Alternative Fuels in Air Transport — from Lab to World Scale Plant

2nd UTIAS-MITACS International Workshop on Aviation and Climate Change

Thursday May 27th 2010

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Overview

- The Energy Challenge and role of Aviation
- Alternative Fuels
  - Fossil Feed – Natural Gas
  - Biological Feed – Sugar
- Summary & Conclusions

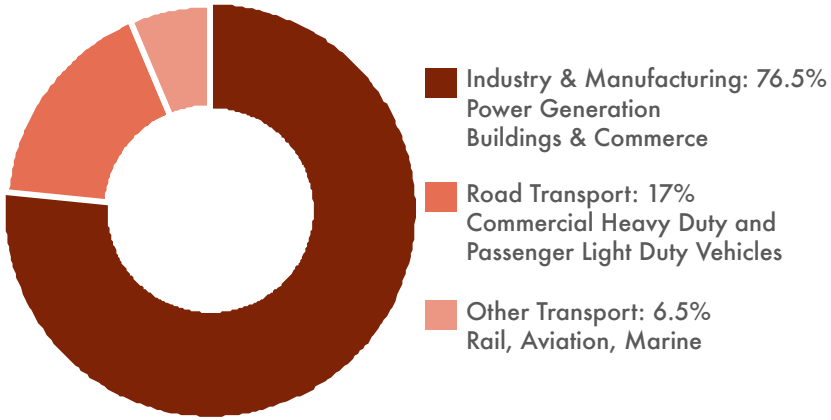
The Energy Challenge

- Global demand for energy will double by 2050
  - 3 billion energy consumers will be added to the world's population
  - These people would like access to electricity and personal transport
- Energy supply - from all sources - will struggle to keep up with demand
  - There will be continued dependence on fossil fuels such as oil, gas and coal
  - We will also need rapid growth in renewables & nuclear
- Environmental stresses from producing and using energy are increasing
- Climate change is chief amongst these but also particulates and air quality issues

Transport Energy Demand

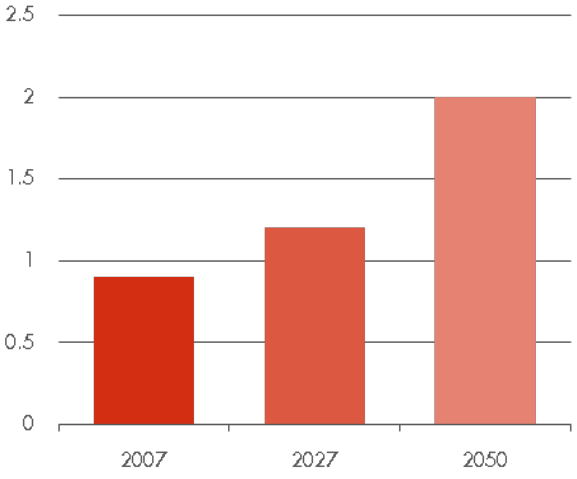
- Oil has been key for transport because it is a liquid and holds high energy density
- Transport accounts for about a quarter of energy-related CO_2 emissions
- Demand for mobility is increasing and emissions set to rise
- We need better vehicle technology, fuels and consumer behavior to constrain this growth
- On the road we will need a mix of options (electric vehicles, biofuels, hydrogen)

