Environmental assessments/initiatives (life cycle assessment, air quality measurement; international initiatives)

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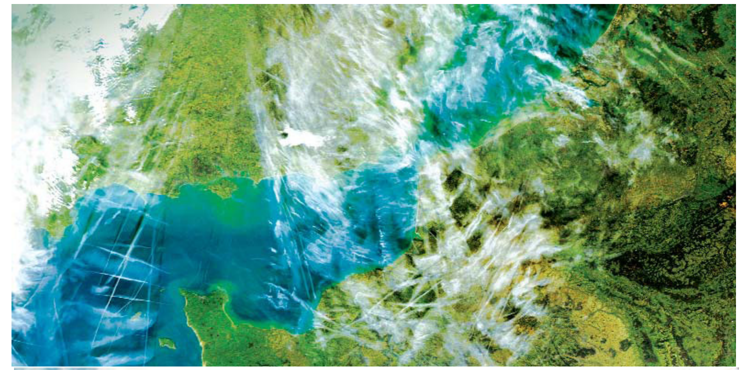
Contents

- Look a some of the UK/European work
  - Omega – UK universities
  - ECATS – European universities and RE's
- Other European projects such as Alfabird, Swafea, etc. covered elsewhere.

Omega partnership

- Advancing knowledge on aviation's environmental impacts and long-term solutions
- UK academic partnership of 9 universities, led by MMU
- Omega funded by Government, initially for 2 years build knowledge across the aviation sustainability debate
- 40 studies and activities – many workshops and conferences
- Alternative fuels expertise mainly from University of Sheffield, University of Leeds and Cambridge University



Alternative fuels

- Technology theme includes alternative fuels
- Collaboration with PARTNER
- Sustainable fuels for aviation study
- Omega Alternative Fuels conference held 24 – 26 October 2008
- Alternative fuels data centre being developed

Main thematic area: Technology

Sustainable fuels for aviation

As the aviation industry grows, so too does concern about its impact on the environment. Developing new more environmentally friendly and carbon neutral aviation fuels may go some way to addressing the issue of pollutants produced by aircraft. At least one airline is pledging to plough profits into researching bio-fuels for aircraft in order to lessen the environmental effects of its fleet.

This study, which involved several aviation and fuels stakeholders, will evaluate the relative environmental impacts of potential alternative aviation fuels. It will look at kerosene and other fuels derived from fossil fuels; synthetic liquid fuels manufactured from coal, biomass or natural gas; and bio-fuels made from agricultural crops. It will assess the noise, emission and engine performance of each sustainable fuel. The evaluation will include a "well to wake study" of the full chain of use from initial energy harvesting/resource extraction, to production and transportation, to use by the aviation industry including any end-of-use/disposal issues. The study will draw upon a range of disciplines including aeronautical engineering, mathematics, chemistry, environmental science, agriculture, transport management and combustion and fuels specialisations. A key feature of this investigation is the development of an approach for constructing and reducing models of complex chemical reactions during bio-aviation fuel high temperature oxidation process.

Using sustainable fuels in aircraft engines poses a number of technical challenges:

- the use of lower energy density fuels may in fact increase engine CO_2 emissions and noise relative to conventional jet fuel
- aircraft need fuel for heating, cooling and other tasks which may prevent the use of solely sustainable fuel and necessitate the need to use blends of sustainable fuel with jet fuel – the study will identify the blend limits suitable for aviation use
- using a low energy density fuel will reduce the journey range of an aircraft and increase its take-off weight. On certain routes the reduced range is not a problem but the increased weight will again result in increased fuel burn and noise. The study will quantify this fuel burn for inclusion into the "well to wake" element and evaluate the increase in noise.

This is a novel highly innovative study aimed at providing credible data to assess the use of sustainable fuels in aviation. It looks at the trade-offs with respect to noise and emissions and the effect of introducing sustainable fuel blends into todays technology. A limited knowledge transfer study such as this cannot answer all the questions which need to be addressed. However, it will comprise both fundamental data on the properties and combustion characteristics of sustainable fuels and fuel blends. It will also develop sustainable aviation fuel reaction models in a systematic, scientifically rigorous way. Finally, a gap analysis workshop will be held with the stakeholder community (including oil companies, manufacturers, airlines and airports) to identify the research needed to fully understand the potential use of sustainable fuels and their limitations.

