydrate**

$H/C_{\text{eff}} \approx 2$



**Hydrocarbon**  
(e.g. Butane, Diesel)

# The Effective H/C ratio staircase...



High O<sub>2</sub> or low H/C feedstocks require more processing and H<sub>2</sub> inputs



# 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  $H/C_{\text{eff}}$**  ratio feedstocks such as lipids are well suited for drop-in biofuel production (“**conventional**” biojet)

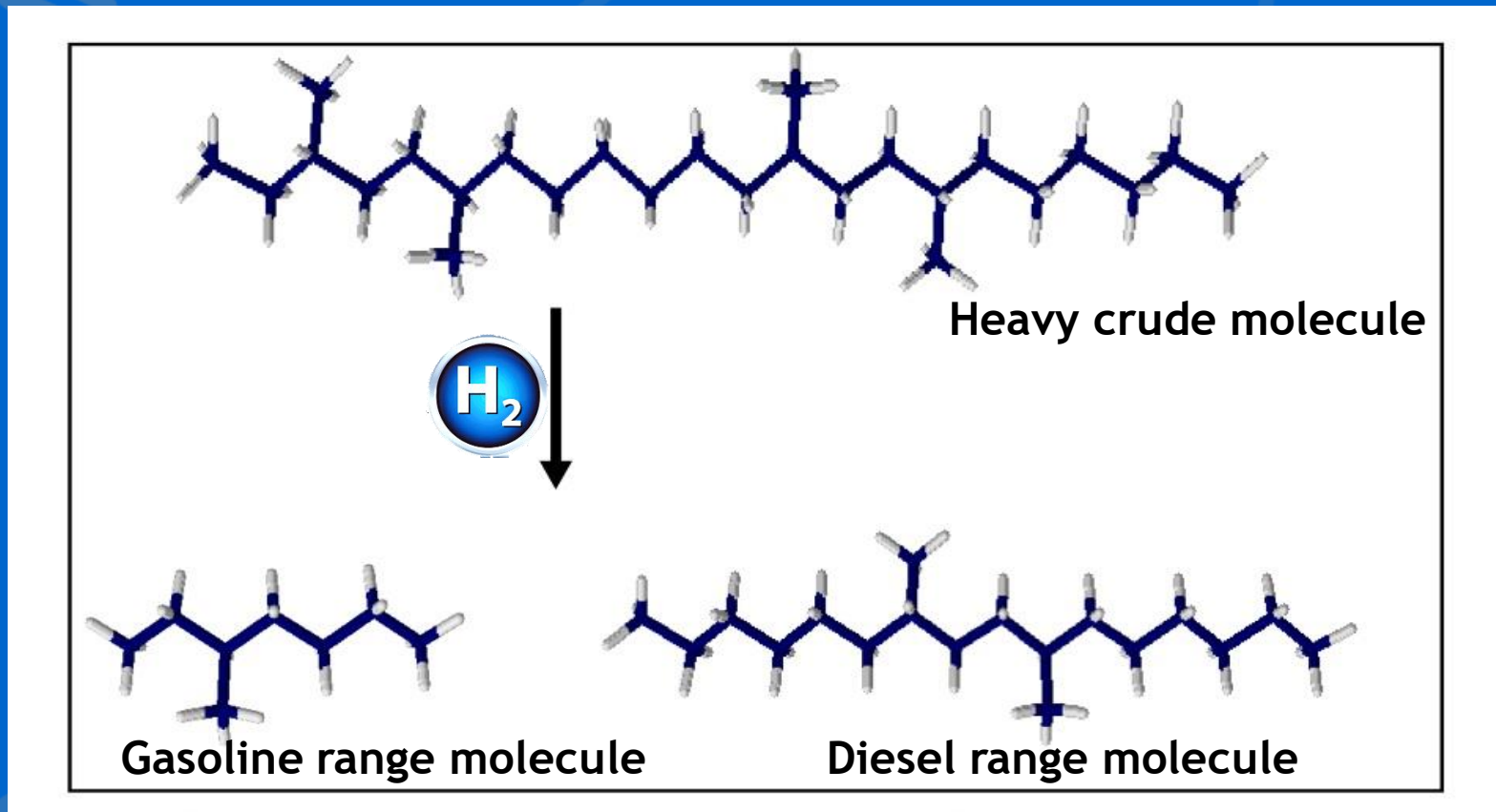


# What will determine the success of “drop in biofuels”?

- Drop-in biofuel technologies complexity, cost, hydrogen demand and how well do they lower carbon emissions (LCA)?
- Commercialization challenges such as capital, yield and refinery insertion
- Crude oil is becoming increasingly hydrogen deficient (‘heavier’ and ‘sourer’)