Energy Related CO_2 Emissions*



Source: International Energy Agency
* 62% of global CO_2 emissions

Estimate of worldwide vehicle demand

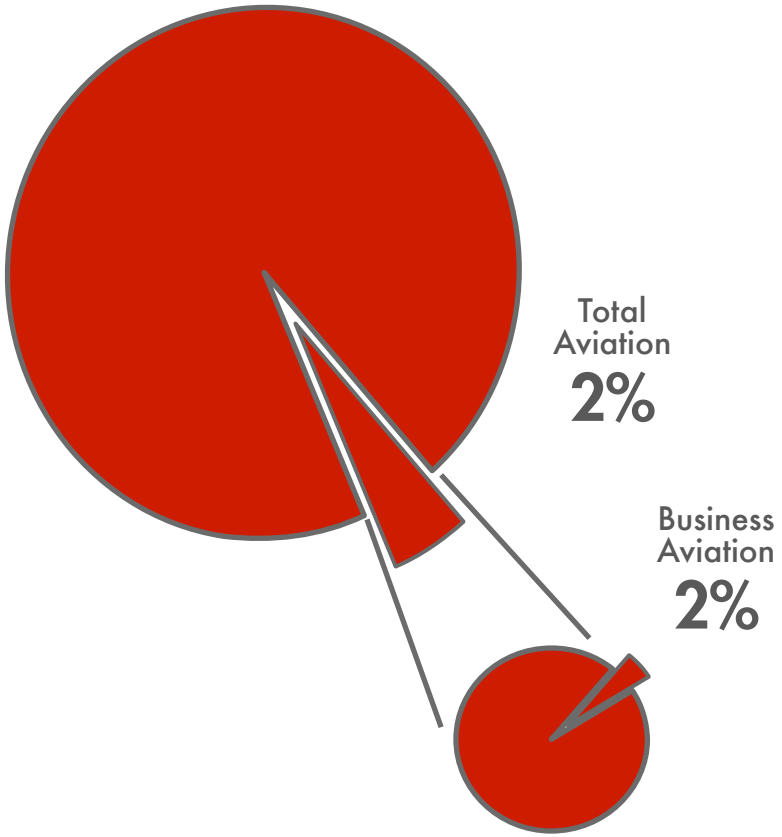


Source: World Business Council for Sustainable Development

Aviation's contribution to global CO_2

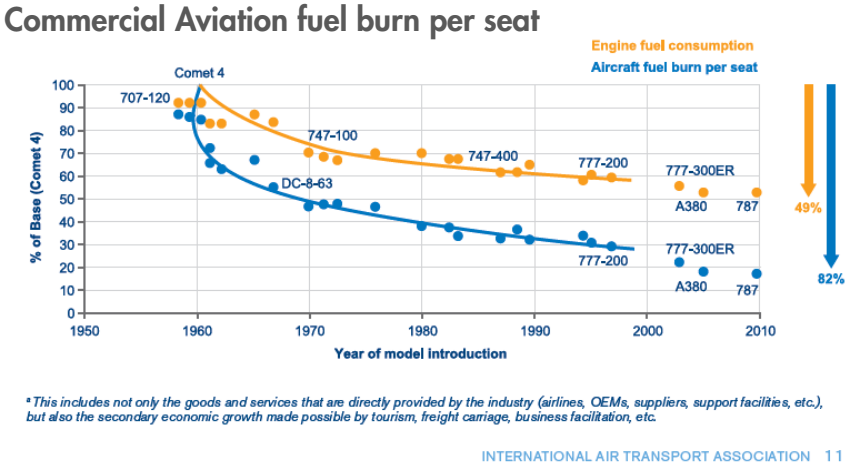
- Kerosene, from oil, has been key for aviation fuel
- Aviation accounts for about 2% of energy-related CO_2 emissions – Business aviation is ca 0.04% and both are growing
- The IPCC reports that the effect of altitude of emissions may have multiplier effect
- Visibility of tackling CO_2 emissions in aviation is high
- Also serious interest in local air quality issues at airports
- We need better aircraft, more efficient engines and improved air traffic management systems