Lead partner: University of Sheffield

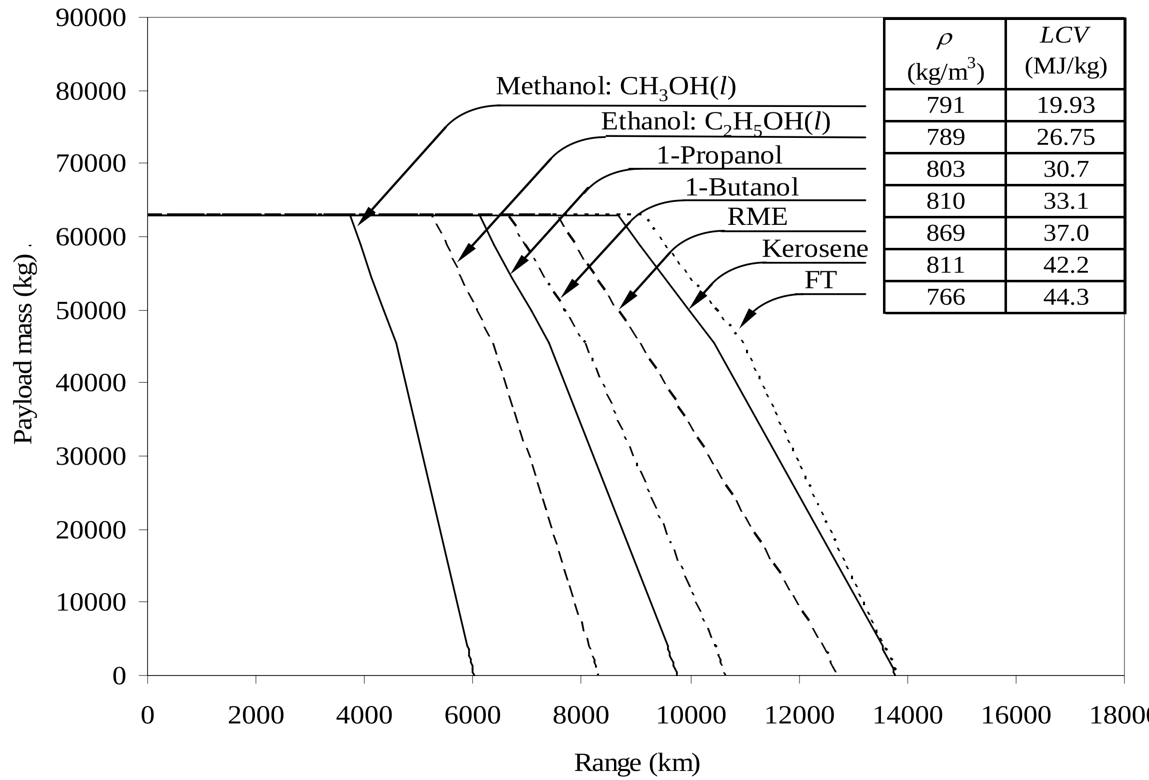
Duration: 24 months

Omega Sustainable fuels for Aviation

- Objective
  - Evaluate the relative environmental and economic impacts of potential sustainable alternative aviation fuels
- Consortium of 5 universities
  - Sheffield, Leeds, Cranfield, Cambridge, MMU
- Industry
  - Rolls Royce, Shell Aviation etc.
- International Collaboration

Impact of alternative fuels

- Aircraft design issues
- Engine Emissions
- Noise
- Well to Wake study



Life-Cycle Analysis

- Analyse the upstream characteristics of
  - ❑ synthetic jet fuel from petroleum and natural gas
  - ❑ oil sands, shale oil, and coal
  - ❑ biomass
  - ❑ biodiesel fuels from rapeseed and microalgae
  - ❑ HRJ from Jathropa and Camelina

to add jathropa and Camelina!

