Aviation and the Environment – Where Next?

EBACE 2010

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Paul Bogers

Aviation Technology Manager

Overview

- The Energy Challenge and role of Aviation
- Abatement options and industry track record
- Alternative Fuels
  - New Fuel Approval Process
  - Gas-to-Liquids Jet Fuel
  - Low Carbon Fuel Options
- Summary & Conclusions

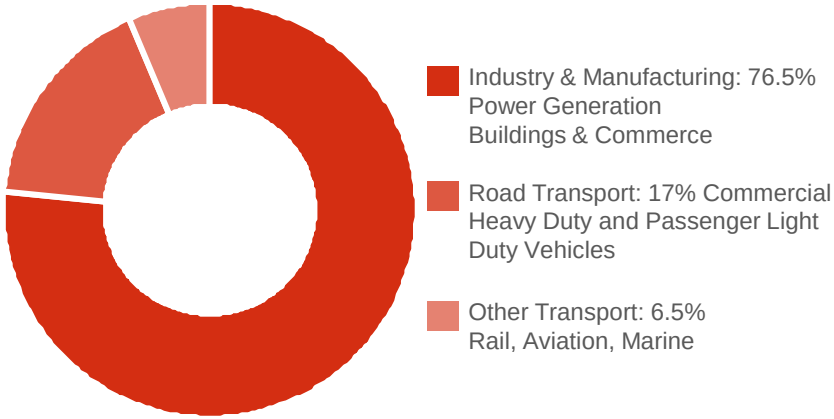
The Energy Challenge

- 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

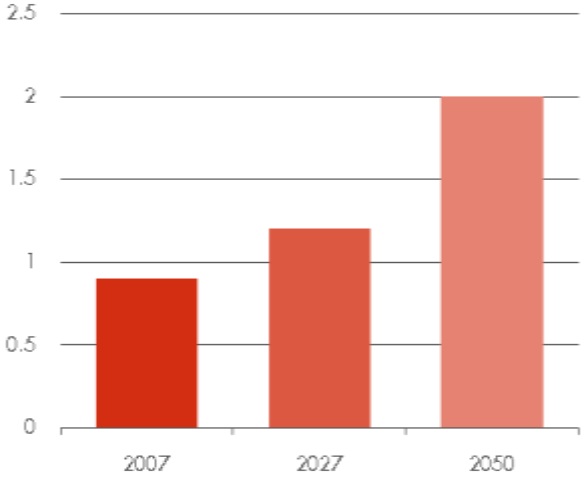
- Oil has been key for transport because it is a liquid and holds high energy density
- Transport accounts for about a quarter of energy-related CO_2 emissions
- Demand for mobility is increasing and emissions set to rise
- We need better vehicle technology, fuels and consumer behavior to constrain this 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 CO2 emissions

