



Shell Global Solutions

Shell Gas to Liquids in the context of a Future Fuel Strategy – Technical Marketing Aspects

**Ralph A. Cherrillo, Richard.H. Clark, Ian G. Virrels
Shell Global Solutions (US) Inc.**

**Roger Davies
Shell Gas & Power**

9th Diesel Engine Emissions Reduction Workshop, 24-28 Aug 2003, Newport RI



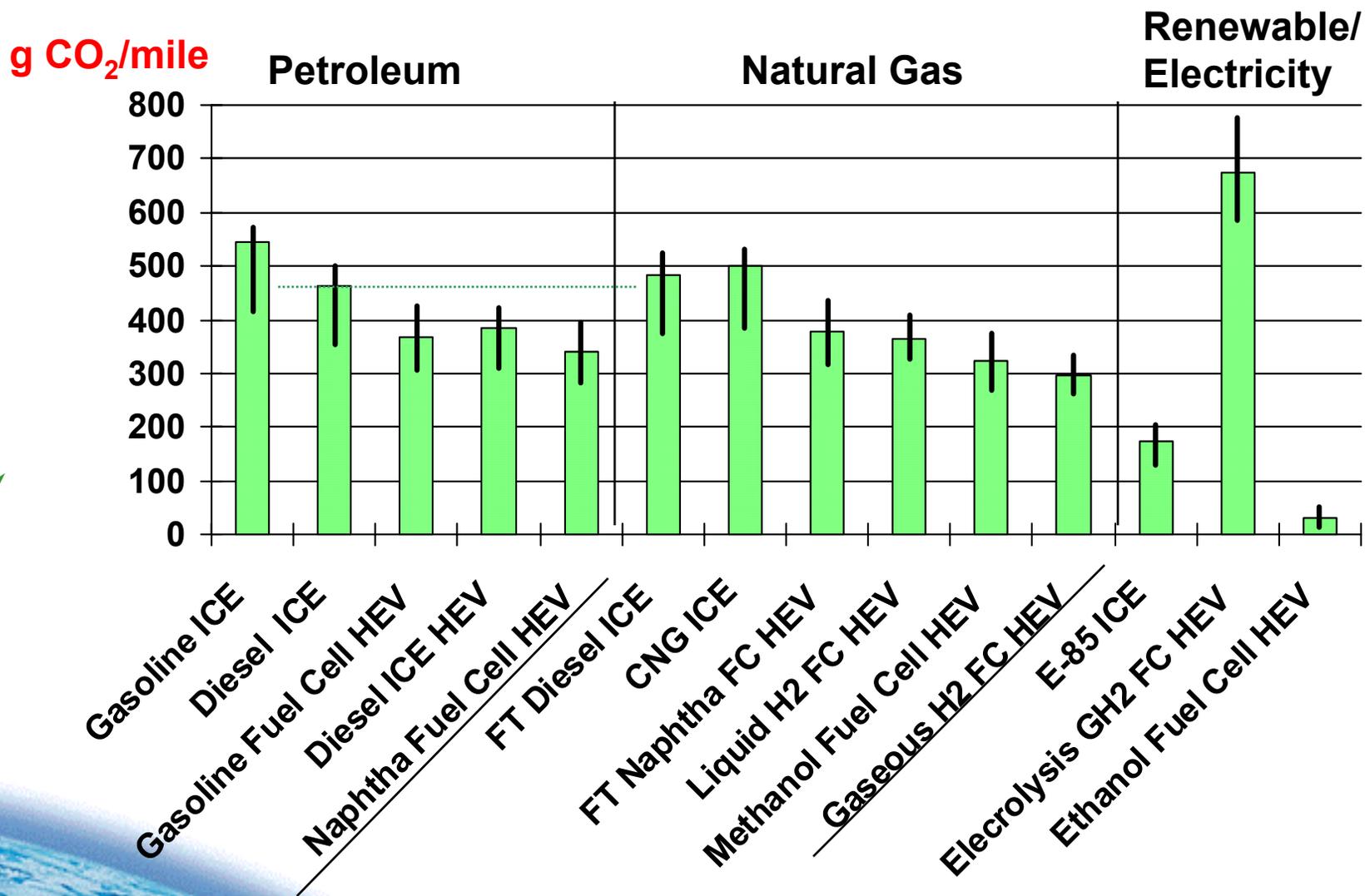
Talk Synopsis

- REQUIREMENTS OF A FUTURE FUEL STRATEGY
 - Sustainability challenges
 - Technology Drivers
 - Fuel Options
- GAS TO LIQUIDS
 - Advantages
 - Background studies
 - Pre-Marketing Activities - Stakeholders
 - Fleet trials
- CONCLUSIONS