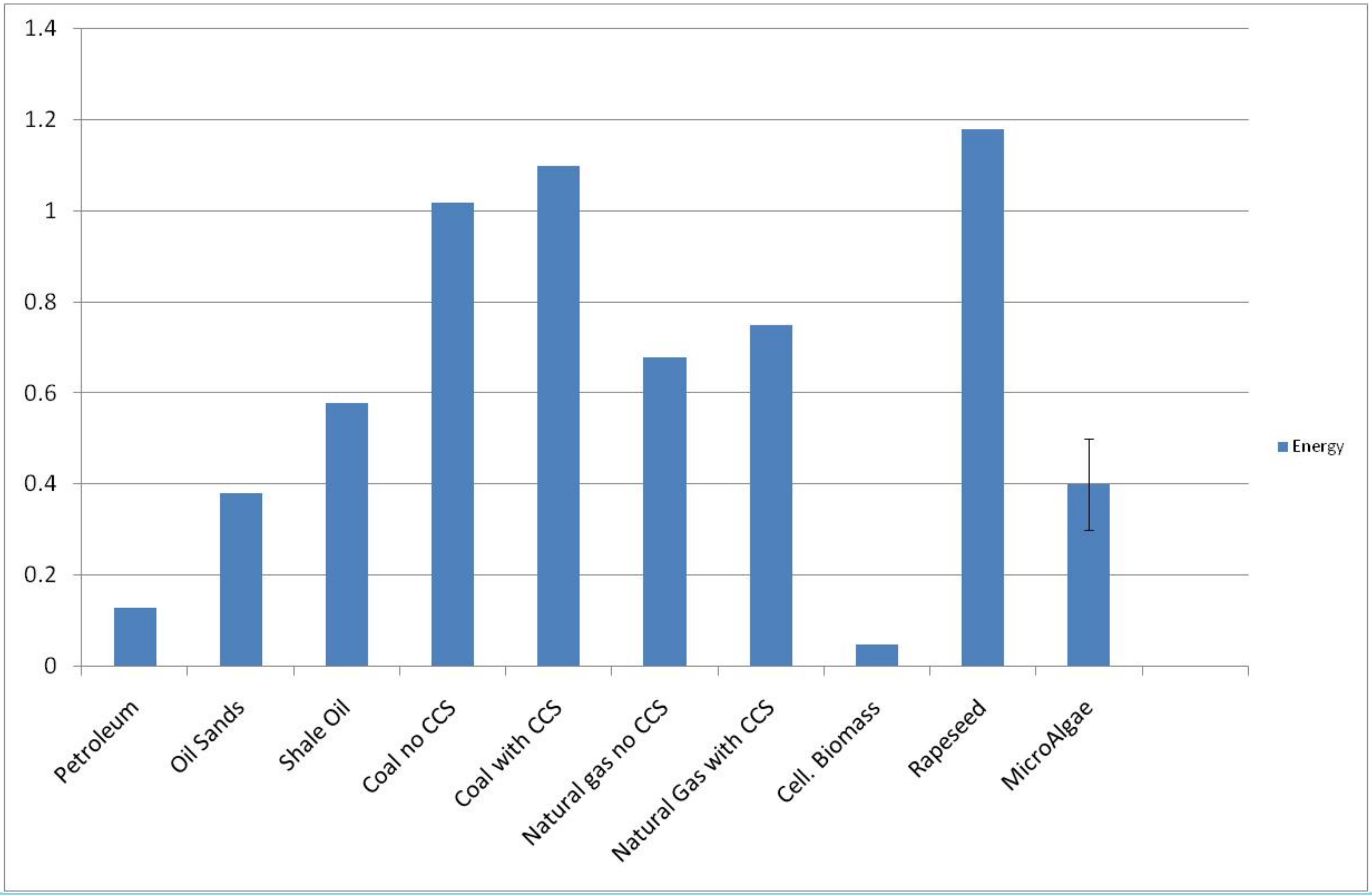
Fuel- and Life-Cycle characteristics

	Jet Fuel								Biodiesel	
Feedstock	Petro-leum	Oil Sands	Shale Oil	Coal		Natural Gas		Cell. Bio-mass	Rape-seed	Micro-Algae
Carbon Capture & Storage	no	no	no	no	yes	no	yes	no	no	no
Fuel-cycle energy use, $MJ/MJ_{Product}$	0.13	0.38	0.58	1.02	1.10	0.68	0.75	0.05	1.18	0.3-0.5
Fuel-cycle GHG emissions, gCO_2-equivalent/$MJ_{Product}$										
Energy-related	9.5	23.4	66.4	111.1	11.1	21.3	2.1	*tba*	*tba*	*tba*
Other	1.2	2.6	14.6	4.2	4.4	3.5	3.7	*tba*	*tba*	*tba*
Total	10.7	26.0	80.9	115.3	15.5	24.8	5.8	12.8	50	40-180
Life-cycle GHG emissions, gCO_2-equivalent/$MJ_{Product}$	85.0	100.3	155.2	189.6	89.8	99.1	80.1	12.8	50	40-180
Other Characteristics										
Production costs of (synthetic) crude oil (equivalent), $/bbl	≈ 50	20-30	60-85	50-65	55-70	25-30	30-35	35-85	160	120-700

Energy Use

- Energy flows from feedstock extraction, the subsequent conversion to secondary energy, and the transport of the processed fuel to the airport (final energy) are calculated via the thermal efficiencies of the individual processes.
- The overall energy efficiency of the supply chain then results from final energy leaving the overall systems boundary to primary energy entering the systems boundary.