Energy–related CO_2 emissions



Source: IPCC, IBAC & GAMA

Efficiency gains impressive… but outstripped by growth

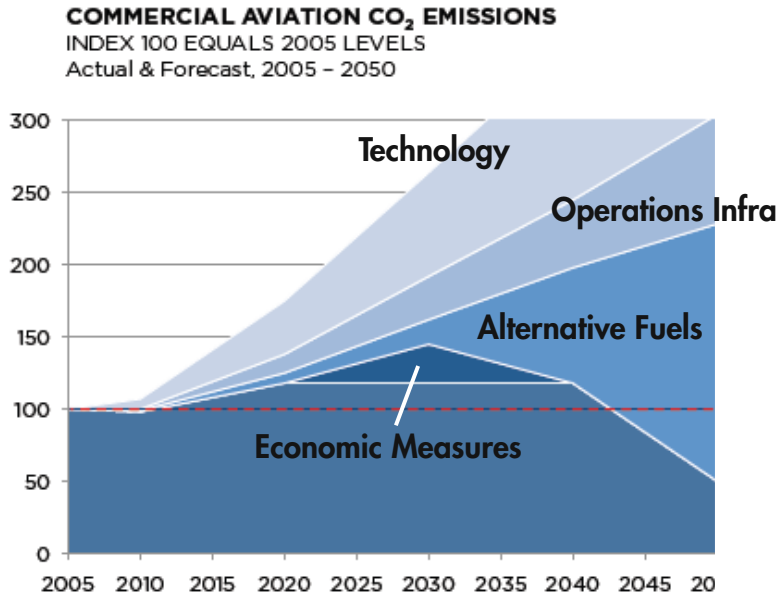


[a] This includes not only the goods and services that are directly provided by the industry (airlines, OEMs, suppliers, support facilities, etc.), but also the secondary economic growth made possible by tourism, freight carriage, business facilitation, etc.

INTERNATIONAL AIR TRANSPORT ASSOCIATION 11

- >80% fuel burn per seat
- >40% fuel consumption

- Economics factors (offsets) may have a small part to play, but not sustainable or productive
- Aircraft Technology improvements are needed to bridge the gap
- Renewable alternative fuels seen as a key solution (or the arrival of the Cavalry!)



Source: IATA, IBAC & GAMA

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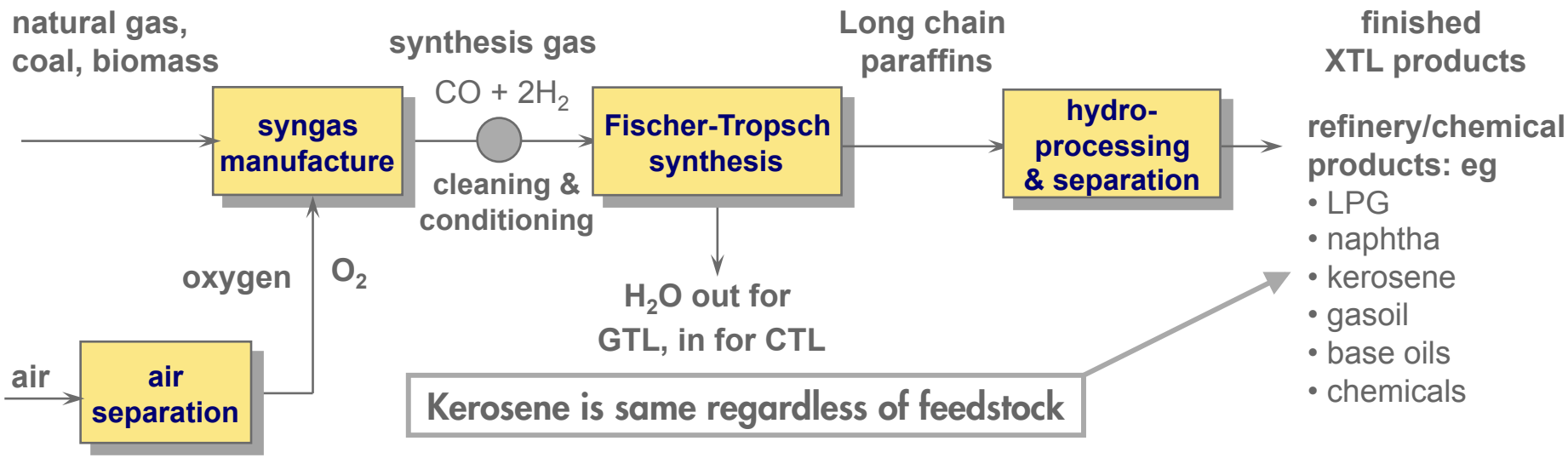
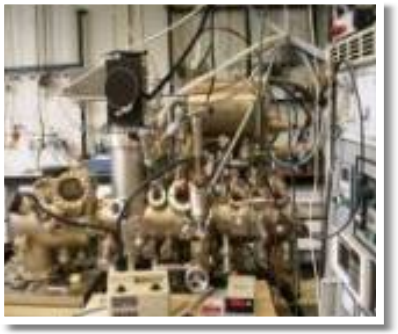
- Currently impossible to supply any biofuel mandates for aviation fuel in a sustainable manner