Estimate of worldwide vehicle demand

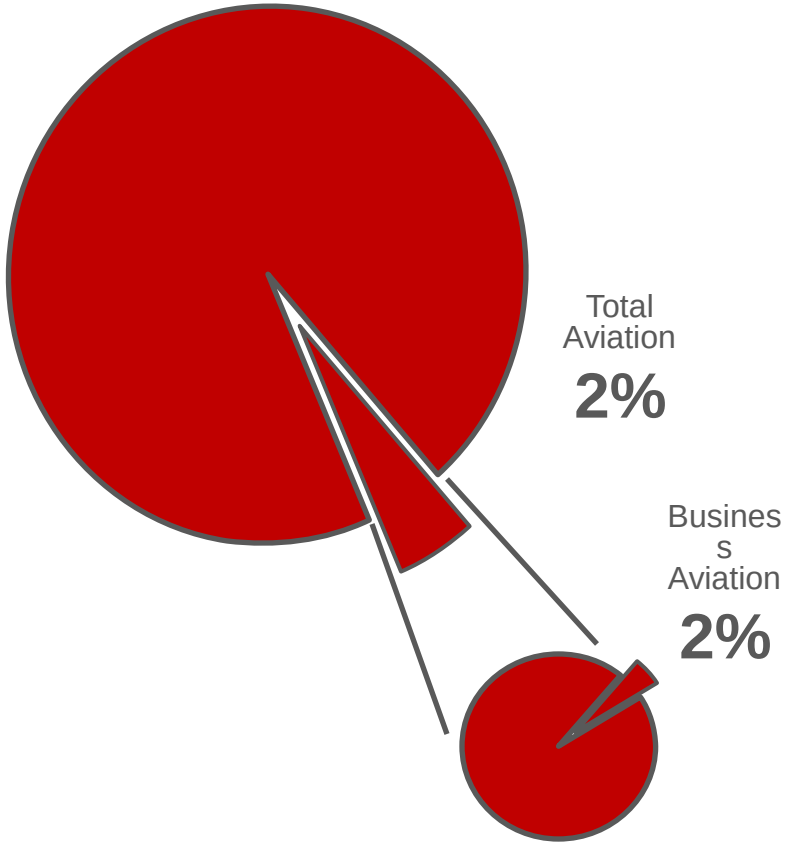


Source: World Business Council for Sustainable Development

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

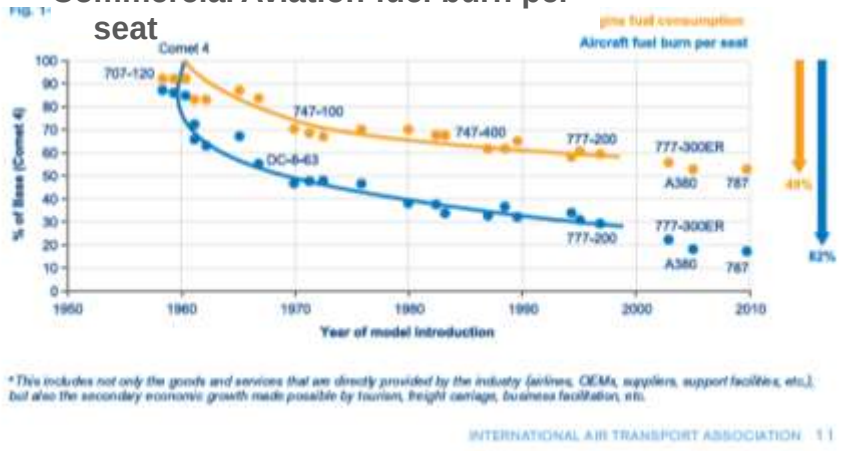
Energy–related CO_2 emissions



Source: IPCC, IBAC & GAMA

Efficiency gains impressive... but outstripped by growth

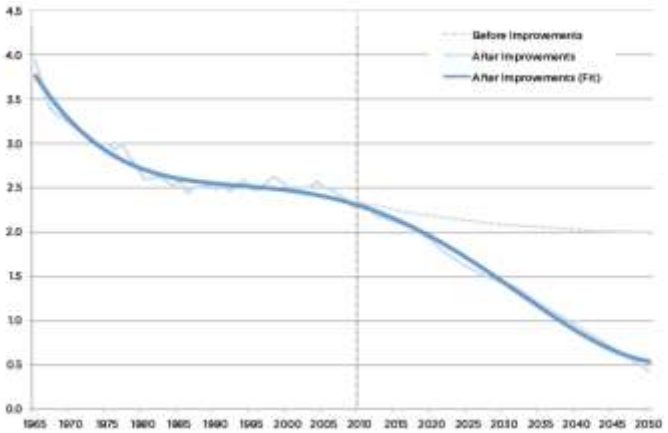
Commercial Aviation fuel burn per seat



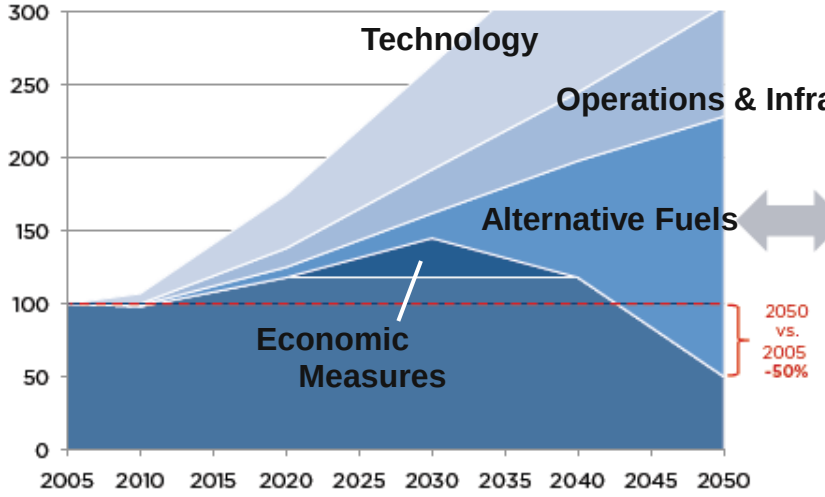