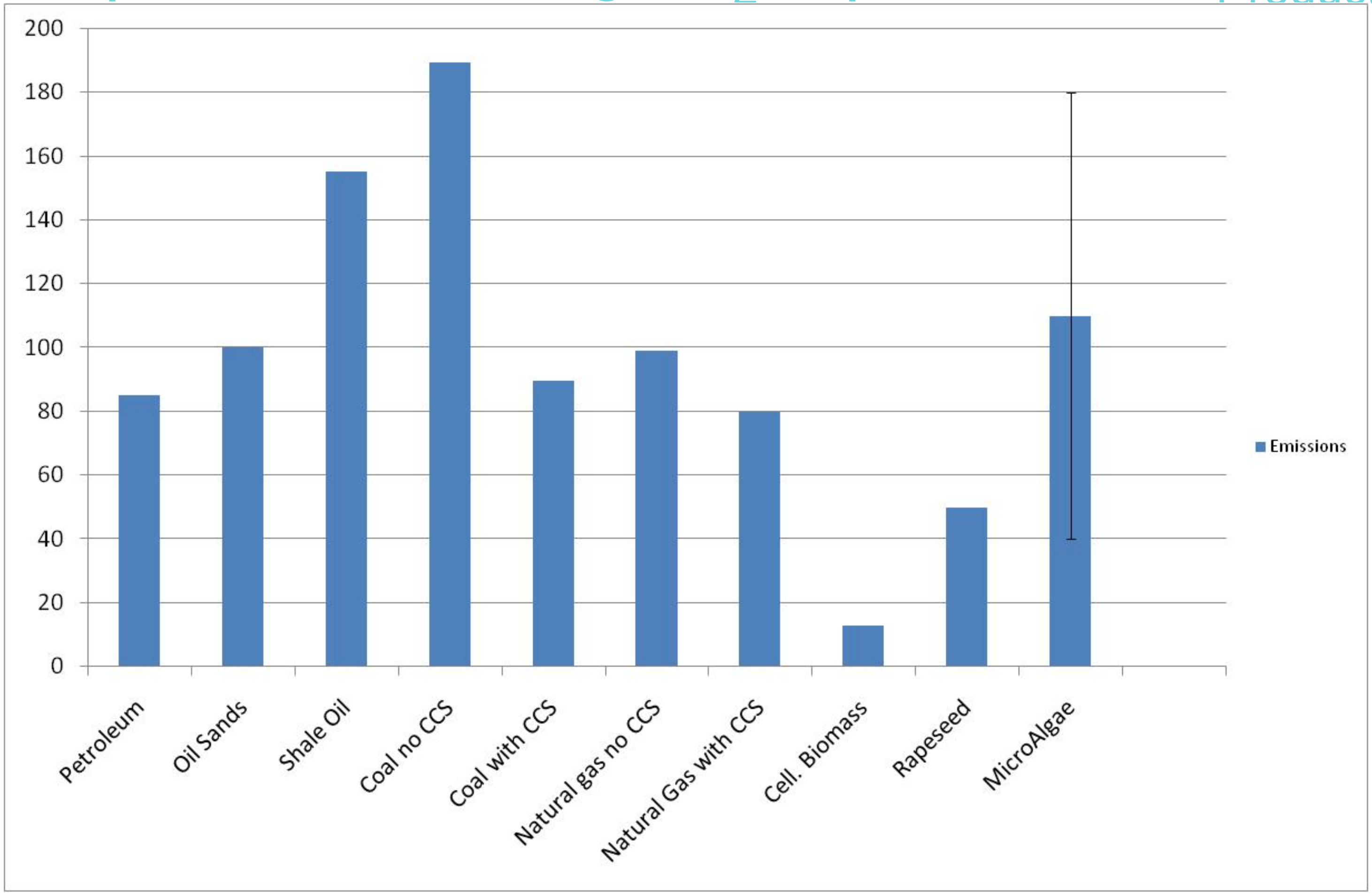
Energy use MJ/MJ$_{product}$



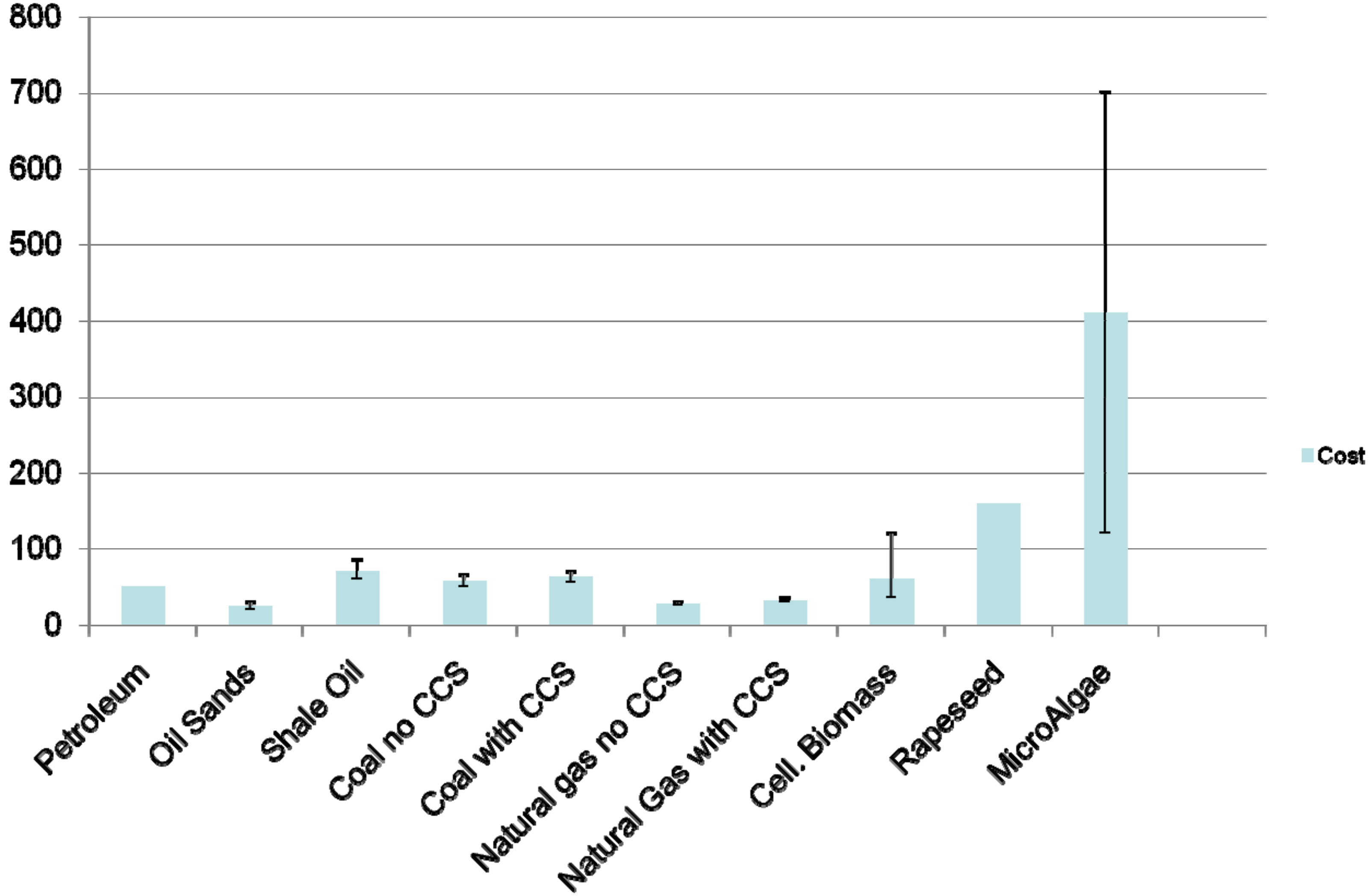
Total Carbon Emissions

- Consist of two components.
  - ❑ One component can be attributed to the ratio in fuel carbon leaving a conversion process to that entering the process, that is, the "carbon efficiency".
  - ❑ The second component of CO_2 is equivalent emissions. Consists of non-CO_2 greenhouse gases, which include methane (CH_4) and nitrous oxide (N_2O).
    - CH_4 emissions result from coal, oil, and natural gas extraction, and the transport of natural gas. Assumed methane emission factors of
      - 0.05 grams of methane per MJ of extracted crude oil
      - 0.1 grams per MJ of extracted coal
      - 0.2 grams per MJ of methane
    - In contrast, N_2O emissions are released from agricultural land are also considered