Sustainability challenges

- Required to be met by any changes in transport fuels
- Need to balance the requirements of affordable mobility while reducing local and global environmental impacts
 - Cleaner Hydrocarbon Fuels enable more fuel efficient/low emission engine technology
 - Renewable Biofuels - e.g. ethanol and vegetable oil esters
 - Radical new technologies - e.g. Fuel cells & Hydrogen
- Alternatives need to meet economic and social sustainability criteria as well as contributing to environmental objectives
- Need to understand the challenge of consumer acceptance

Well-to-Wheel Greenhouse Gases - US Study



Technology Drivers

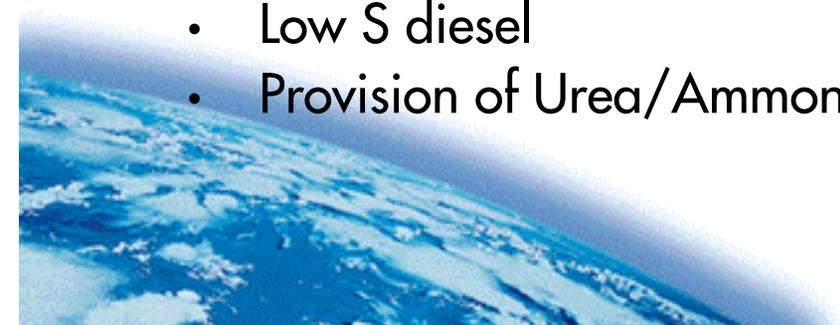
- First step is to extend availability of improved fuels which enable more efficient and lower emission engine technology
 - Diesel direct injection
 - Diesel particulate traps
 - NOx traps
 - SCR NOx reduction (selective catalytic reduction)
 - DPNR (diesel particulate & NOx reduction)
 - EGR
 - Hybrid engines
 - Gasoline direct injection
 - 3 way catalysts (NOx, CO, HC)
 - EGR (exhaust gas recirculation)
 - De-NOx storage & reduction catalysts
 - Hybrid engines

Fuels for the future

- Low S diesel
- Provision of Urea/Ammonia?