# Hydrotreating and Hydrocracking

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



# Natural gas: Where H<sub>2</sub> comes from

- 90 % of commercial H<sub>2</sub> comes from steam reforming natural gas



# Role of H<sub>2</sub> 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**

# The commercialization potential of Drop in Biofuel platforms and their H<sub>2</sub> dependence

## “Conventional” Drop-in Biofuels

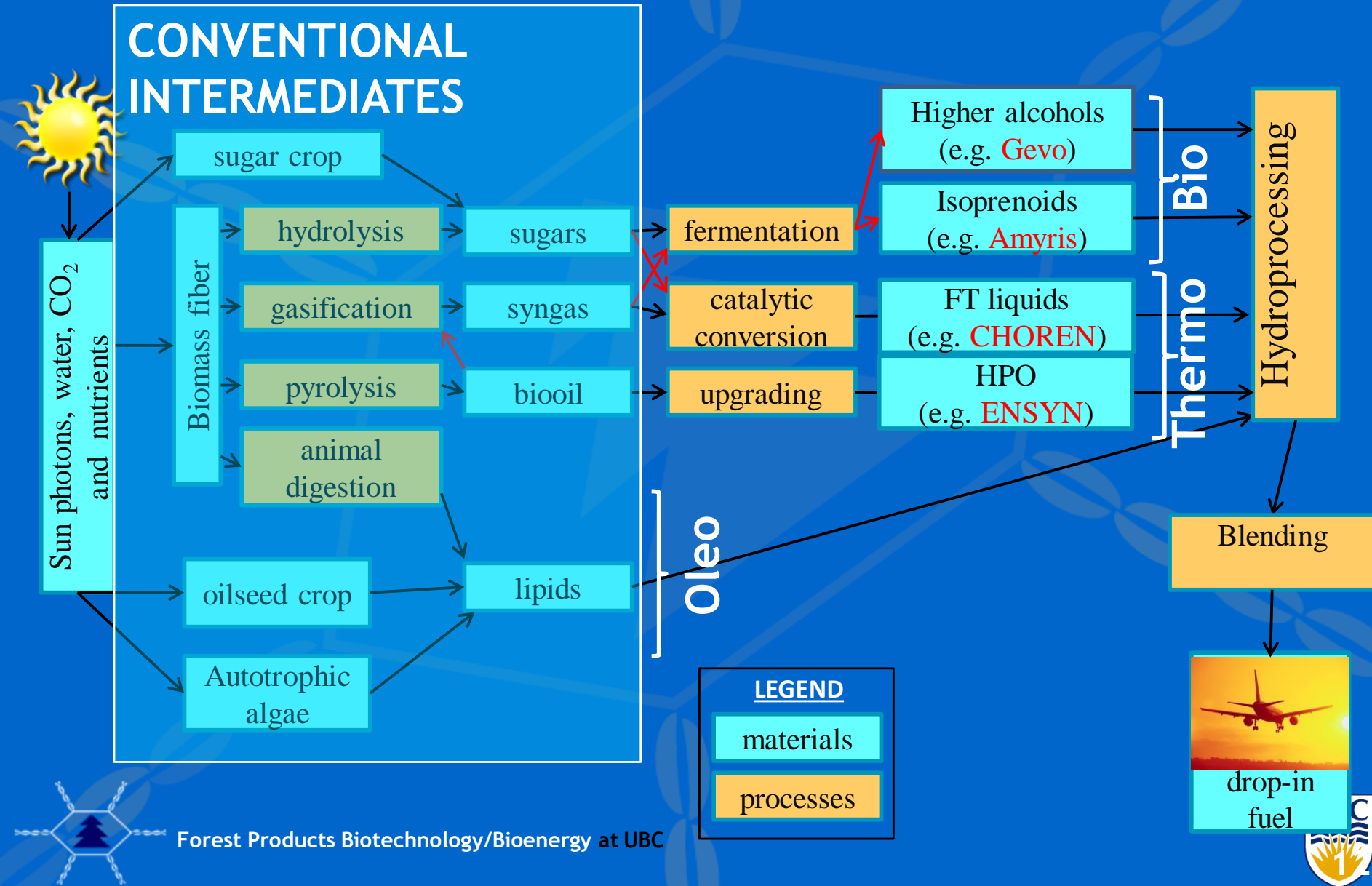
- Oleochemical (HVO, algae)