GHG equiv. Emissions gCO_2-equivalent/$MJ_{Product}$



Cost

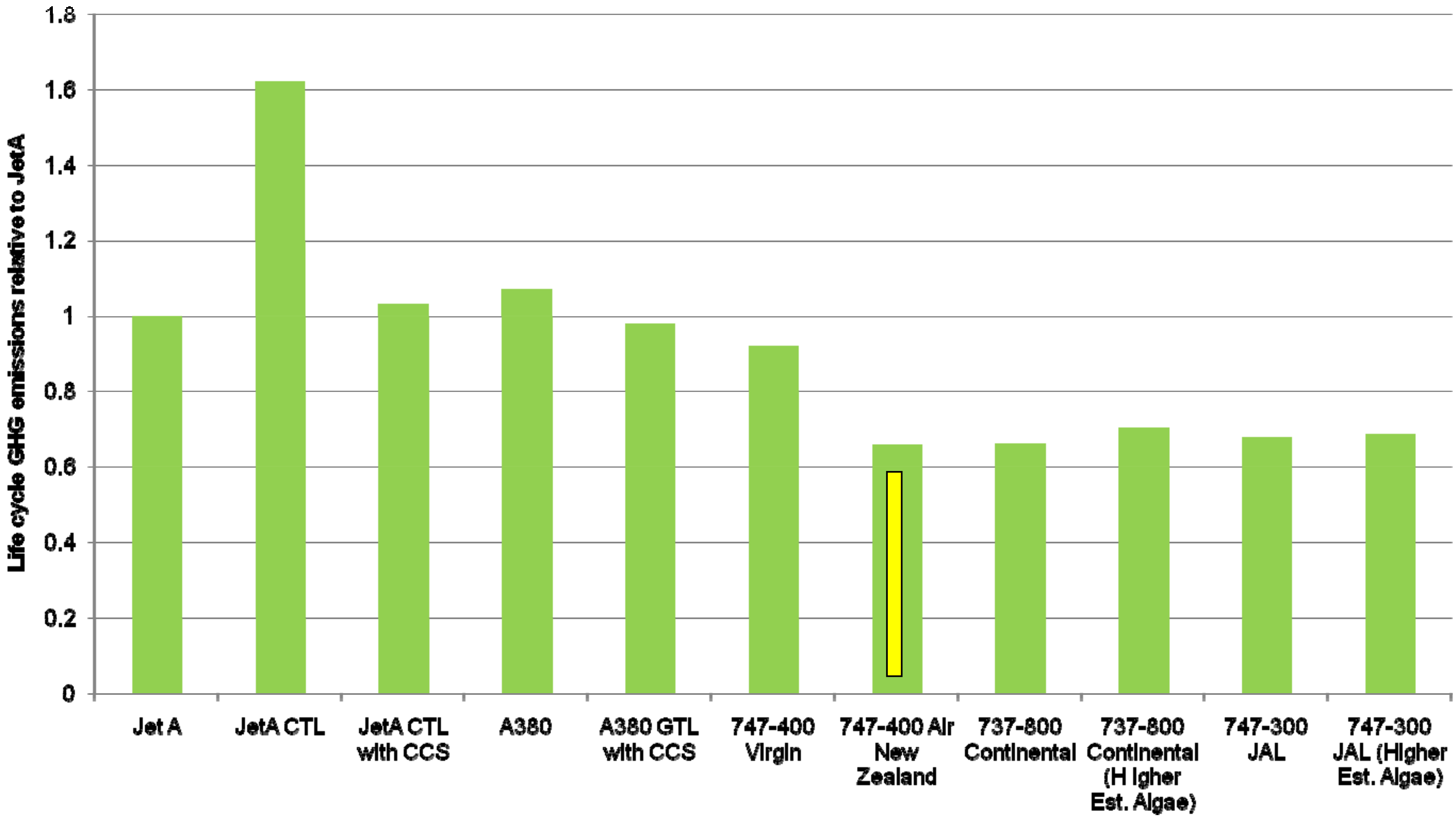


800
700
600
500
400
300
200
100
0
Cost
Petroleum
Oil Sands
Shale Oil
Coal no CCS
Coal with CCS
Natural gas no CCS
Natural Gas with CCS
Cell. Biomass
Rapeseed
MicroAlgae

