ICAO /Transport Canada Workshop, Montreal
20-21 September 2006

FUTURE AVIATION FUELS

What are the challenges?
What are the options?

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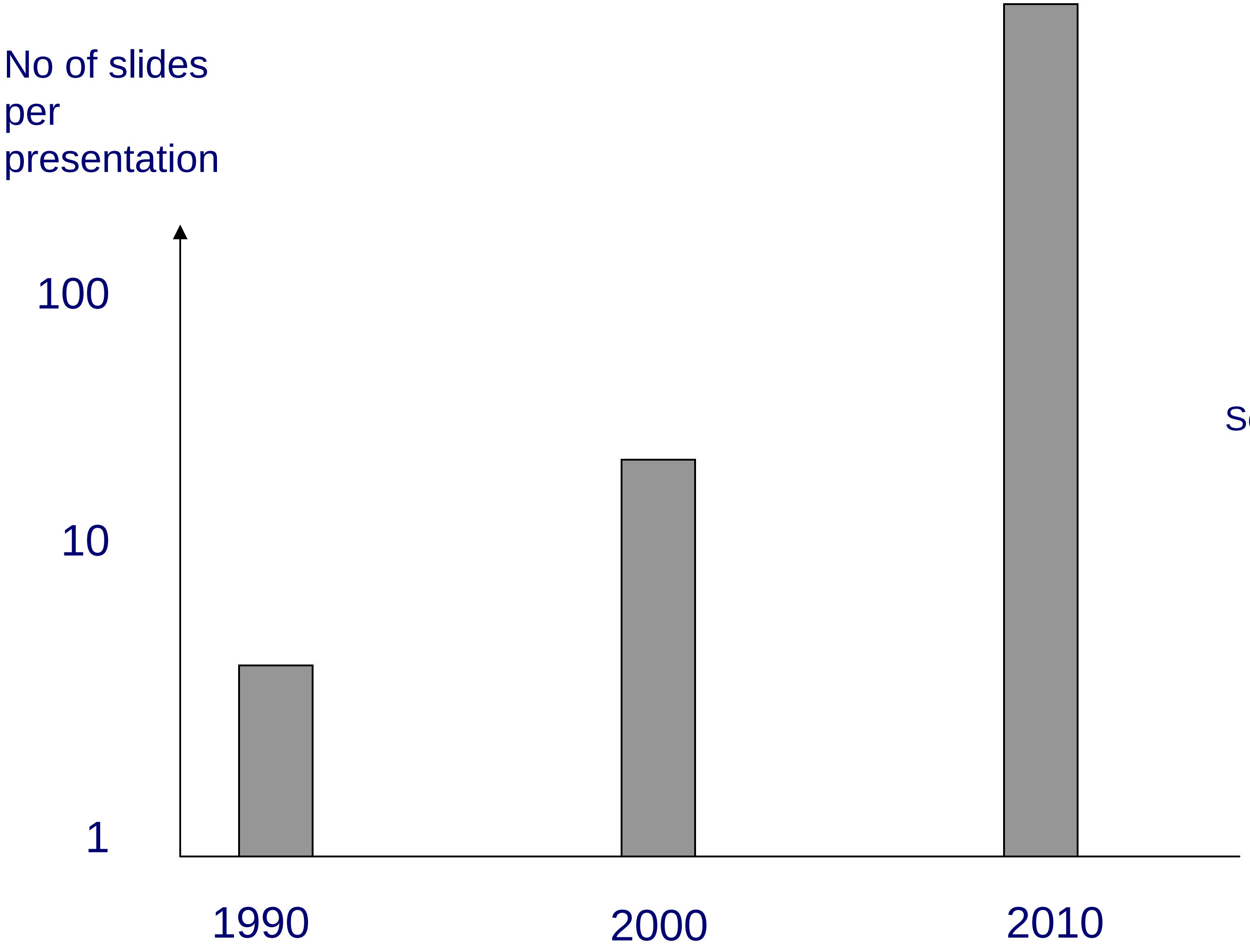

Source : McKensey

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AVIATION & ENVIRONMENT SUMMIT

Geneva, April 2006

IATA

IATA FUEL FORUM
Lisbon, May 2006

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Kerosine is a very good aviation turbine fuel

- Good cold flow characteristics
  - Viscosity
  - Freeze point
- Clean combustion, low luminosity
- Good energy density
- Good thermal stability

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Aviation is a very special global industry – but not much scope for special fuels

- Long lifetime and high capital cost of aircraft – kerosine is preferred jet fuel for next 30 years
- Focus on safety means lead times for fuel or additive development are long (~10 years)
- Airlines don't like aircraft that need special fuel
- Little incentive for OEMs to develop aircraft/engines running on a special high performance or alternative fuel
- Local alternative fuel solutions common in ground transportation fuels only applicable to General Aviation
- Hydrogen would need completely new aircraft and infrastructure

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Any new or alternative aviation fuel must be a drop-in replacement

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The main challenges that future aviation fuels must address

- Reducing environmental impact of aviation
- Reducing operating costs
- Improving fuel availability and allowing diverse supply options

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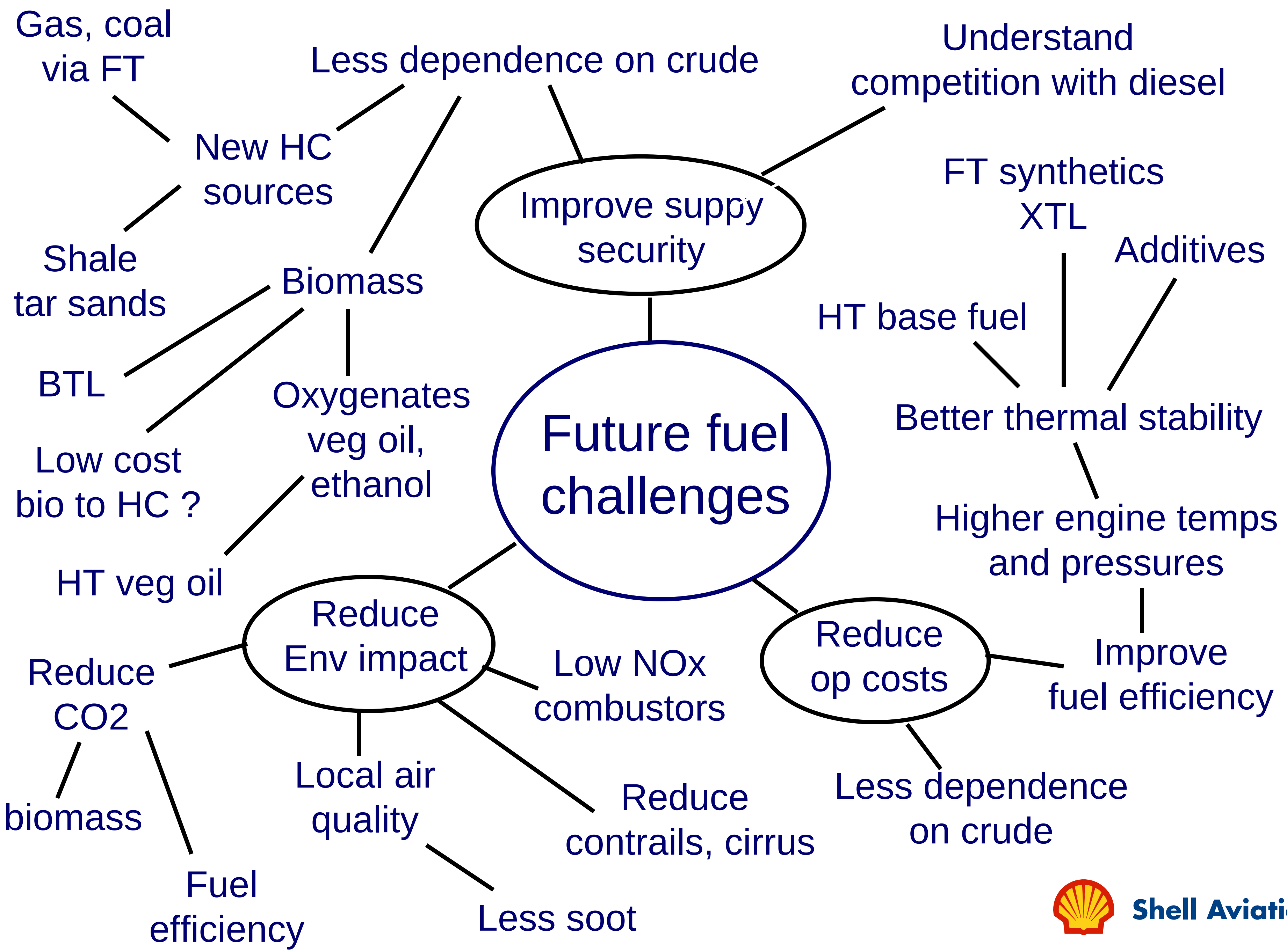