*This includes not only the goods and services that are directly provided by the industry (airlines, OEMs, suppliers, support facilities, etc.), but also the secondary economic growth made possible by tourism, freight carriage, business facilitation, etc.

INTERNATIONAL AIR TRANSPORT ASSOCIATION 11

Business aviation fuel burn per tonne-km



COMMERCIAL AVIATION CO_2 EMISSIONS
INDEX 100 EQUALS 2005 LEVELS
Actual & Forecast, 2005 – 2050



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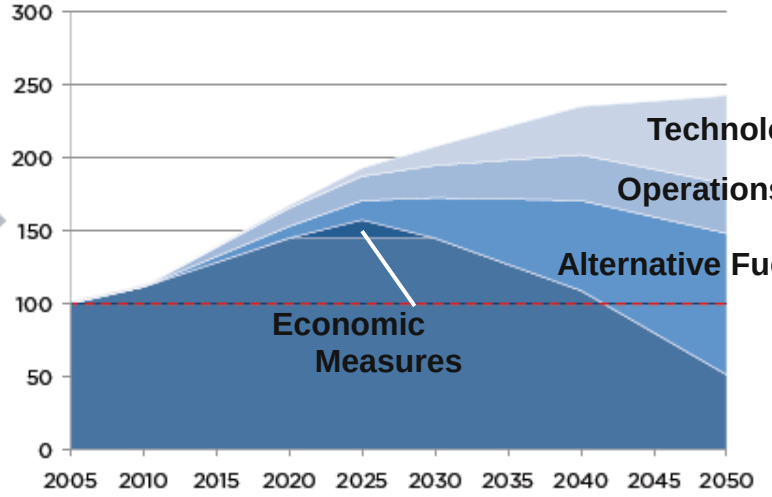