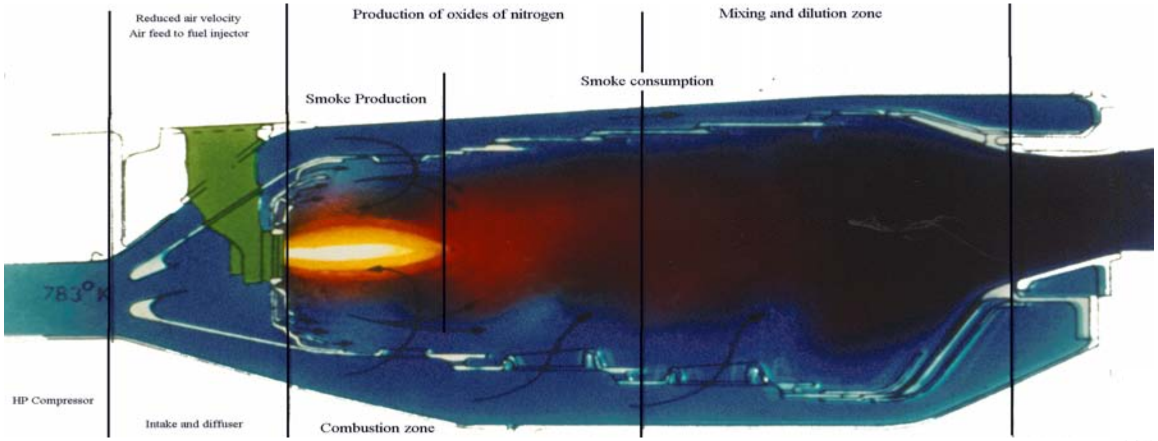
08/09 flights

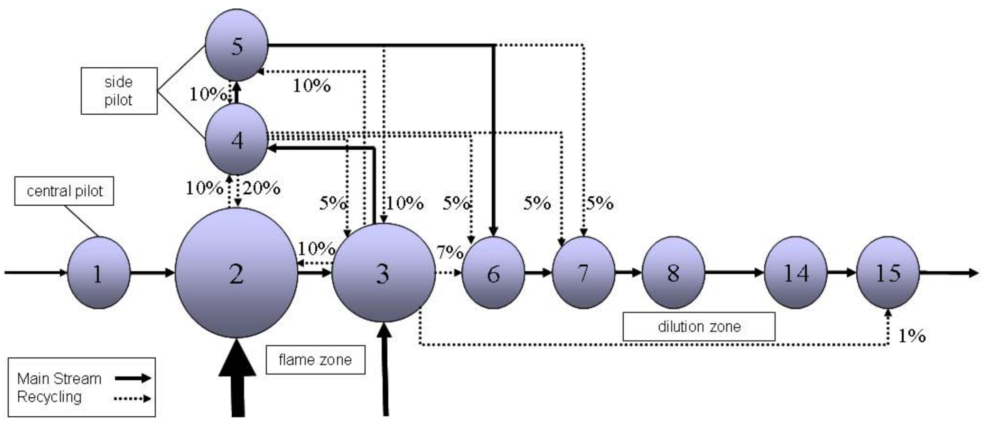
- Airbus-Shell-RR A380
  - 3 hrs, GTL 60-40
- Virgin Airways 747-400 LHR-Schipol
  - 40 mins, 80-20 bio diesel from babassu and coconuts!
- Air New Zealand 747-400
  - 2 hrs, 50-50 jathropa derived hydrogenated oil
- Continental 737-800
  - 2 hrs, 50-47.5-2.5 Jathropa and Algae
- JAL 747-300
  - 90 mins, 50-50, with bio made from camelina (84%), jatropha (under 16%) and algae (under 1%)

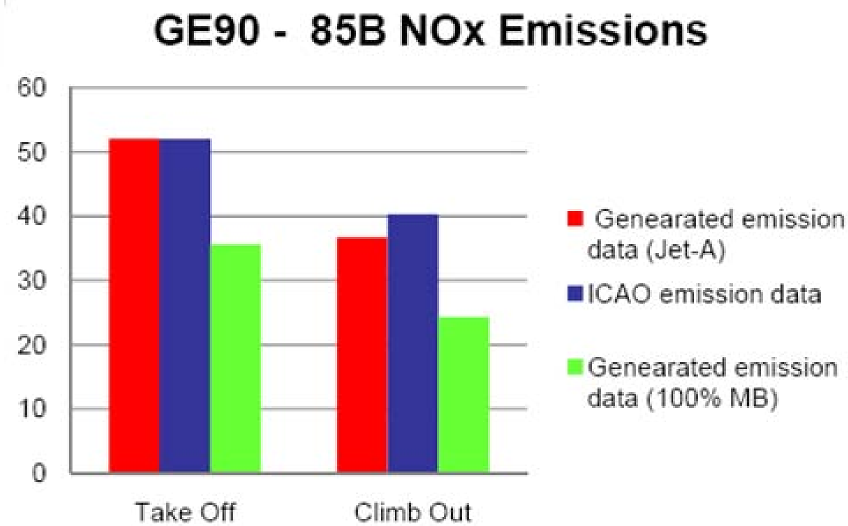
Who’s green cup floweth over?