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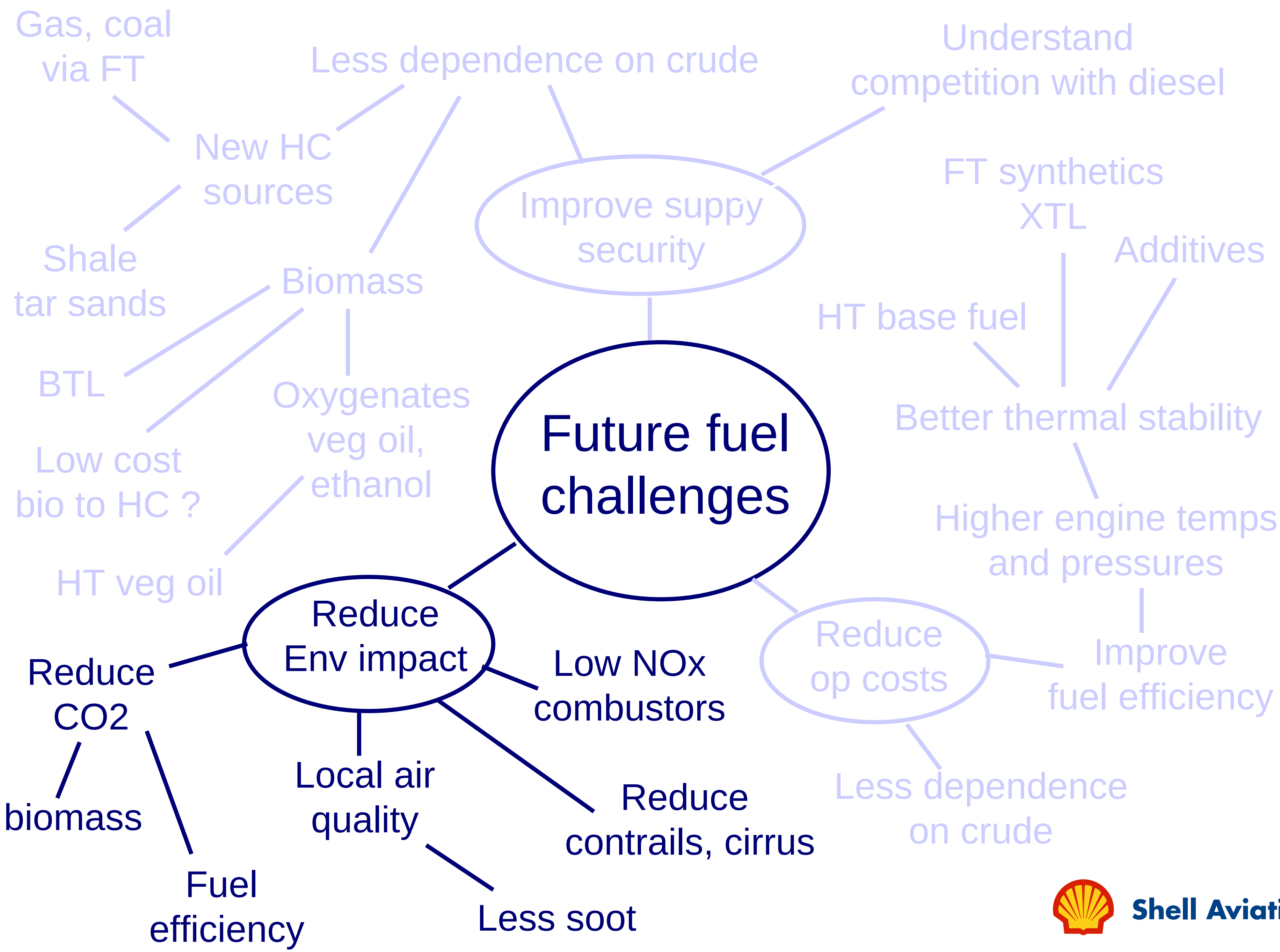

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Aviation's is only 3% of man-made CO2 but its environmental impact is under the spotlight

Aviation's impact estimated at 2.5x basic CO2 effect due to cirrus, contrails and NOx

EU wants to include Aviation in Emissions Trading

Local air quality is a major factor limiting Heathrow airport expansion – NO2 levels main issue but particulates also on the agenda

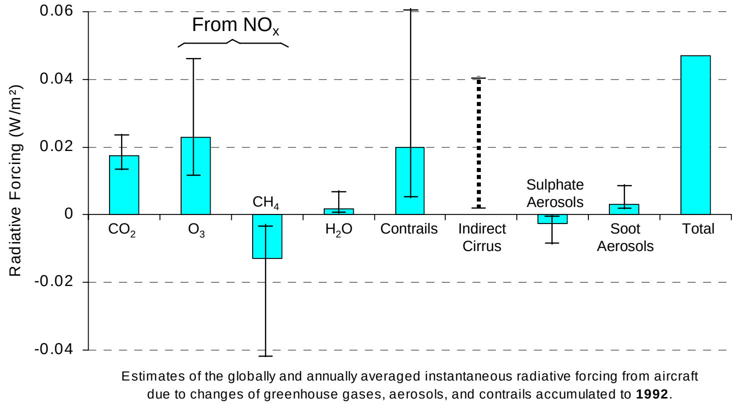

Figure 2 : Aviation Global Radiative Forcing

(Excerpt from the IPCC Special Report on Aviation and the Global Atmosphere, 1999)