Fuels for the future

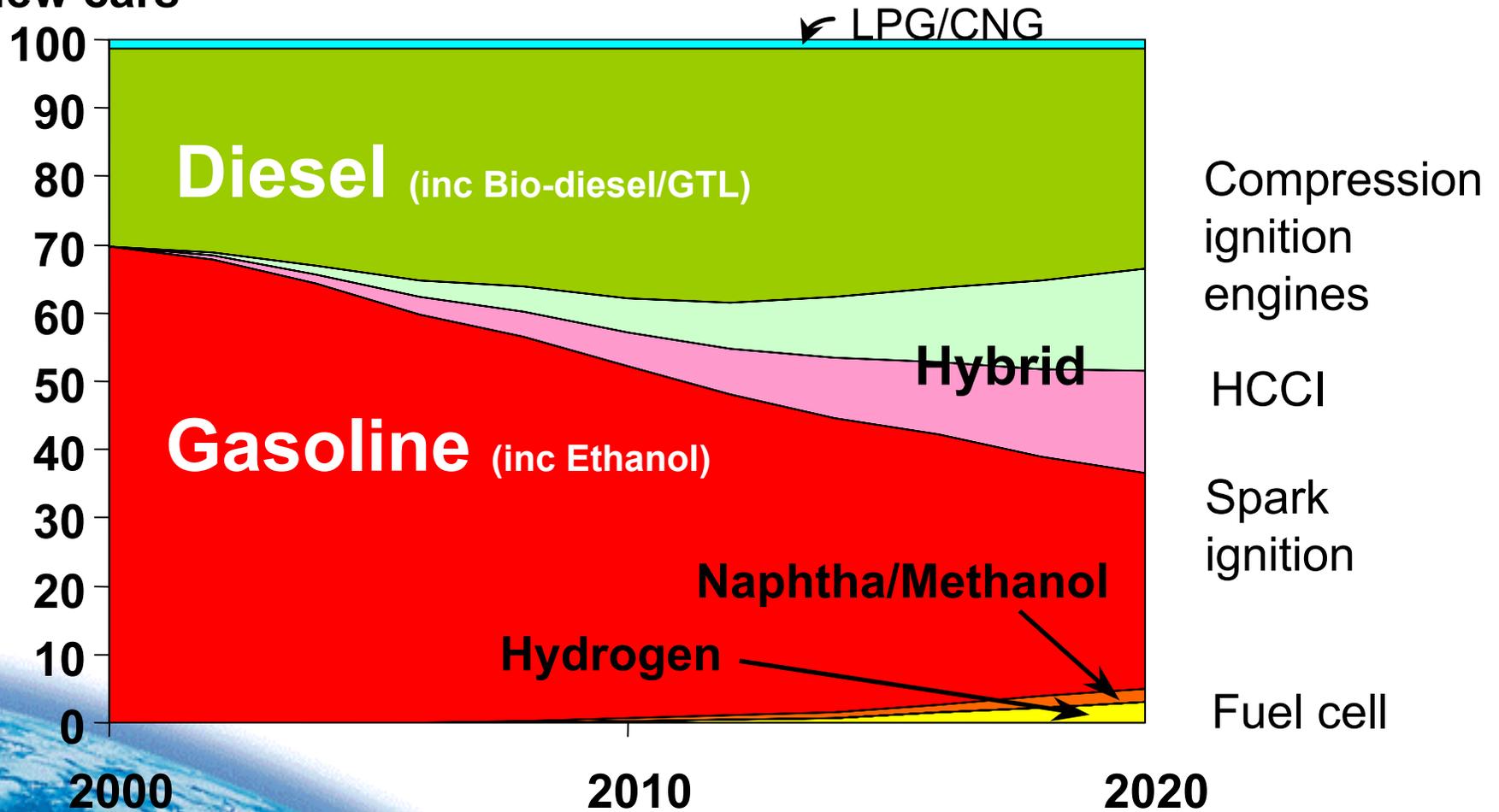
- Low S gasoline
- HCCI (homogeneous charge compression ignition) ...new fuel types?



One view of the Future

- The next 20 years will see a wider range of technologies and fuel types, especially in the developed world.....one possible scenario is:

% of New cars



Fuel Options – Bio-fuels, CNG, LPG & GTL

Bio-fuels

- Ethanol, ETBE (gasoline), Esters (Diesel)
- Can substitute oil imports & use agricultural surpluses, but practical limits on availability
- Use existing infrastructure
- Significant GHG reduction potential on WTW basis, but depends on production
- Cost 2-4 x conventional fuels, although still cheaper than some alternatives