Source: IATA, IBAC & GAMA

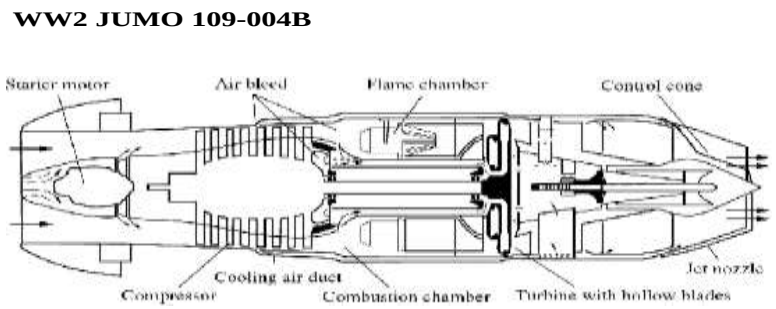
Alternative Fuels for Aviation

Challenges & Options

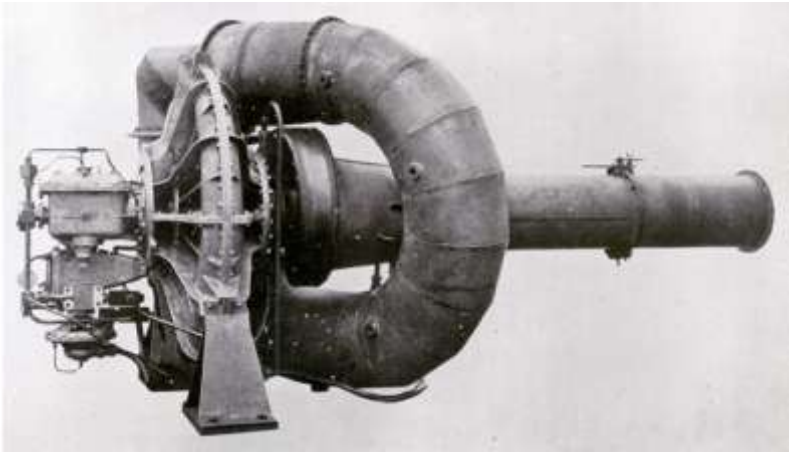
Kerosene in Aviation Accident or choice?

- Hans von Ohain's gas turbine ran on gasoline because of ease of evaporation and known piston engine

- Sir Frank Whittle's engine ran on 'illuminating kerosene' due to the shortage of gasoline



Picture from the RAF museum at Cosford, Wolverhampton, England



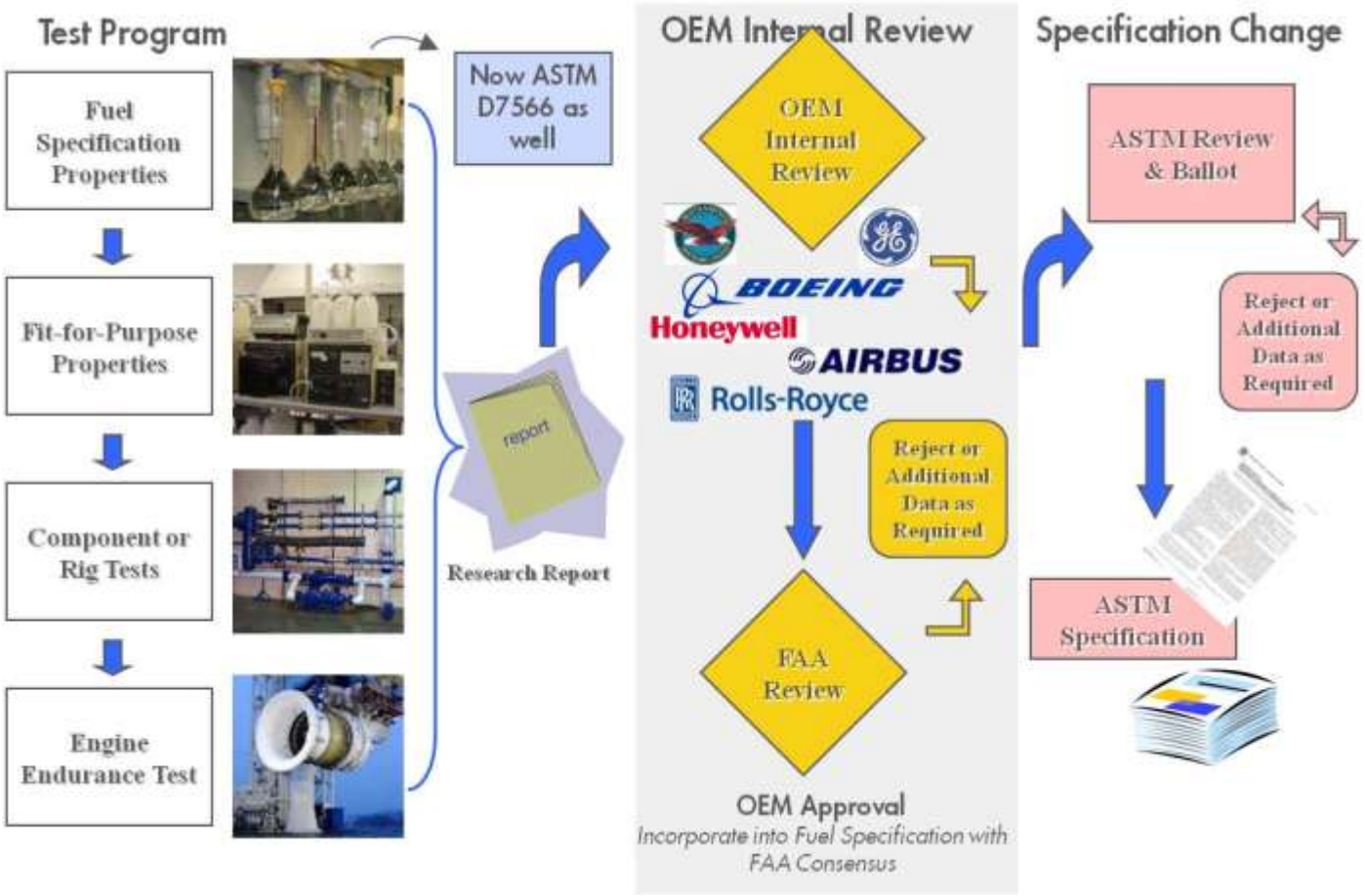
Fuel more than likely produced by the Fischer-Tropsch process from coal