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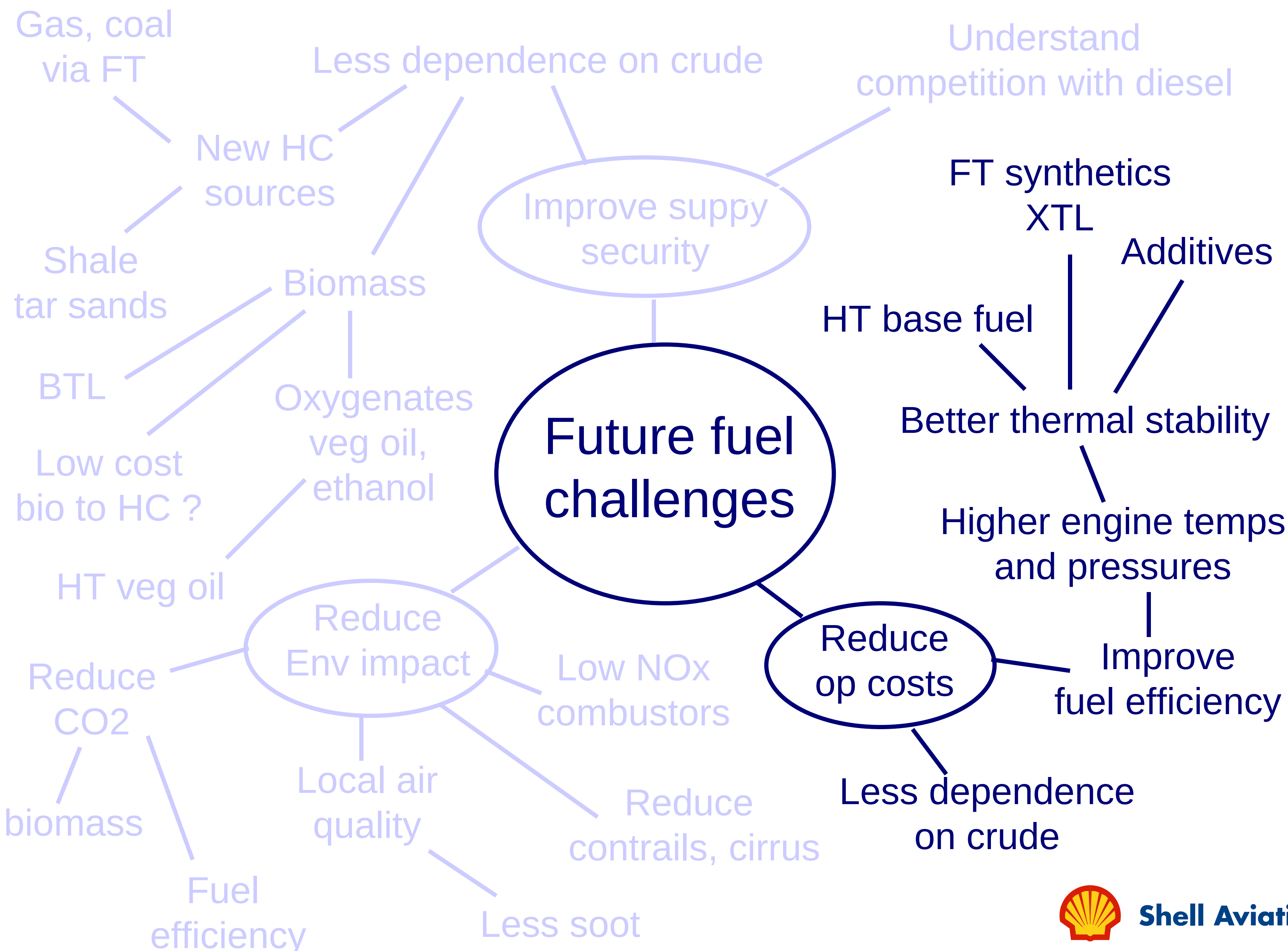

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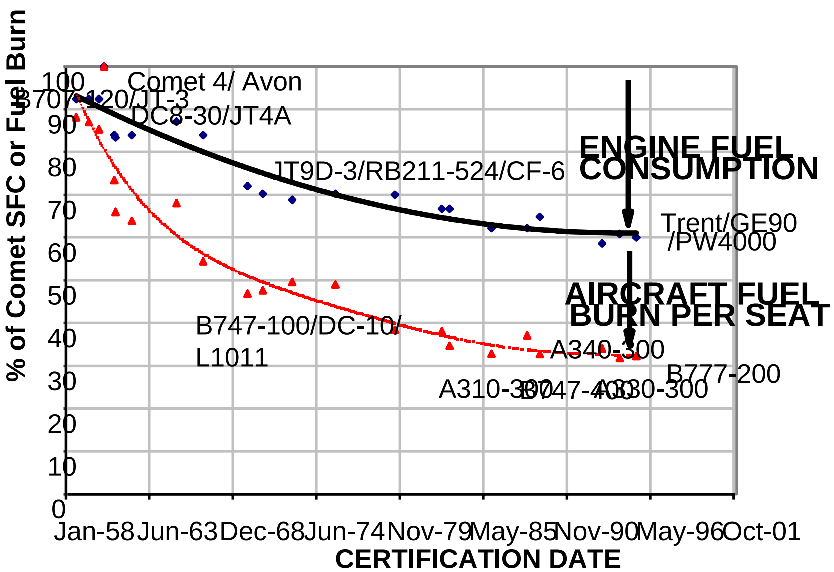
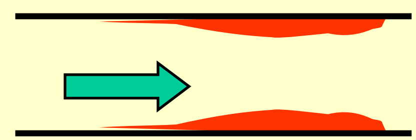
Better thermal stability would allow engines to run hotter



20 deg C estimated to give 0.1% improvement in SFC

Current engines are pushing the thermal stability of both fuels and lubricants to the limit