## “Advanced” Drop-in Biofuels

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



# Technology pathways to “drop-in”



# Commercial volumes of drop-in biofuel through oleochemical (conventional) platform



Neste Oil facility, Rotterdam

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

# Test and commercial flights with biojet

1600 flights; 21 airlines

>90% based on hydrotreatment of oils and fats (oleochemical “conventional” platform)

Supply chain initiatives

1107 of commercial flights on biojet fuel

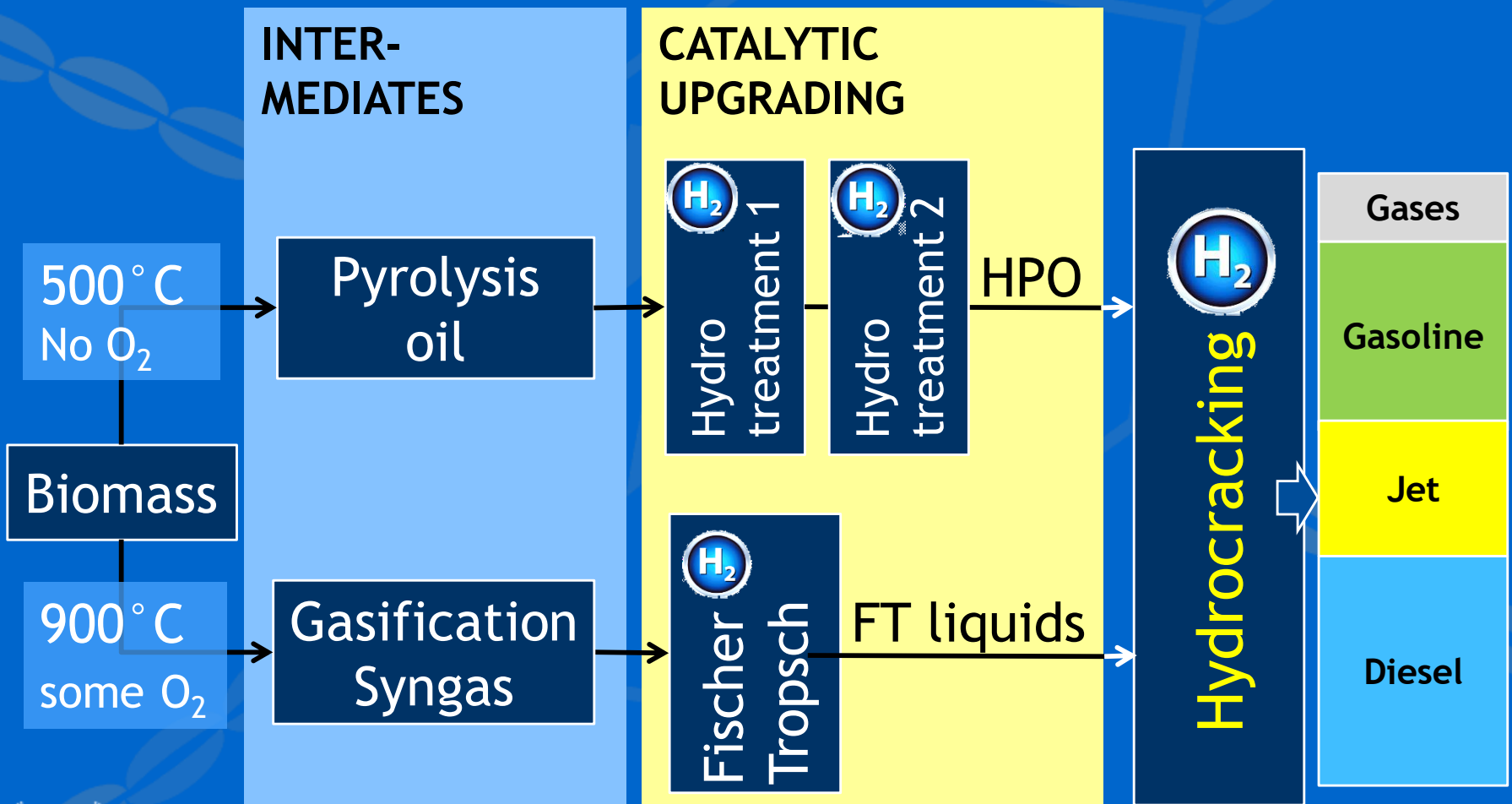
Several airlines have partnered up to develop supply chain activities.