Courtesy Rolls-Royce

Limited options for alternatives to kerosene

- Long lifetime and high capital cost of aircraft – kerosene is preferred jet fuel for next 30 years
- Focus on safety means lead times for fuel or additive development are long (~10 years)
- Specifications are global and more stringent than for road transport
- Today's options for road (biofuels- ethanol and FAME, electric, hydrogen) cannot be used
- Currently impossible to supply any biofuel mandates for aviation fuel in a sustainable manner

Certification of a new fuel is a slow process

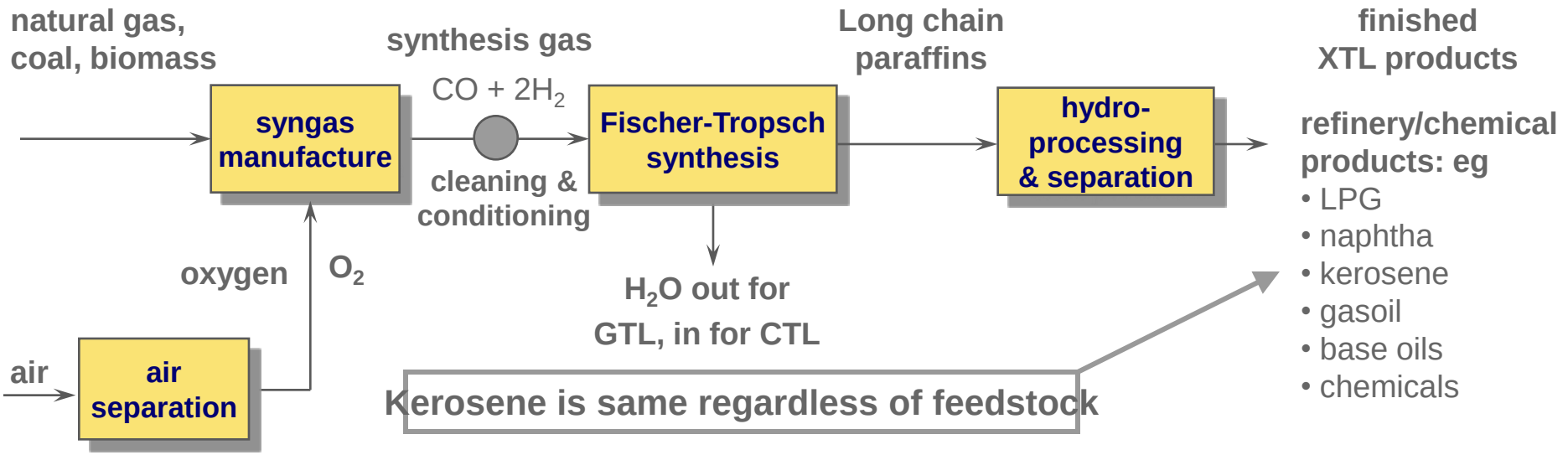


History was made on 25th September 2009 when the new jet fuel specification D-7566 for Fischer-Tropsch synthetic jet fuel was accepted