Inadequate thermal stability causes deposits and blockages in fuel systems



The engine equivalent of cholesterol

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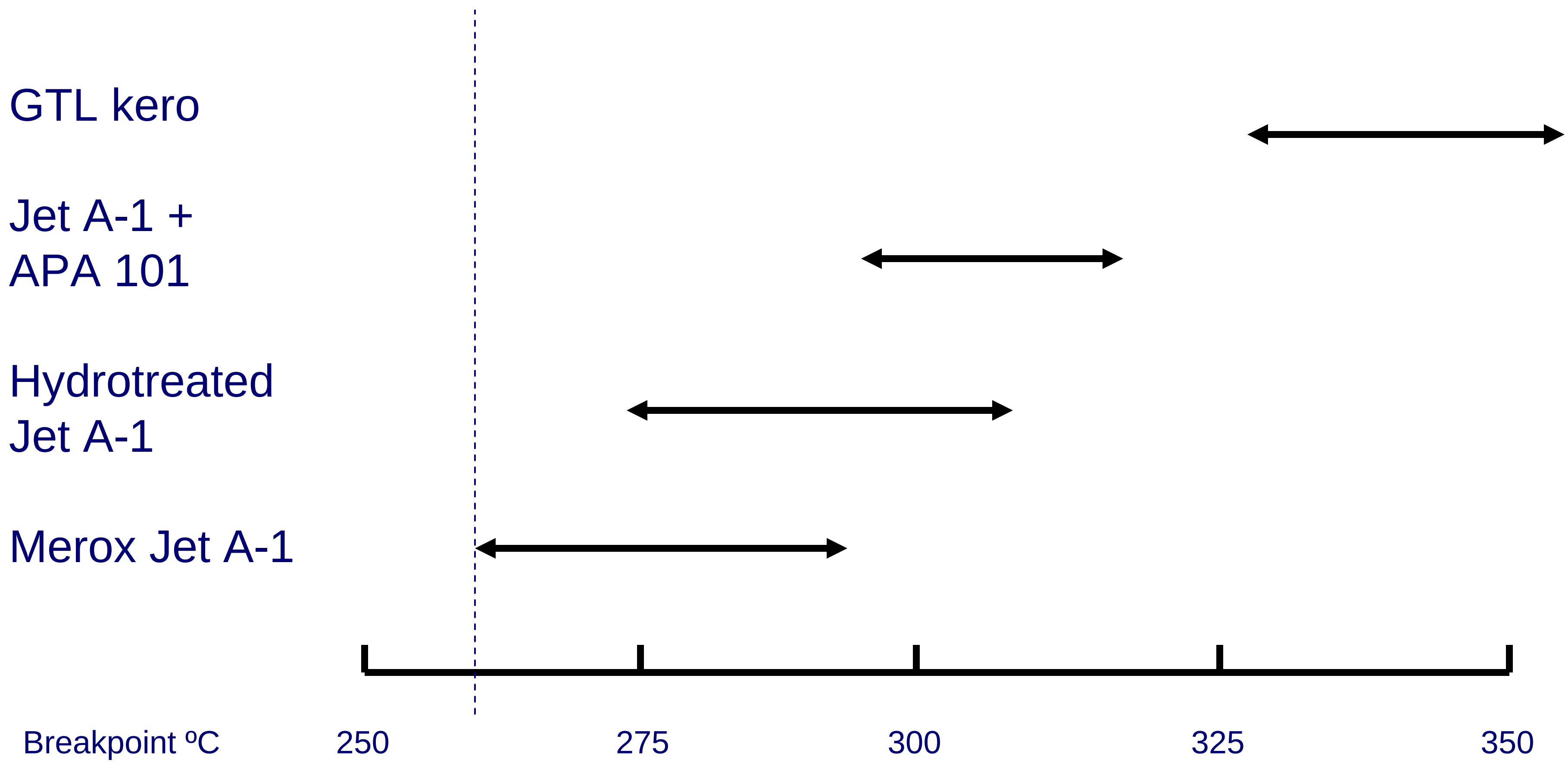
We can improve thermal stability by processing and additives



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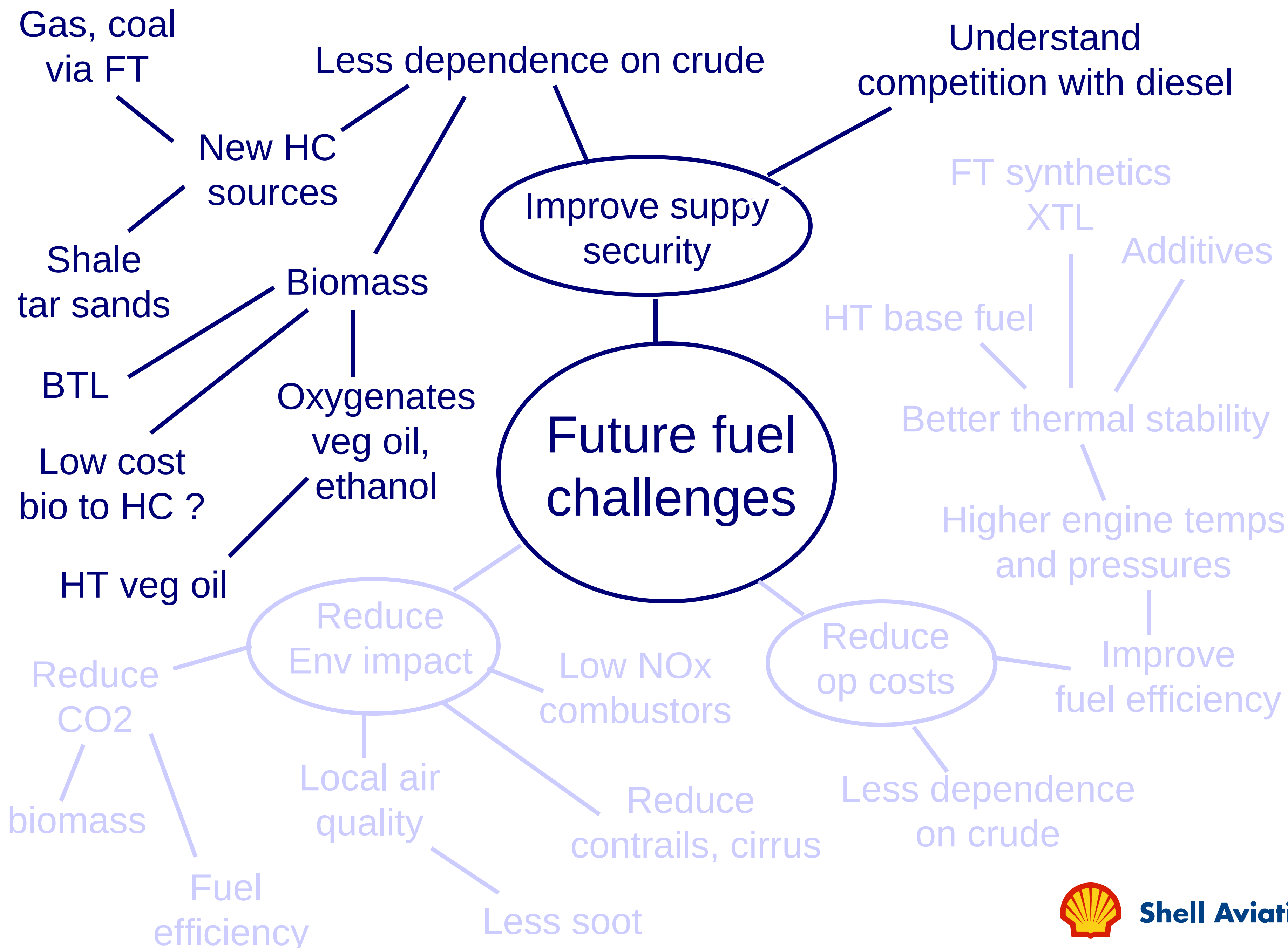