Fossil Feed – Natural Gas

The Fischer-Tropsch Process & Shell GTL projects



1973



Laboratory
Amsterdam

1983

Pilot plant
Amsterdam

1993

Bintulu Malaysia
current capacity
14,700 bbl/d

Project ramp up 2011

Pearl GTL Qatar
planned capacity
140,000 bbl/d

GTL Jet Fuel – a new source of kerosene

- Convenient – drop-in replacement
- Diversity of supply – not a biofuel!
- GTL kerosene has no aromatics and virtually sulphur-free
- Local emissions benefits (PM, SO_X) – could help to improve local air quality at airports
- Aircraft may have to carry slightly less weight of fuel to cover the same distance
- Currently investigating other possible benefits

GTL's combustion (on the right) is less sooty

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Bio-jet technically feasible...

Bio-jet technically feasible... 3 key areas to consider

1. **CAPEX**

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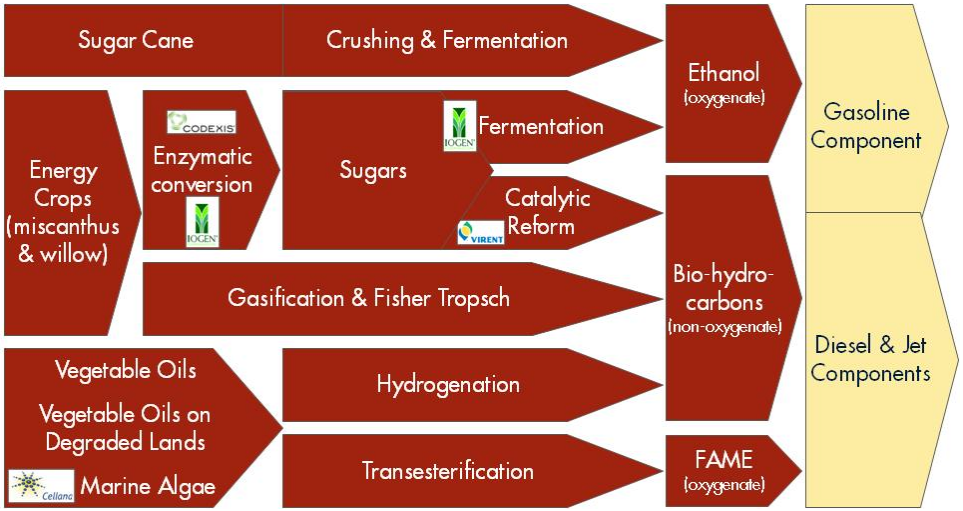
Bio-jet technically feasible... Commercial-scale some way away

BIOJET MANUFACTURING PATHWAYS



THREE KEYS TO SCALABILITY

1. **CAPEX**
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2. **FEEDSTOCK COST**
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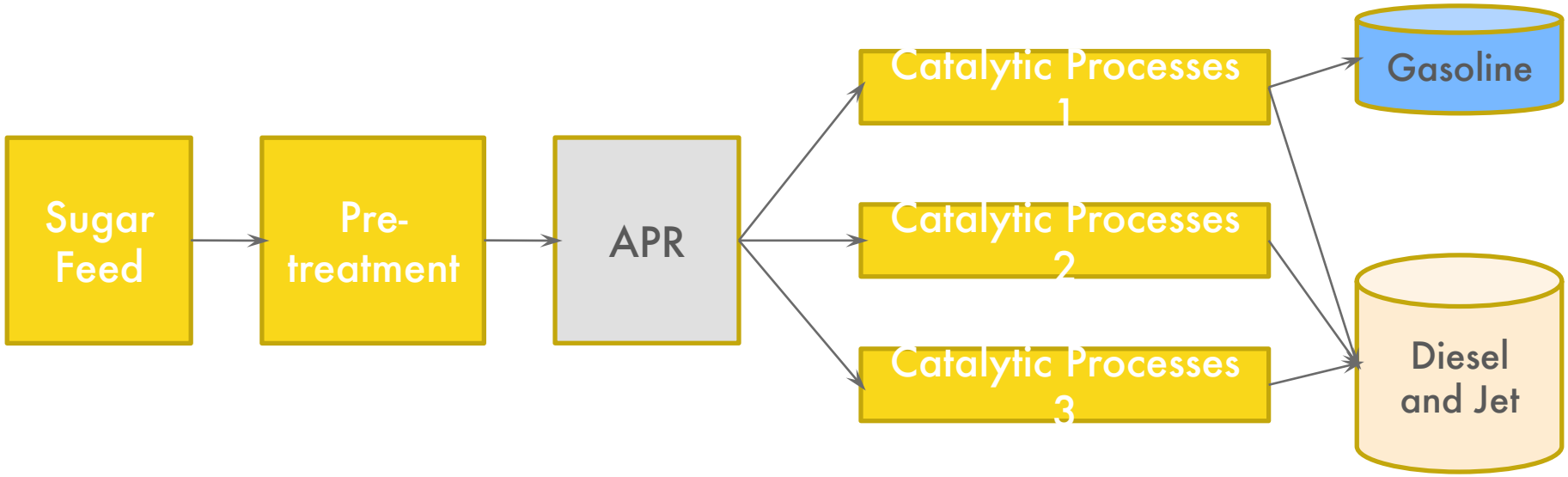
- Shell has one of the broadest portfolios of R&D projects and ventures to create low carbon fuels with emphasis on scalability, yield and product cost
- Typically processes will produce a range of components suitable for both diesel and kerosene with varying yields in each boiling range
- Specific to Aviation Shell is an active member of CAAFI, ASTM, IATA and EU programmes SWAFEA (EU DG-TREN) and Alfa-Bird (EU DG-Research)