Virgin Australia recently announced a partnership with Brisbane Airport and SkyNRG to develop a biojet fuel supply chain in Brisbane

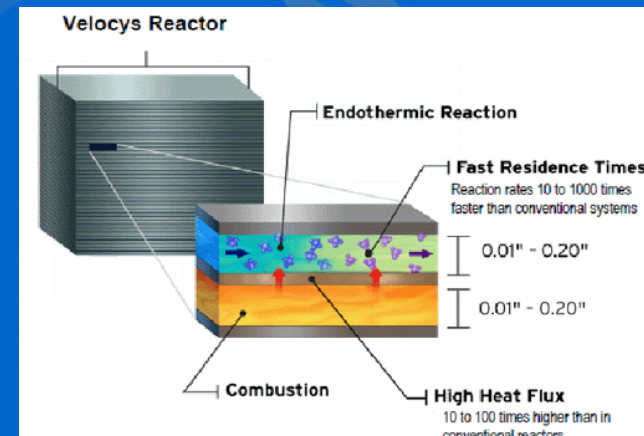


Bioport development (SkyNRG)

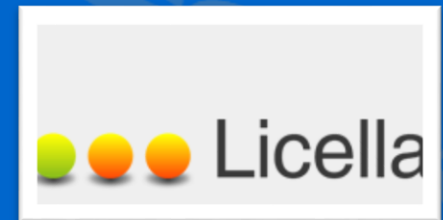
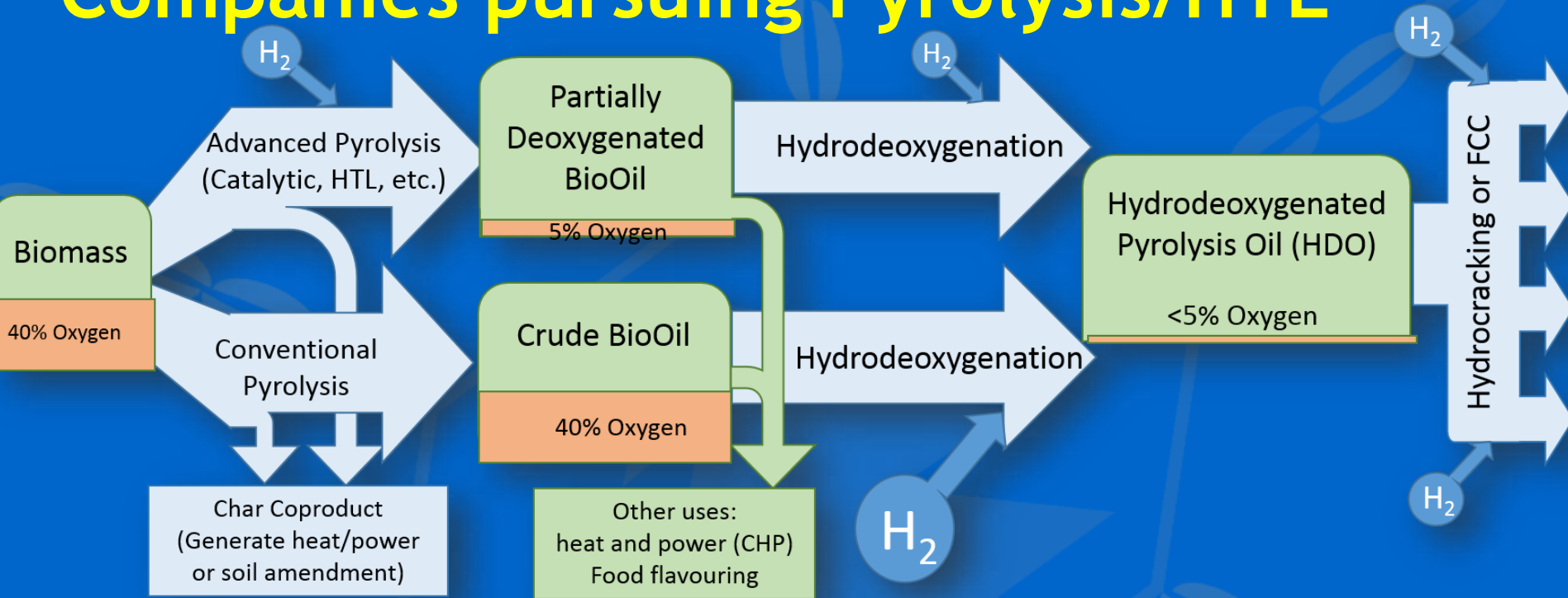
# Thermochemical (Advanced) drop-in biofuel platforms