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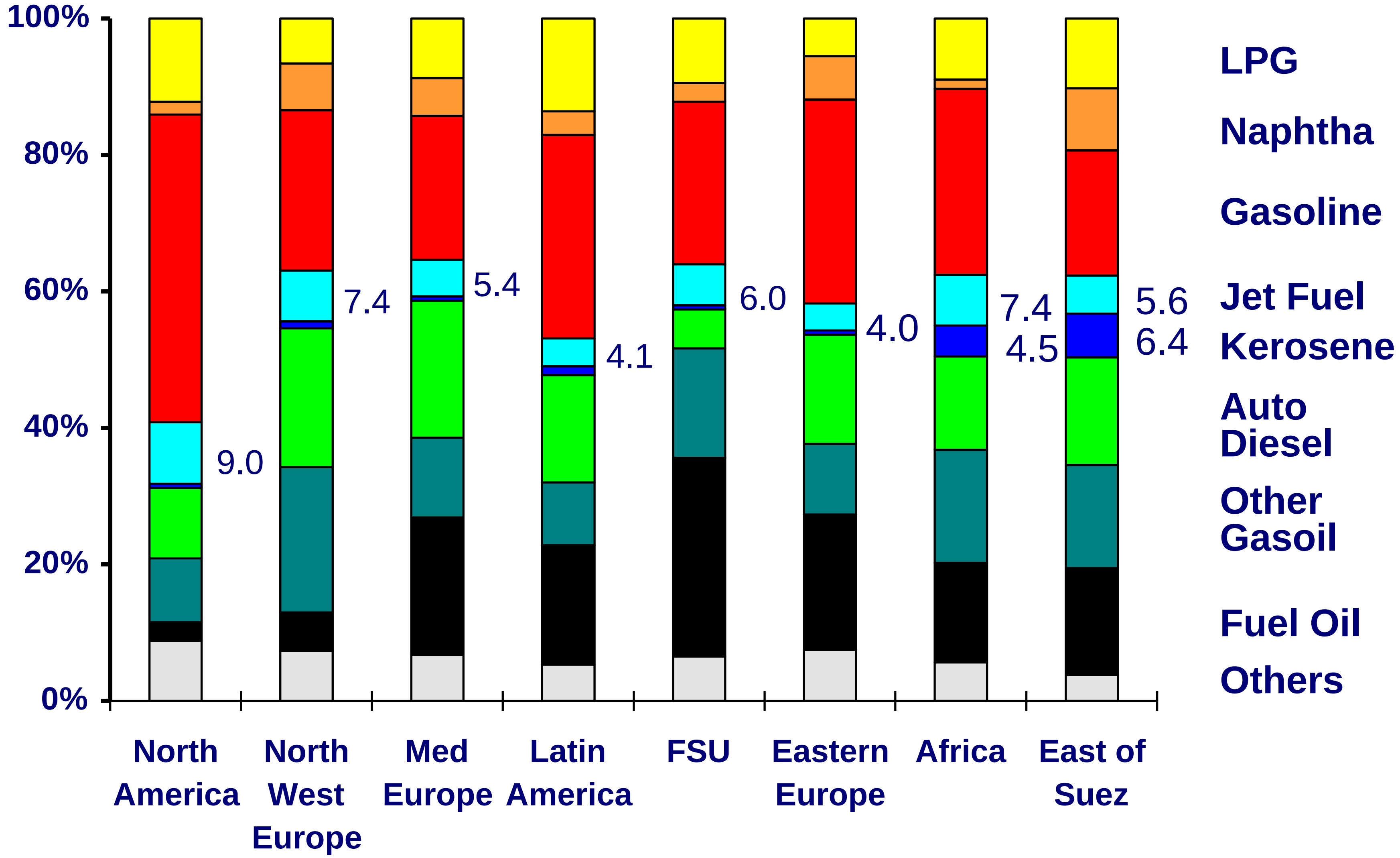
Total Industry Demand Cut of Barrel by Region



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Current automotive biofuels are oxygenates- either ethanol or FAME (veg oil)

- Oxygen content gives weight penalty with no benefit
- Resultant energy density is poor
- FAME characteristics depend on original vegetable oil
- Oxygen in fuel can be an advantage in diesel combustion but not in a gas turbine
- Significant engine and airframe issues – eg thermal stability and freeze point (+ corrosion for alcohols)
- May have applicability in bespoke local solutions, especially for piston engines eg ethanol in crop dusters in Brazil

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Energy content, freeze pt are important

Fuel	Density kg/m3	Energy MJ/kg	Energy MJ/L	Freeze pt, ºC
Jet A-1	800	43.2	34.8	<-47
Ethanol	790	27.7	22.0	<-115
FAME	880	37.5	33.0	-5
GTL kero	740	44.0	32.5	<-50
Hydrogen	70	120	8.4	-259!

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HYDROTREATED VEGETABLE OIL
A better option for aviation than FAME

- Uses conventional type hydrotreating technology
- Removes oxygen, hence good energy density
- Kerosine produced is very similar to similar to GTL kero (low S, low aromatics)
- A number of processes proposed, driver is biodiesel
- Produces products across the distillate range
- Principal limit is the availability and cost of vegetable oils

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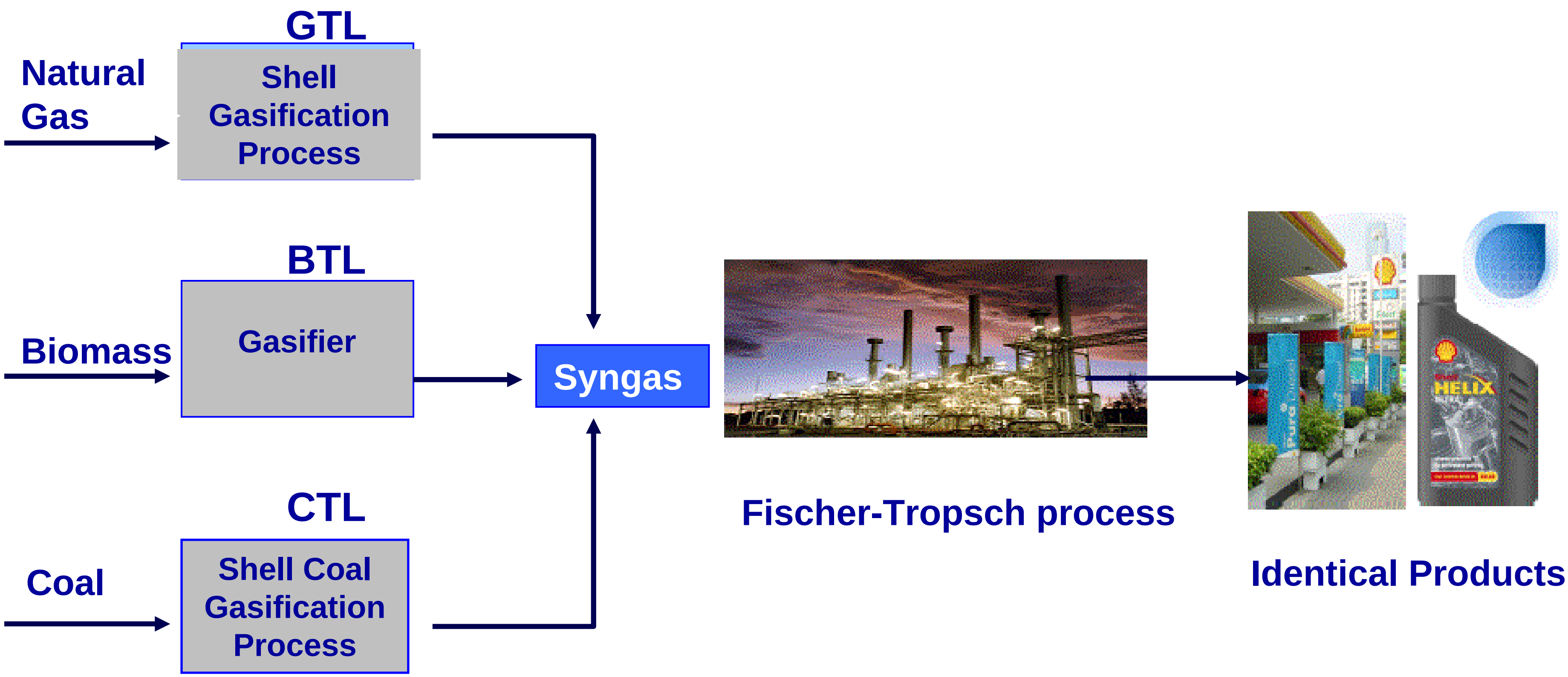
The Synthetic Fuels continuum