CNG

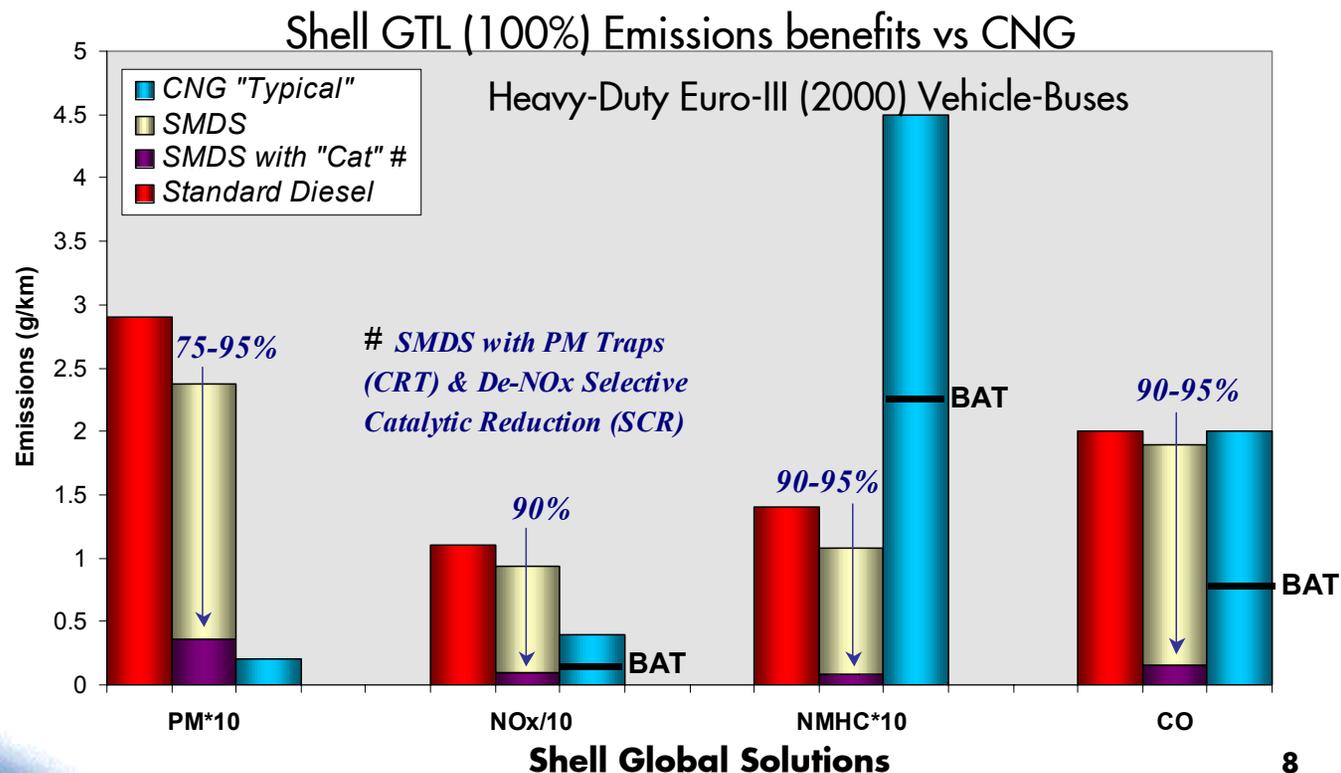
- Lower Sulphur, low PM, NO_x & SO_x
- Can substitute oil imports
- Expensive infrastructure
- Bulky on-board storage
- Shell companies assess locally whether to supply (eg. Argentina)

LPG

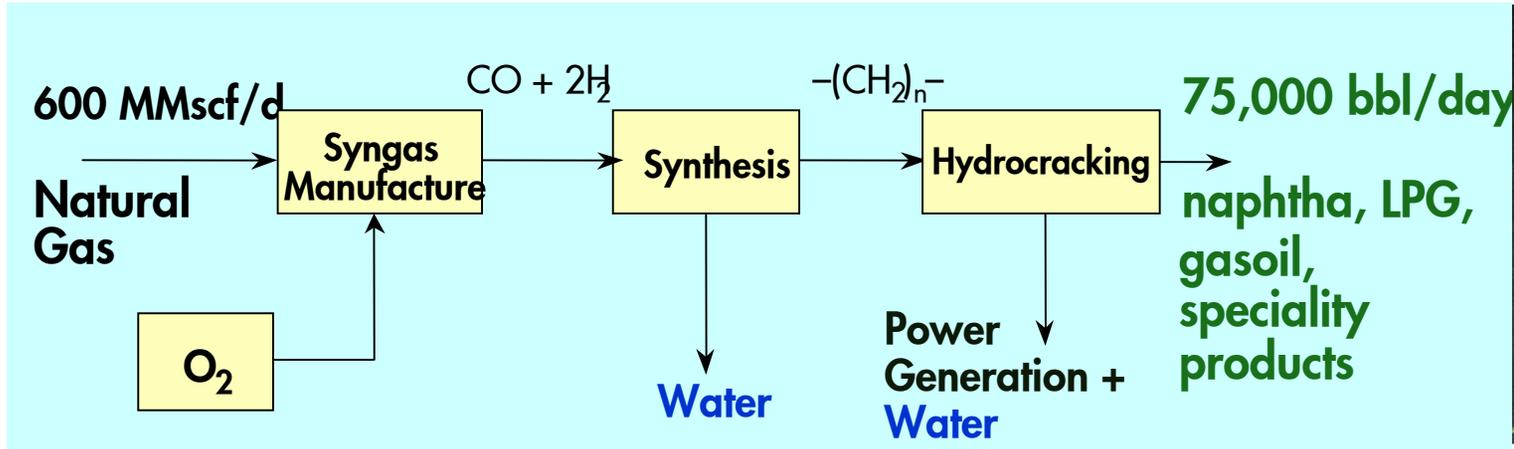
- Lower sulphur, PM, NO_x and SO_x
- Overall emissions similar to CNG
- Infrastructure costs lower than CNG
- Less bulky storage
- Supplied by Shell in many markets for both fleet and private motorist,