# Companies using gasification & FT synthesis (under construction)



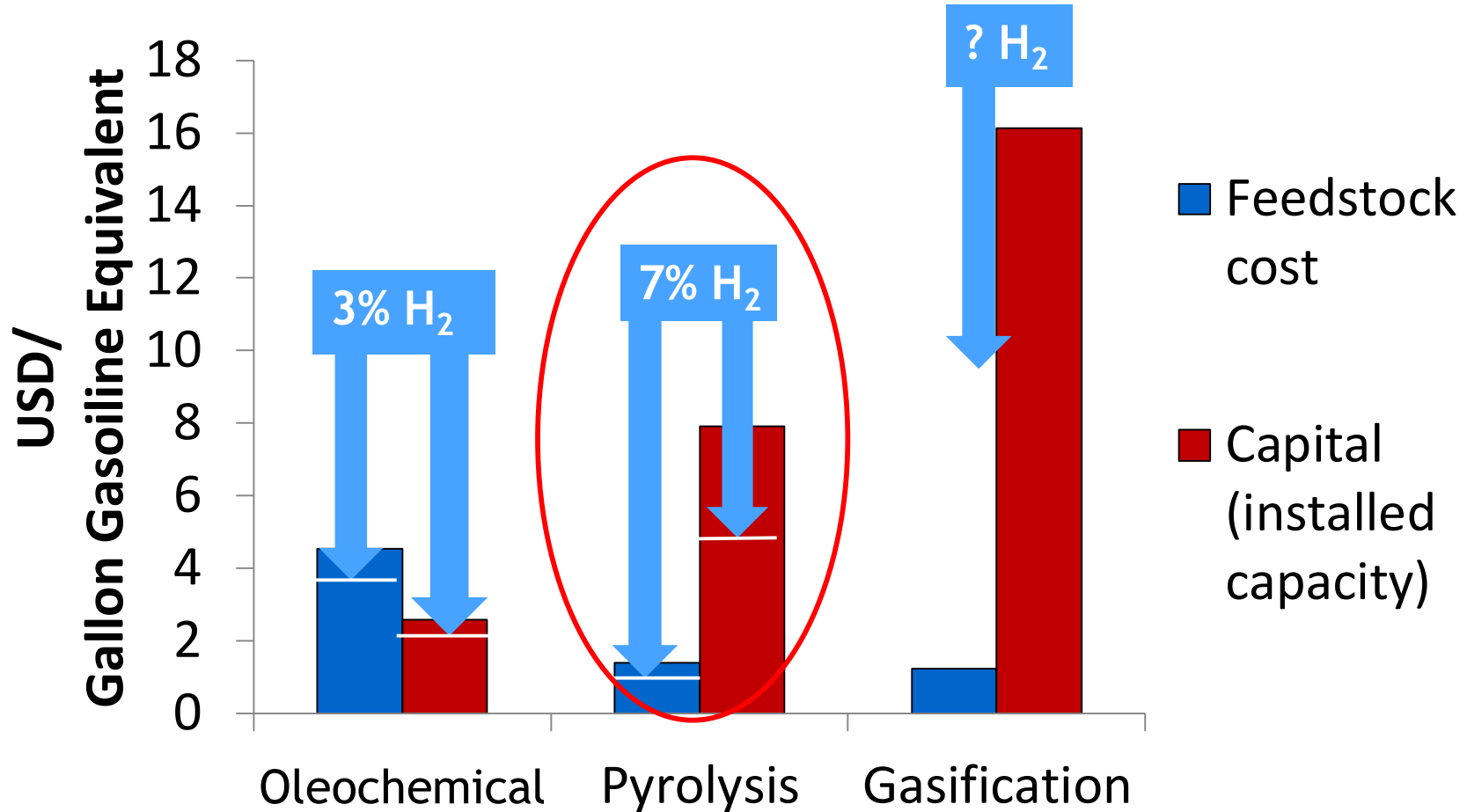
# Companies pursuing Pyrolysis/HTL



Forest Products Biotechnology/Bioenergy at UBC



# “Over the fence” Hydrogen inputs can reduce capital and feedstock costs

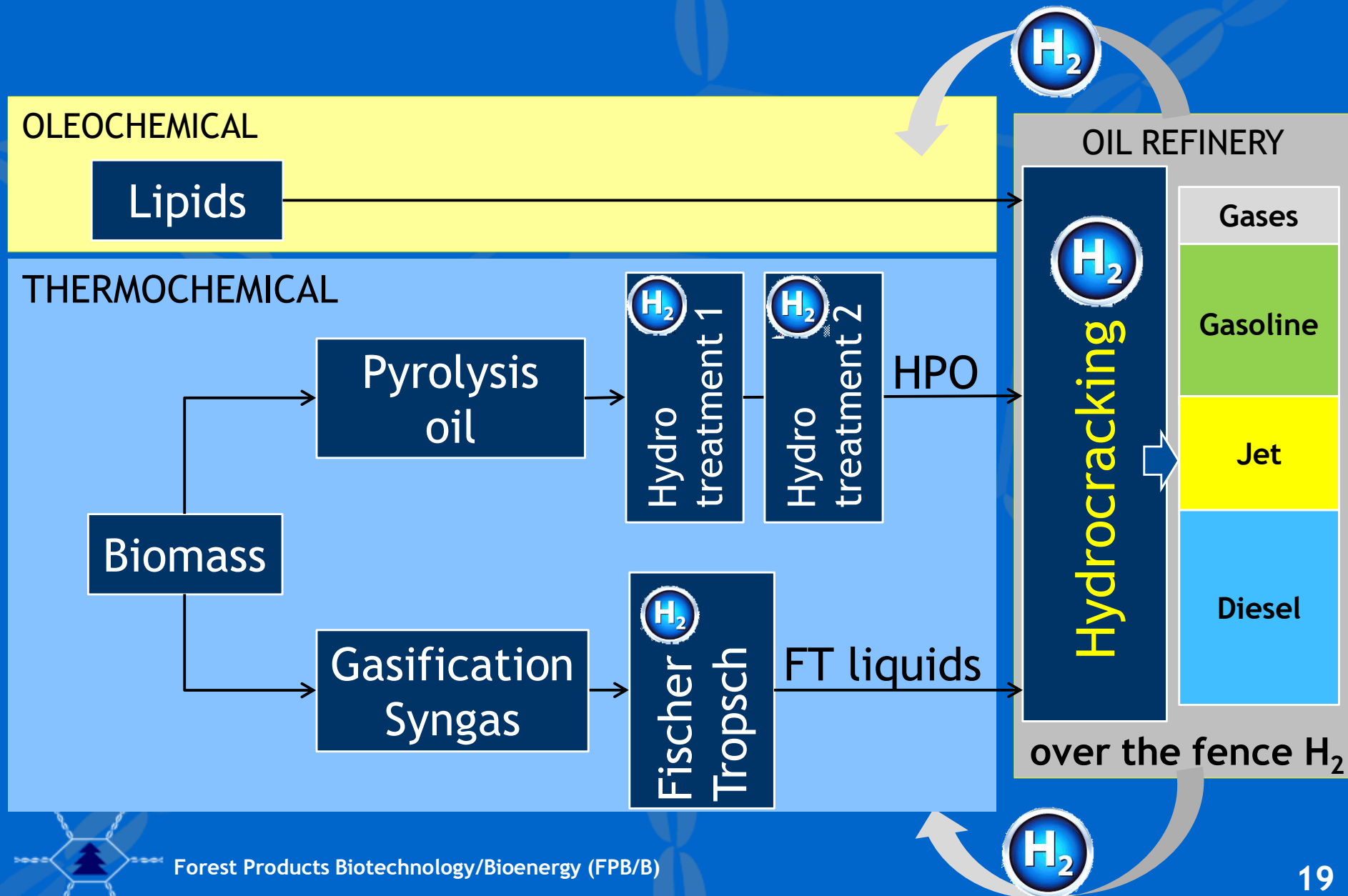


**Pyrolysis is highly dependent on access to cheap Hydrogen**

Source: Kazi et al. 2010, Pearlson et al. 2011, Jones et al. 2009



# Drop in biofuels leveraging on Oil refineries



# Challenges of hydrocracking biofeed: The Haldor Topsoe experience



- 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<sub>2</sub>O
- Heterogeneity of feedstock (Catalyst design challenges)