Biological Feed – Sugar

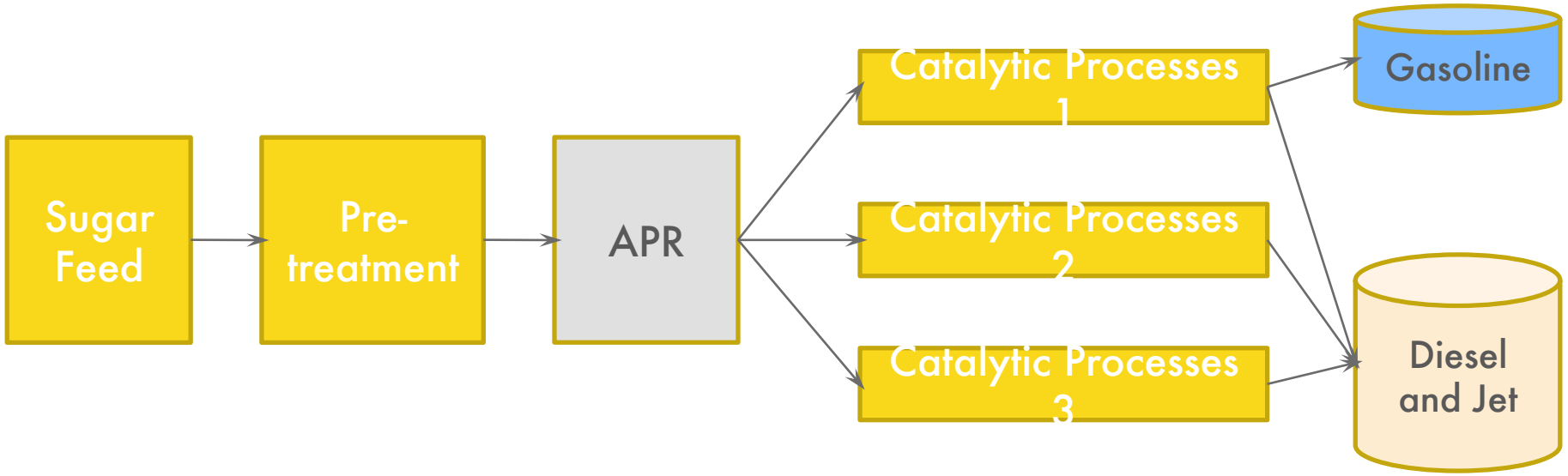
Sugar to Alkanes – Shell-Virent Joint Venture Process



2002 2006 2009

Courtesy Virent Energy Systems

Sugar to Alkanes – Full scale plant???



2002 2006 2009 ???