Fuel Options – Bio-fuels, CNG, LPG & GTL

- Alternatives such as CNG, LPG and GTL have a role in the future fuel mix, but unlike bio-fuels do not provide significant GHG benefits
- CNG, LPG and GTL have potential as niche fuels, especially where urban air quality is problematic
- GTL combined with appropriate engine technology would offer CNG type emissions benefits at lower overall cost



Shell Gas to Liquids –Process and Products



**Commercially proven technology,
at Bintulu, Malaysia since 1993**



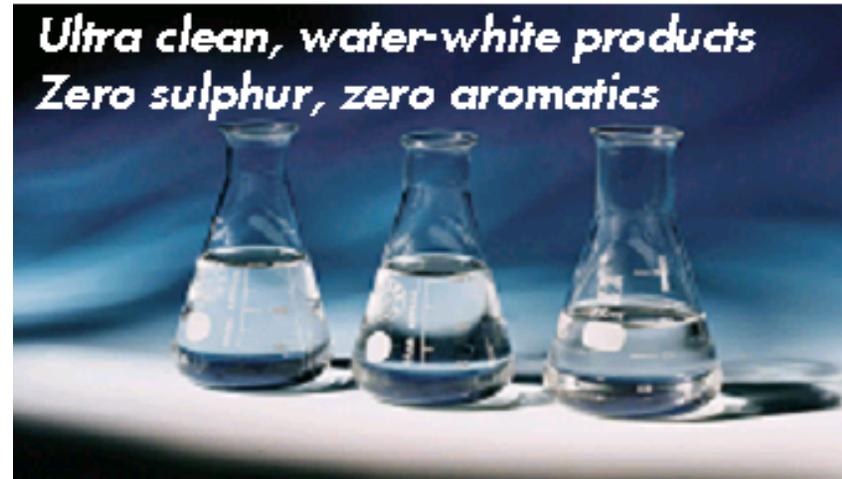
Gasoil product

- Odourless, low-toxicity, biodegradable, water-white
- Paraffinic
- Cetane 75-80
- Sulphur 0 ppm
- Density 780 Kg/m³
- Pour Point -18C*