Identical products from gas, coal and biomass

Flexible feedstock options

Common development of advanced efficient engines



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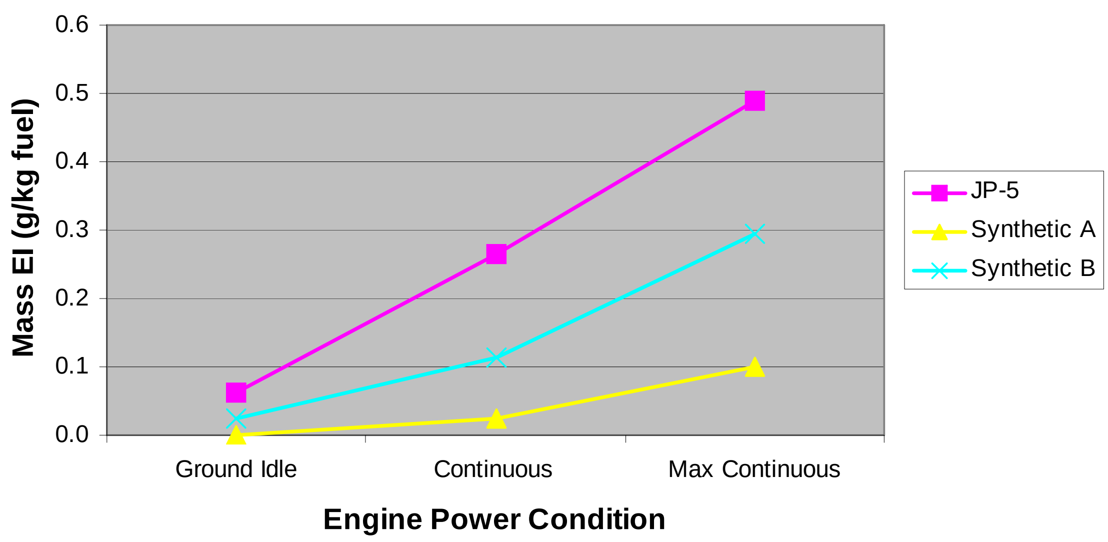
Synthetic kerosine is great turbine fuel

Better thermal stability	- hotter engines
Zero aromatics	- reduced soot emissions
Low luminosity flame	- longer engine life
Zero sulphur	- engine life, emissions



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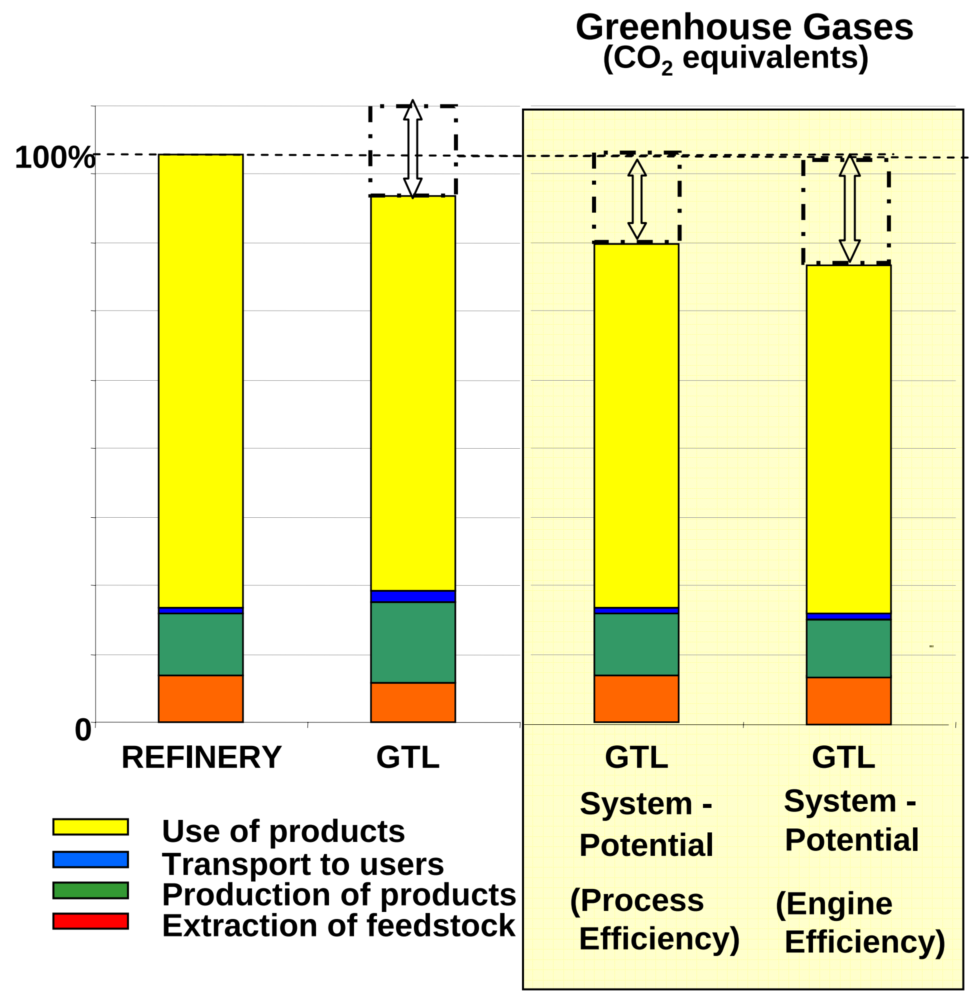
US Military are leading the way on synthetics

- Performance benefits in military jet engines
- Less engine smoke (smoking effects your stealth)
- Less dependence on imported oil (big Government push)
- Good diesel fuel (single battlefield fuel)
- Suitable for fuel cells
- Based on coal (Appalachians don’t have hurricanes)

CO2 production well-to-wheel - GTL

- Industry consensus on LCA studies showing that the GHG emissions of a GTL system is comparable to a modern, complex refinery system, it also has
  - ✓ significant lower impact on air acidification and smog formation
  - ✓ lower emissions of particulate matter
  - ✓ less hazardous waste production
- Considerable efforts are focused on GTL process efficiency through focused R&D programs, targeting up to 20% efficiency improvements



Shell sponsored life-cycle assessment by PricewaterhouseCoopers LLP in accordance with ISO14040 standards.