Reactor network modelling

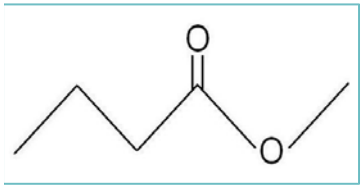


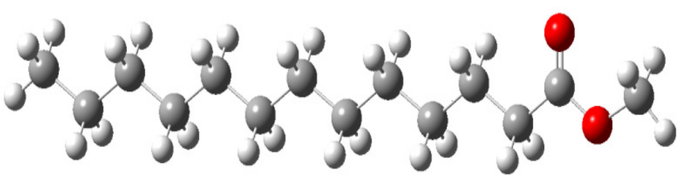


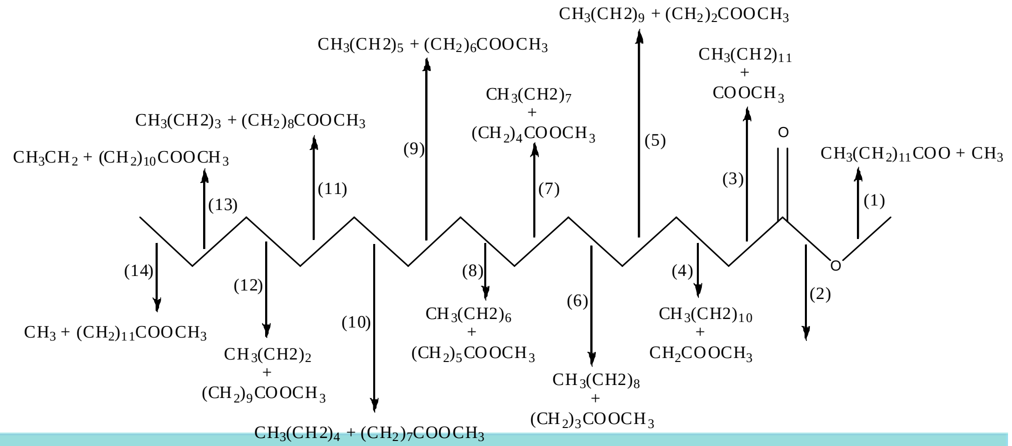


Reaction Mechanisms

- Developed Reaction Mechanisms
  - Previously developed JetA
  - Modified Heptane for GTL
  - Methyl Butanoate for Bio Diesel
  - C-14 methyl ester (methyl tridecanoate)
- Combined scheme AFRM v2.0
  - Models all fuels inc NOx and SOx chemistry
  - 203 species, 1600+ reactions







Aviation Fuels database

- To provide a single source of relevant data
- Sourced from available literature
  - Chemical Abstracts Service (CAS)

    see http://www.cas.org/index.html
  - NIST Chemistry WebBook

    see http://webbook.nist.gov/chemistry/

- bio-aviation fuels (eg soya beans, palm oil, switch grass, jatropha and algae)
- butanol, methanol and ethanol
- Hydrogen
- Fischer-Tropsch aviation fuel
  - ❑ gas to liquids
  - ❑ coal to liquids
- hydrogenation-derived renewable Jet fuel (HRJ)

ECATS

DLR
NLR
FOI
ONERA
FZK
BUW
MMU
USFD
UiO
EBI
NTUA
UP
NKUA

ECATS

Environmentally Compatible Air Transport System

ECATS Objectives

- ✈Re-structuring and re-organisation of research organisations and universities in Europe and preparing the ground for a European Virtual Institute for Research on the Environmental Compatibility of Aviation
  - ➢integrating related areas of technology and atmospheric science
  - ➢integrating competences and capacities of partner organisations
  - ➢aiming for a common research programme
  - ➢extending capabilities to be more competitive
  - ➢offering one point of contact for stakeholders
- ✈Research Establishments and Universities within Europe