*future Shell GTL plants

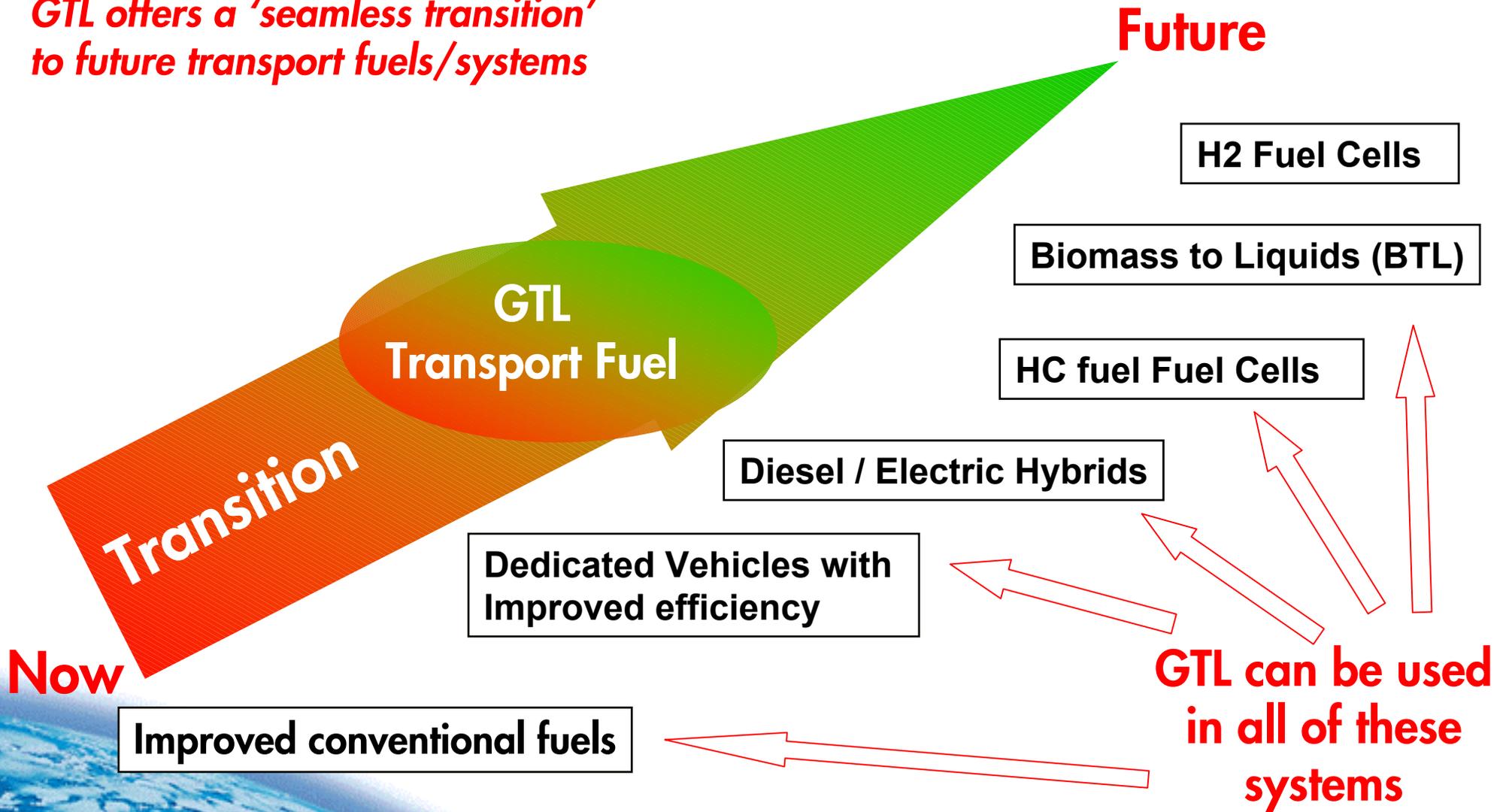
Advantages of GTL Automotive Gasoil

- Strategic diversification of energy supply - Gas-derived fuel
- Significant emissions benefits as a blend or 100%
- Compatible with existing diesel infrastructure
- Life cycle analysis (PWC), GTL vs. Refinery system (DEER2002 paper)
 - GTL, less impact on on air acidification and smog formation
 - No greater impact on global warming.
- “Future-Proof”. Compatible with most conceivable directions of the fuels market
- More cost effective in reducing emissions than any competing fuel



Bridging the gap to Renewable Transportation Fuels

GTL offers a 'seamless transition' to future transport fuels/systems



Emissions Performance

-Current “on the road” technologies

We have a good idea of emissions benefits in current engine technology

Summarised %benefits for 100% Shell GTL

Benefit	Light-Duty			Heavy-Duty		
	Euro I	Euro II	Euro III	Euro I	Euro II	Euro III
(%)						
PM	42	39	41	18	18	34↔10
NOx	10	5	5	16	15	5↔19
HC	45	63	62	13	23	<9
CO	40	53	75	22	5	16

But....

Emissions Performance

-Future Challenges

- Developed world is rapidly moving towards “sulfur free” diesel
 - E.g. <15ppm or <10ppm S
 - Is there a benefit of GTL over other sulfur free systems ?
- Modern engine technologies with or without advanced aftertreatment are liable to make all fuels look similar
 - Does GTL still have an edge on emissions performance ?
- Research effort and collaborations to address these issues
 - Collaborations with VW and Bosch on light- and heavy duty engines
 - Shell commission work with AVL (Austria) in Euro-4 (2000) and Euro-5 (2005) prototype heavy duty engines