Alternative Fuels for Aviation

Gas-To-Liquids Jet Fuel - Case Study

The Fischer-Tropsch Process & Shell GTL projects



1973	1983	1993	Project ramp up 2011
			
Laboratory Amsterdam	Pilot plant Amsterdam	Bintulu Malaysia current capacity 14,700 bbl/d	Pearl GTL Qatar planned capacity 140,000 bbl/d

GTL Jet Fuel – a new source of kerosene

- Convenient – drop-in replacement
- Diversity of supply – Made from Gas, not Oil
- GTL kerosene has no aromatics and virtually Sulphur-free.
- Local emissions benefits (PM, SOx) – 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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GTL Ground trials – October 2009, Schiphol Airport

- 6 fuels - 0 to 50% GTL kerosene - run in Starboard engine of Cessna Citation, jointly owned and operated by NLR and TUD.
- Engine handling & emissions performance tested
- Shell responsible for fuelling, DLR conducting full suite of emissions measurements, KLM Jet Centre provided ground handling

Heated sampling line

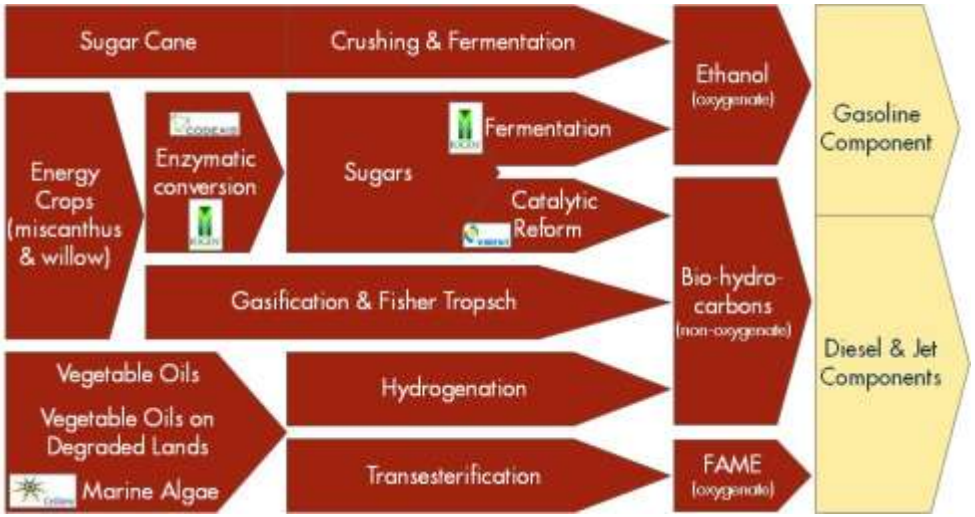
9-hole probe giving average emissions at ½ D behind engine

Low Carbon Transport Fuels

Options & Challenges

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

BIOFUELS MANUFACTURING PATHWAYS



THREE KEYS TO SCALABILITY

1. **CAPEX**
   Bio-refining routes are an order of magnitude larger than conventional refining
2. **FEEDSTOCK COST**
   The most promising feedstocks are short and sustainable sources carry additional premia
3. **YIELDS**
   Processing and conversion yields are poor for the majority of viable biomass feedstocks

- Shell has a broad portfolio of R&D projects and ventures to create low carbon transport 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)

What can Shell offer?

Credits

- We can sell you Emission Credits (CERs, ERUs & EUAs) today
- We can bundle fuel with carbon credits (under trial)

Fuels & Lubricants

- We have developed a high performance turbine engine oil *Aero*Shell Ascender enabling more efficient turbofans
- We are carrying out R&D on low carbon Jet fuels that are still some time away and face significant technical and commercial challenges

Information

- We are keen to exchange views with our customers on the subject of CO_2 management

Questions & Answers