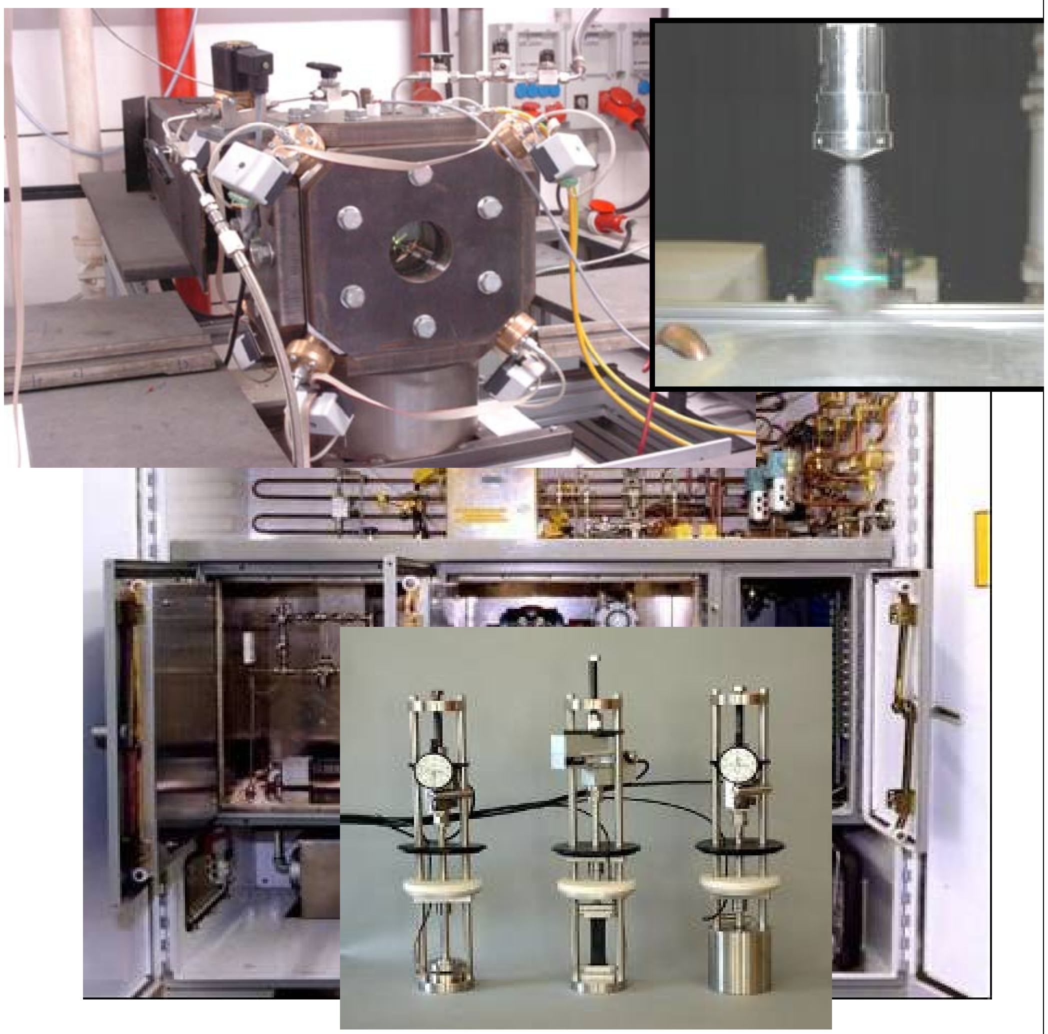
ECATS - Network of Excellence

Thematic Area 1	Thematic Area 2	Thematic Area 3
Engine Technology, Near Field Plume and Alternative Fuels	Local and Regional Air Quality	Green Flight and Scenarios

Activity	WP	Title
Integrating Activities	WP1	Management and Organisation
	WP2	Strategic Drivers
	WP3	Assessment
	WP4	Capability Gap Analysis
Jointly executed research	WP5	Capability Enhancement
	WP6	Research Initiatives
Spreading of Excellence	WP7	Education
	WP8	Interface Management
	WP9	Dissemination

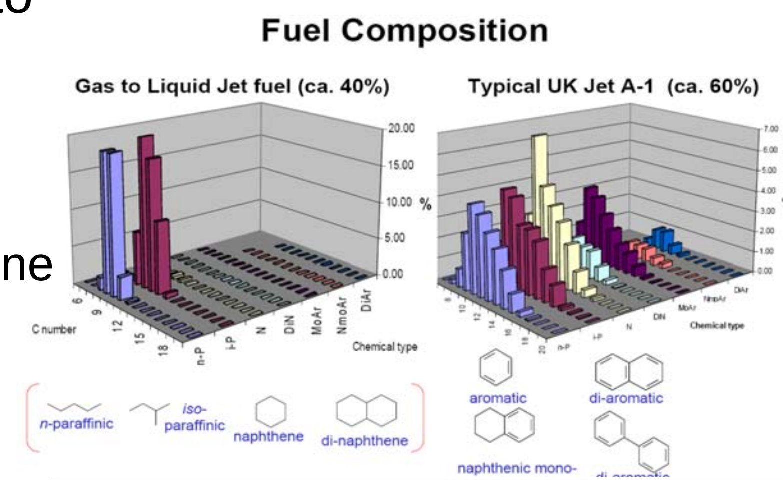
Fuel Centre Capability

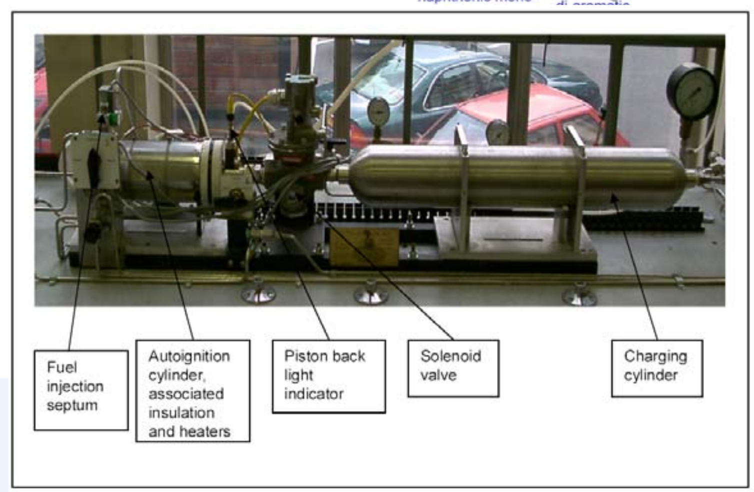
- Most partners have combustion facilities. Specialist facilities required by the consortium were identified as:-
  - ❑ A fan stirred bomb for ignition and flame speed measurements – EBI
  - ❑ An engine fuel system simulator for fuel thermal stability – USFD
  - ❑ Fuel spray diagnostic facilities – EBI, UP
  - ❑ Soot modelling capability – DLR
  - ❑ Combustion modelling – UP, FOI/(ONERA)
  - ❑ Engine modelling for alternative fuels – FOI/DLR/NTUA
  - ❑ Reactivity measurements – BUW
  - ❑ Material compatibility issues
    - ▪Elastomers - USFD
    - ▪Metals - ONERA



xTL programme

- Working with industry
- Base fuel + additions
- Tests will be conducted at partner establishments to characterise in geometry independent way the following properties:-
  - ❑ Ignition and flame propagation performance EBI,
  - ❑ Autoignition performance Rapid Compression Machine
  - ❑ Smoke DLR/MMU
  - ❑ Thermal stability USFD
  - ❑ Spray and Cal. Val. - UP
  - ❑ Emissions from a simple burner BUW
  - ❑ Material compatibility issues USFD, ONERA.
  - ❑ Engine Modelling NTUA,NLR,FOI
- Parametric modelling studies using chemical kinetic schemes also carried out - NTUA





Summary

- Looked at Omega and some preliminary results
  - Fuels programmes underway
  - Sustainable fuels
    - Life cycle characteristics – What's the question Environmental/Security of Supply or both?
    - Emissions changes - Potential reduction exist
- Looked at ECATS
  - The Virtual Fuel Centre
  - The programme on xTL fuels delivering fundamental knowledge

The University Of Sheffield.

Thank you!

http://www.omega.mmu.ac.uk/

http://www.ecats-network.eu/