Emissions Performance – Collaborations with Bosch & VW

BOSCH-SHELL

- Bosch HD research engine configured to Euro-4 or Euro-5 NO_x limits
- 100% GTL showed PM benefits against other sulfur free fuels

VW-SHELL

- Studies with prototype Euro-4 engines and cars with 100% GTL & EU standard diesel
- PM benefits of ~50%
 - i.e. better than in earlier technologies

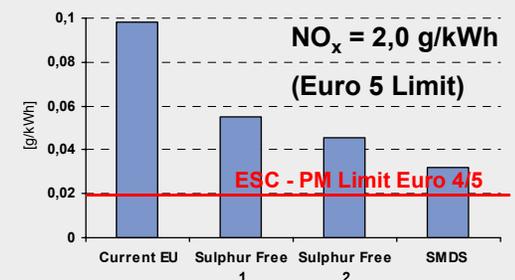
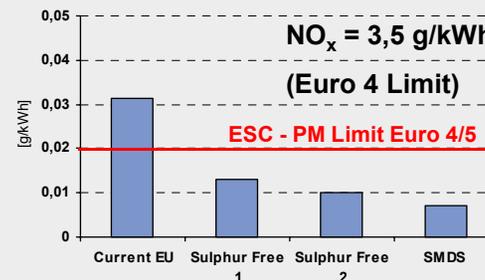


1Cyl. HD Diesel Engine, V_d approx 2l ,
Comparison of Fuels

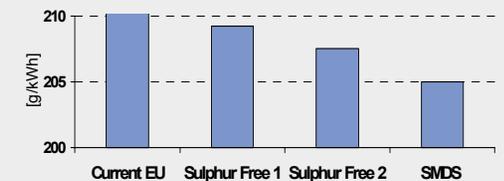
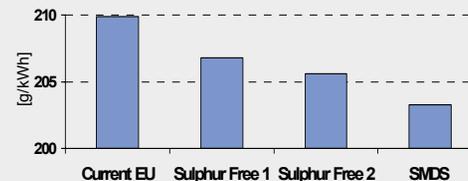
BOSCH

Soot Emission

n = 1710 rpm, load = 100%, EGR- Rate ≤ 18%,
inj. pressure 1800 bar



spec. Fuel Consumption

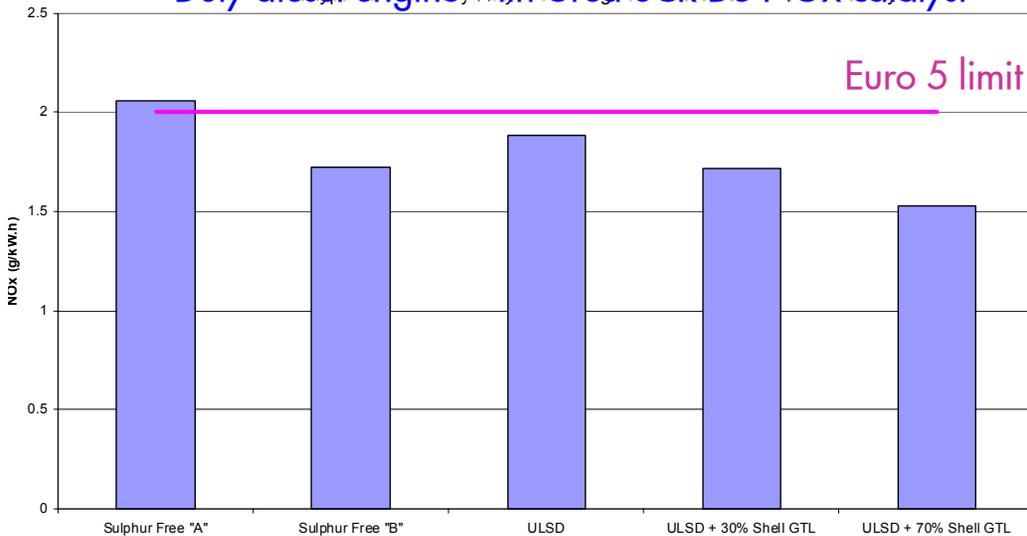


DS/EMF C 2967shell 23.12.2002

© Alle Rechte bei Robert Bosch GmbH, auch für den Fall von Schutzrechtsanmeldungen. Jede Verfügungsbefugnis, wie Kopier- und Weitergaberecht, bei uns.