# 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

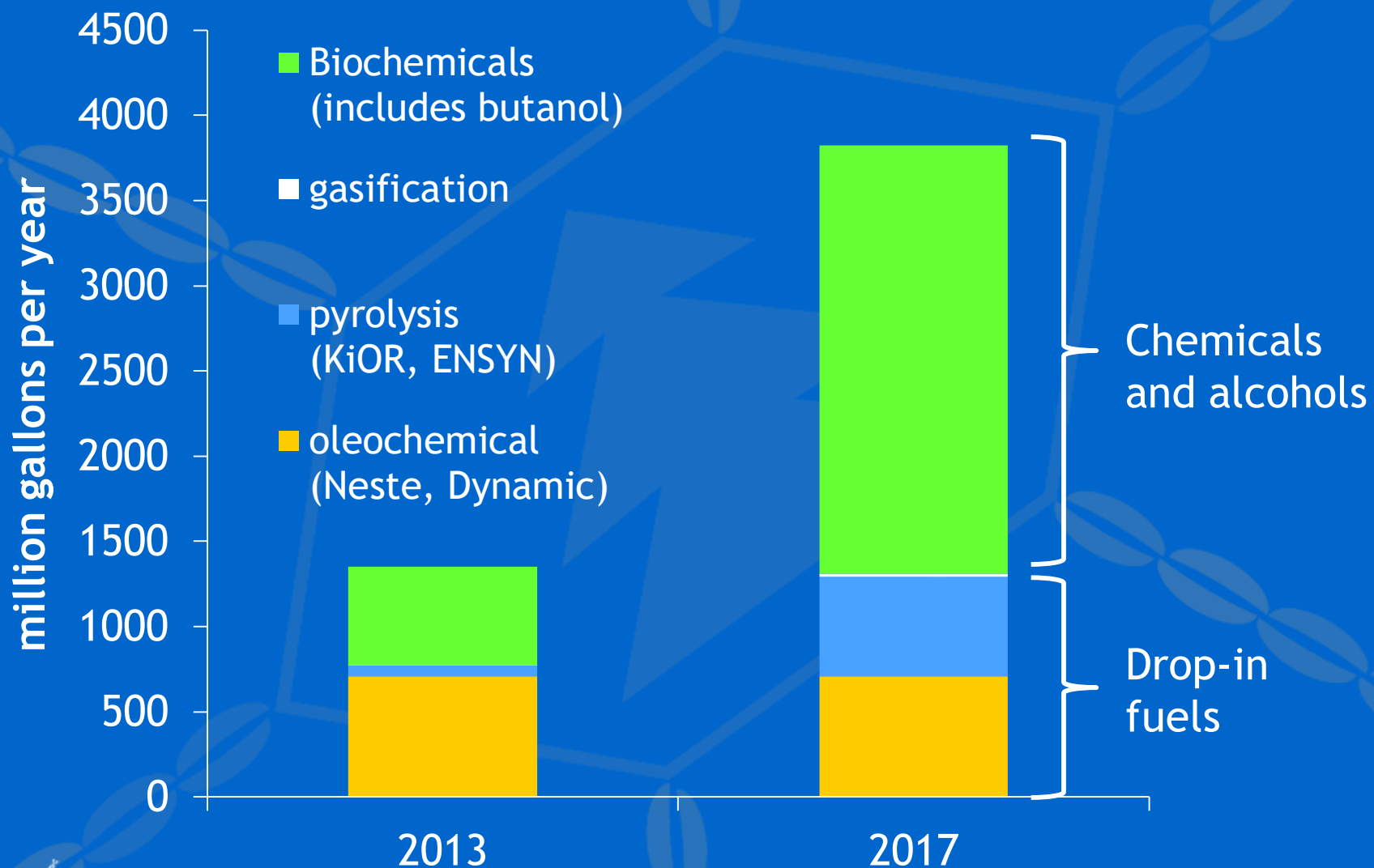


# Biochemical: Sugar fermentation to drop-in



- 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 ( $H/C = 0$ )

# Announced advanced biofuel capacity





# Establishment of a biojet supply in Canada (conventional) (advanced)

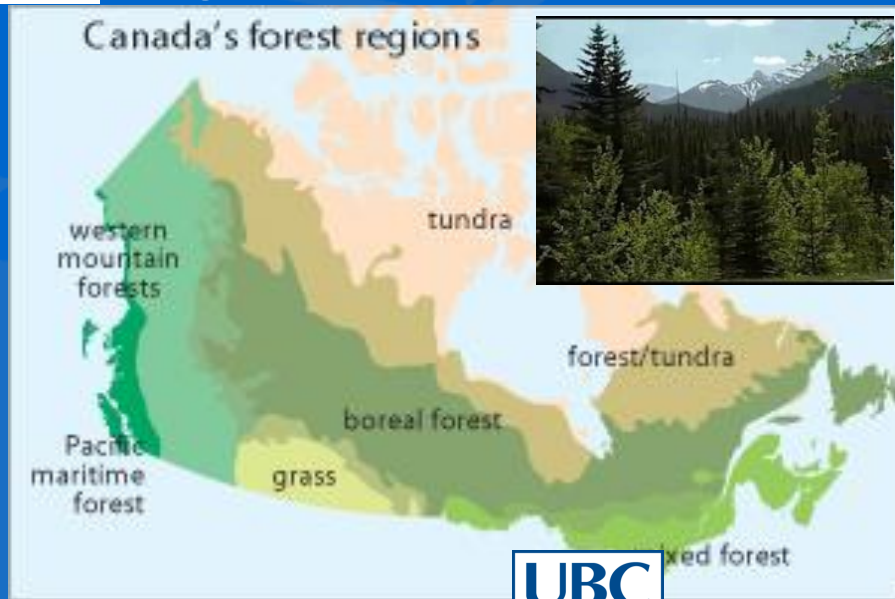


Oleochemical feedstock

Lignocellulosic feedstock



Canola growing regions



Source: Canola Council of Canada



# Canadian Biojet supply chain initiative: *Assessment of likely Technology Maturation pathways used to produce biojet from forest residues (The ATM project)*



by (FPB/B)

# Summary (good policy drivers will be essential!!)

- Oleochemical (**Conventional**): commercial now and less H<sub>2</sub>-dependent with considerable potential for growth  
(But, feedstock challenges. Cost, sustainability, volumes?)
- Thermochemical (**Advanced**): well suited for long term drop-in biofuels
  - H<sub>2</sub> and catalyst challenges (Pyrolysis), Scale challenges (Gasification)
  - Leveraging on oil refineries: likely more challenging than expected
- Biochemical “drop-in” products: much more valuable in rapidly growing chemicals markets (i.e. Amyris)
- Accessing cheap/renewable Hydrogen will be a key challenge for drop-in biofuels (**and crude oil of decreasing quality**)

# ACKNOWLEDGEMENTS

International Energy Agency Bioenergy Task 39 colleagues

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