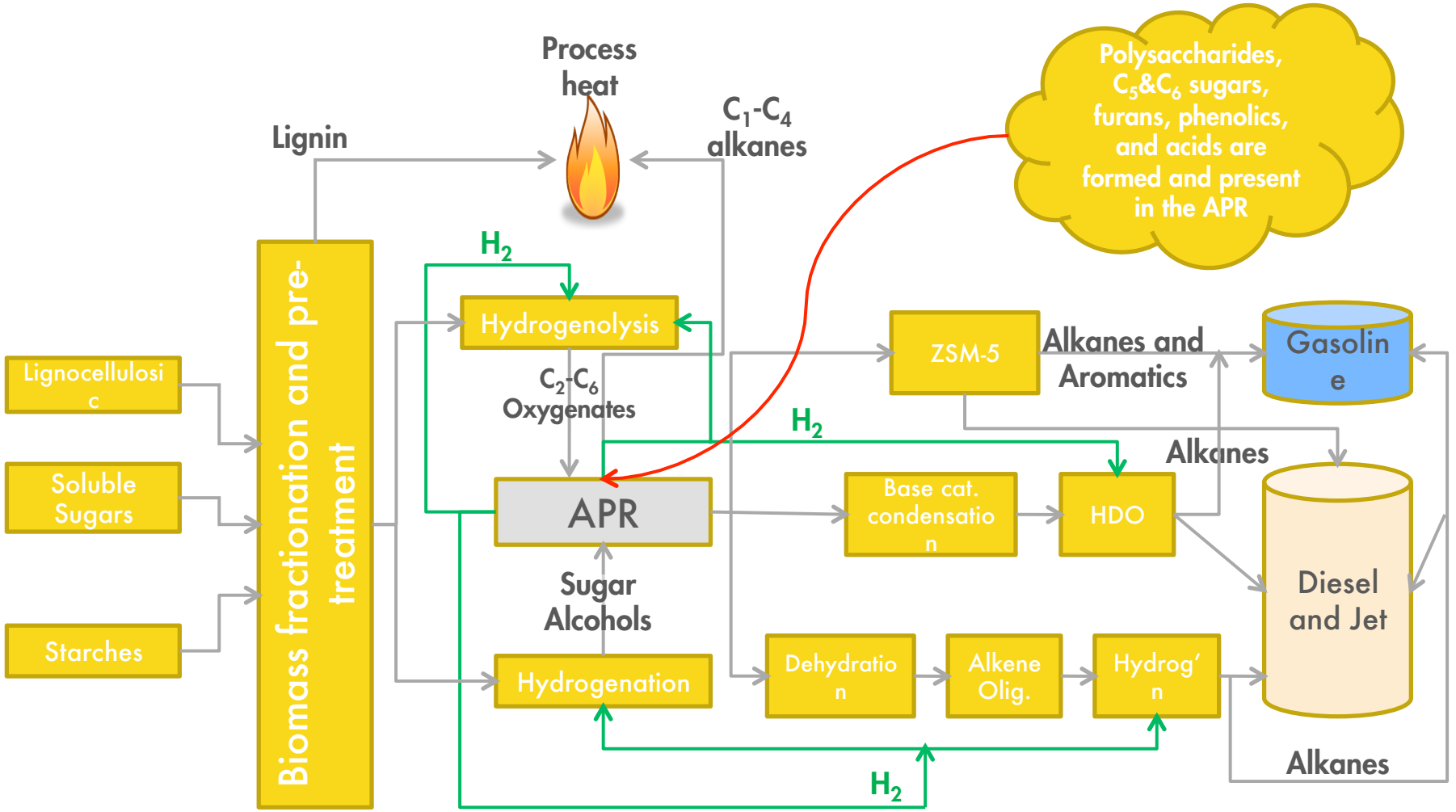
Courtesy Virent Energy Systems

Summary & Conclusions

- Environmental pressures on the aviation sector, including business aviation, are here to stay...
- Shell is committed to help meet these environmental challenges through a range of product and service offerings
- Long term we aim to offer improvements in local air quality with Sulphur and Aromatics free GTL jet fuel and R&D into low carbon fuels
- We are working towards scaling-up our biofuels R&D programmes
- We are constantly looking at new components from novel routes and feedstocks
- Shell is looking at the LCA of all of our novel routes and we are making a huge effort to help provide practical solutions for the Aviation fuels industry

Questions & Answers

Sugar to Alkanes – Shell-Virent Joint Venture



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