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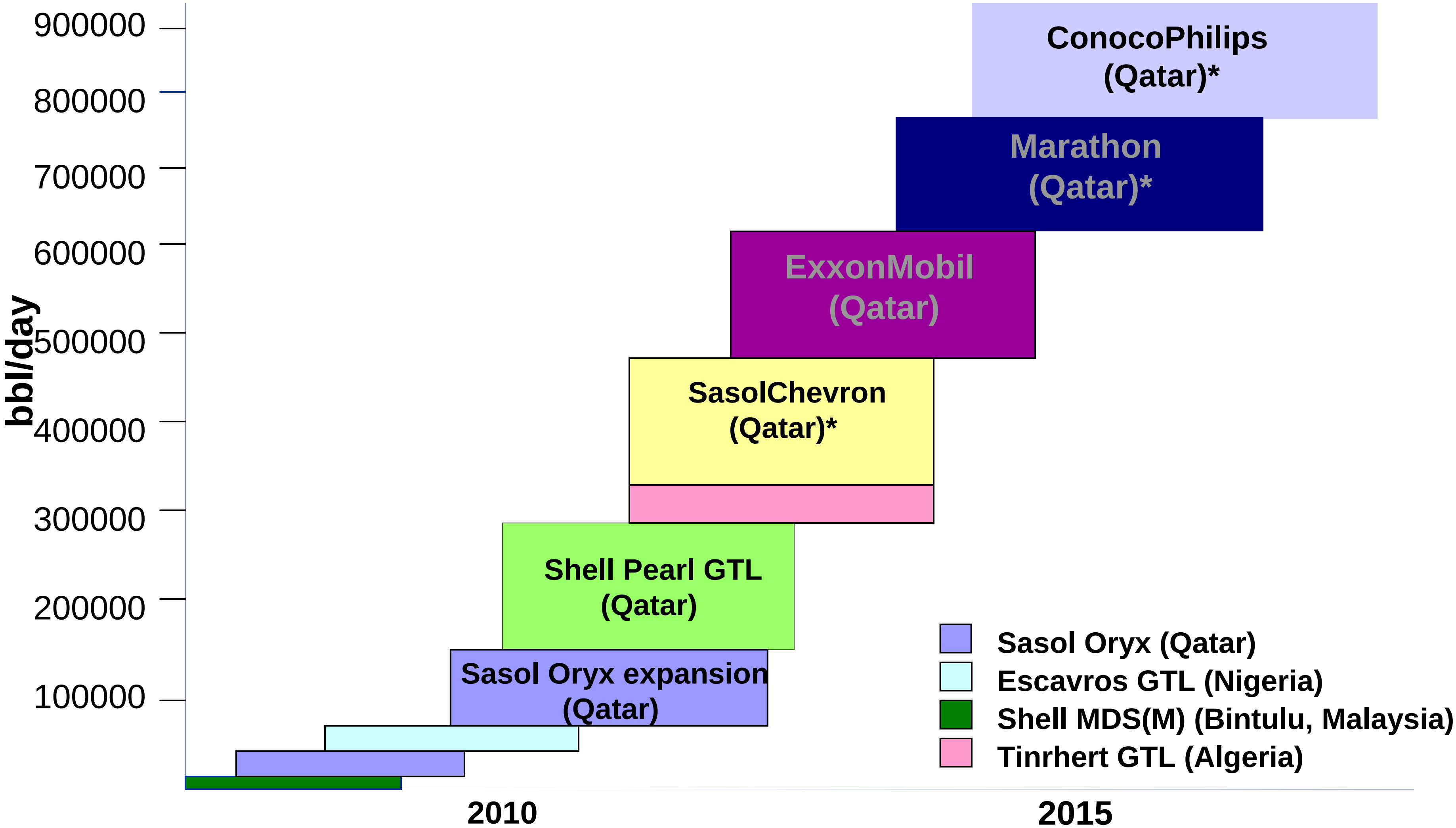
Planned GTL capacity



* Currently on hold

Sources: World Market Analysis/Global Insight, Gas Matters Today.

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Current position with synthetics

- SASOL CTL iso-paraffinic kero approved up to 50% dilution in conventional kero (at JNB)
- SASOL going for approval of 100% fully synthetic kero using synthetic aromatics from same process
- Likely that specifications will allow FT iso-paraffinic kerosines up to a similar 50% provided certain conditions are met
- Low volumes will mean 50% approval adequate for short/medium term
- However, blends give supply benefit but generally don't give performance benefit

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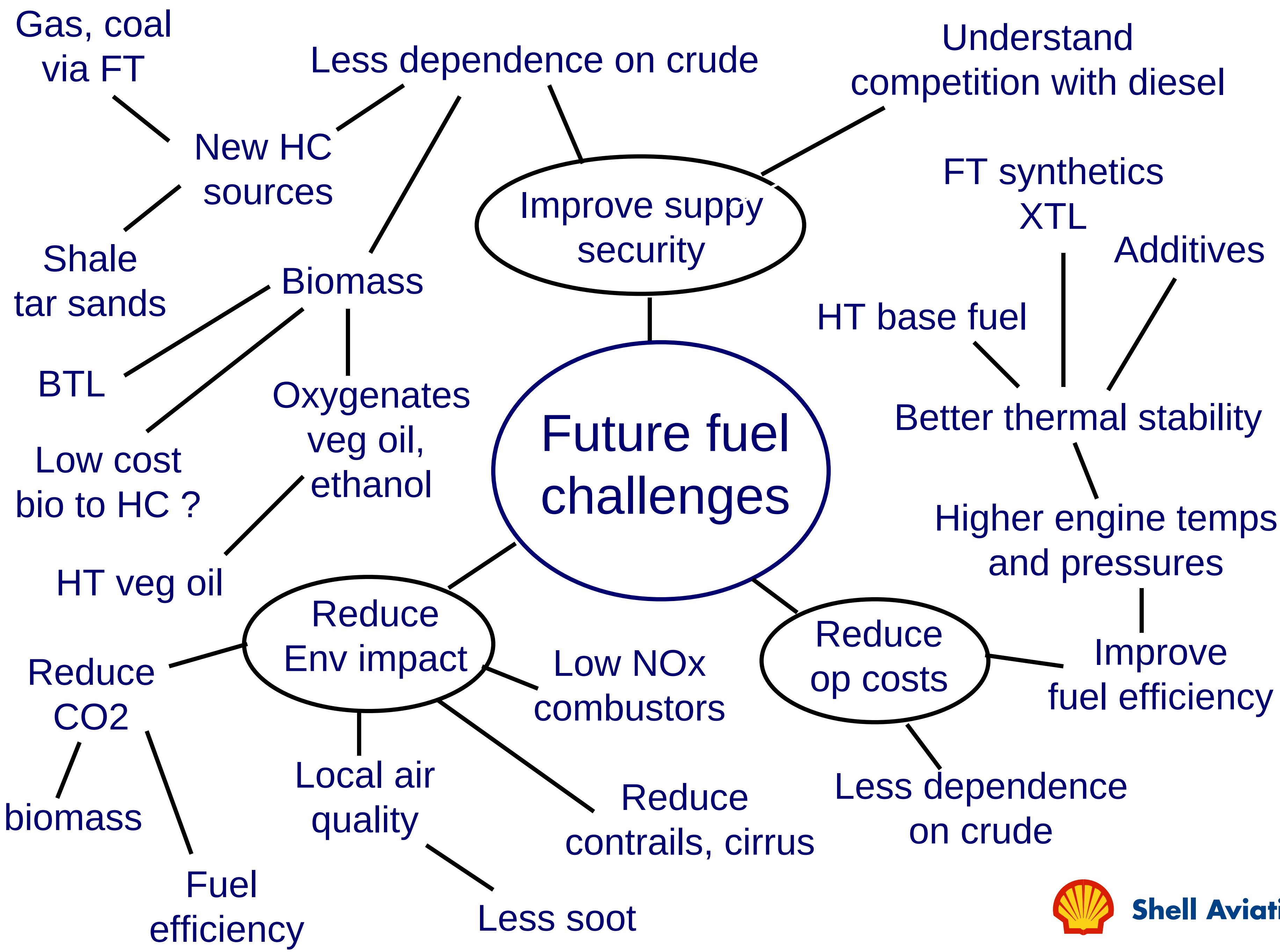

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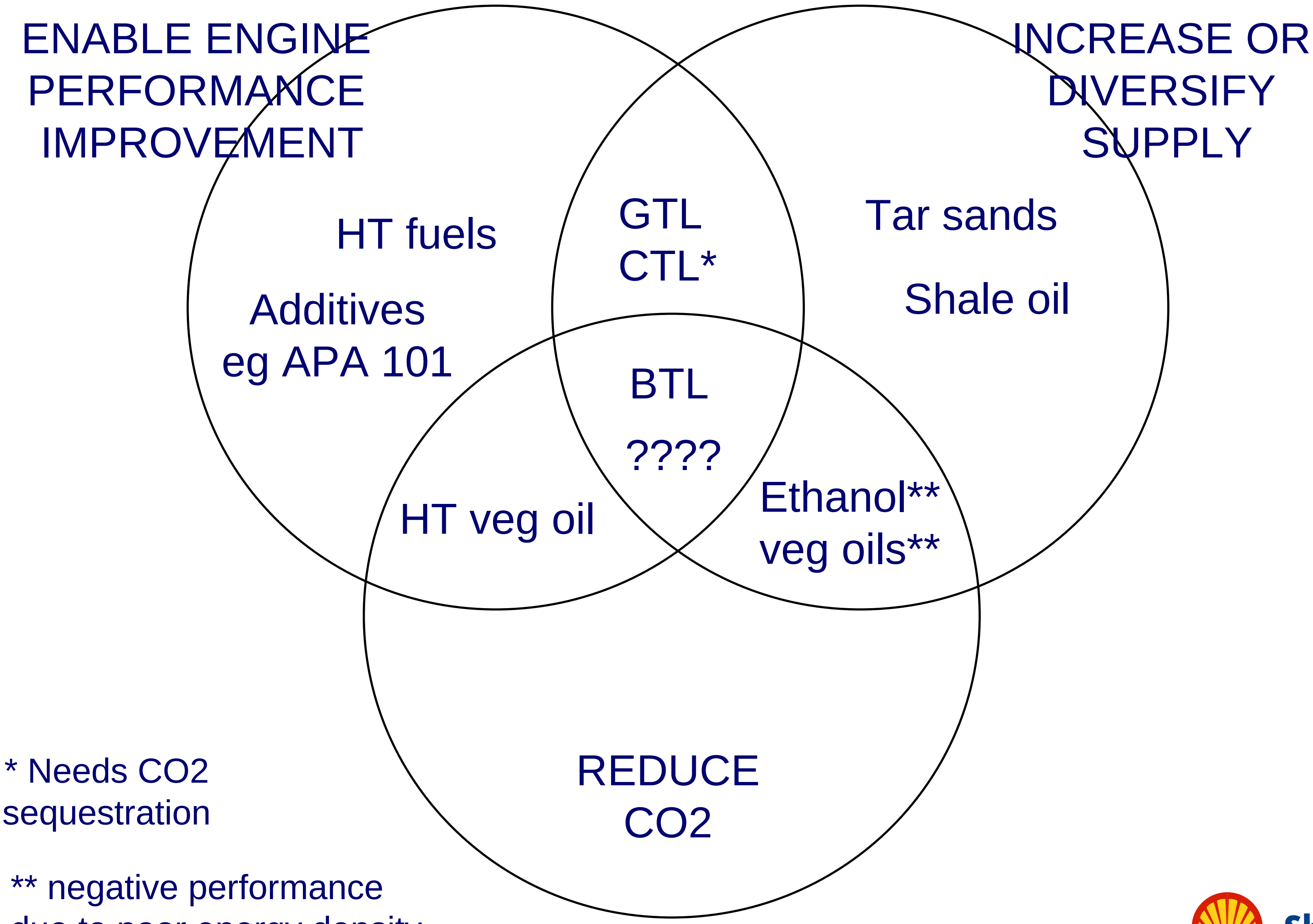
The fuel options map



* Needs CO2 sequestration

** negative performance due to poor energy density

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BTL kero – the future is green?

Better thermal stability – **hotter engines**
Zero aromatics – **reduced soot emissions**
Low luminosity flame – **longer engine life**
Improved supply – **new molecules**
Reduced CO2 footprint – **renewable**

BUT……..

Not all benefits blend
VeryHigh cost of production plants
Availability of biomass
Transport of biomass

Need a low cost biomass to hydrocarbon route

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Summary

- Simple bio-extenders (FAMEs, ethanol) not attractive for aviation
- CTL and GTL kero offer performance benefits plus new molecules (but remember neat/blended issue). Need to find solution to CO_2 esp for CTL (sequestration)
- BTL offers the benefits of synthetic kero with a CO_2 bonus
- Synthetics (esp BTL) will require major investment to produce significant volumes
- Other bio-options (HT veg oils) attractive but not proven
- Supply of biomass will be a major challenge – aviation is not the only game in town
- The Holy Grail is a low cost biomass to hydrocarbon process

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Any Questions ?

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