Emissions Performance -Shell study at AVL

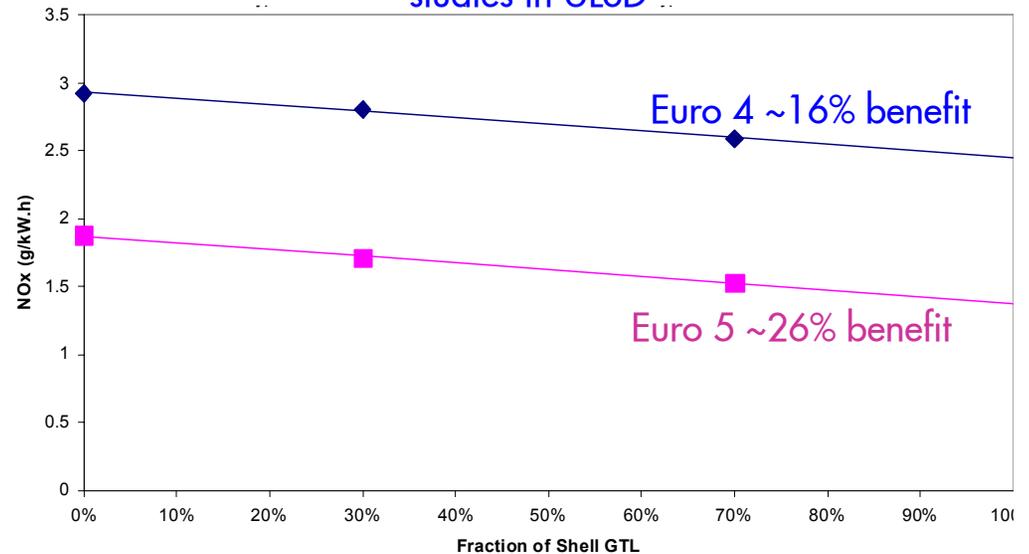
NOx emissions comparison from prototype Euro-5 Heavy Duty diesel engine with Urea SCR De-NOx catalyst



- Significant NOx benefits of GTL still seen in both advanced engine systems (Euro-4 and Euro-5)
- NOx benefits of GTL blends (30 & 70%) when compared to either ULSD or sulfur free fuels

- Engines
 - Prototype Euro-4 (2005) engine with PM trap
 - Prototype Euro-5 (2005) engine with SCR deNOx
- Fuels
 - Blends of GTL in ULSD (50ppm S)
 - 2 sulfur free fuels (<10ppm S)

Extrapolated NOx benefits of 100% GTL from blends studies in ULSD



Shell Global Solutions

Cost-effectiveness Study USA

Recent independent WTW study performed by TIAX:

For 2002:

- GTL fuels offer significant reductions in criteria pollutants
- Other gas-based fuels can achieve greater reductions (per vehicle), but the cost impact of using GTL fuels is significantly less
- GTL fuels are (several times) more cost-effective for reductions in criteria pollutants

For 2010:

- GTL fuels will continue to be the most cost-effective option for reductions in criteria pollutants from existing engines
- Emissions will be strictly controlled and all new engines will have similar emission levels, eliminating the environmental drivers for CNG / LPG
- But, after-treatment technologies are in the early stages of development and new emission limits may not be achievable (without “zero” sulfur diesel).

**Good fit with draft strategy document (Assembly Bill 2076)
“California Strategy to reduce Petroleum Dependence”**

Taking GTL advantages to Market

- What product is to be marketed ?
 - 100% GTL product
 - Blends of GTL in automotive diesel
- Key stakeholders
 - Governments and Regulators
 - OEMs
 - Consumer Groups
- Stakeholder engagement
 - Focused discussions
 - Collaborative field trials with stakeholders



Blends or 100% GTL ? -Properties & Benefits

Blend (20 – 30%) GTL

- Demonstrable emissions benefits
- No vehicle modification required
- Use existing diesel infrastructure
- Larger volumes of product available

.... but

- Emissions benefits could reduce as refinery diesel specs and engine technologies improve

Pure (100%) GTL

- Larger emissions benefits
- Minor vehicle modification required
- Use existing diesel infrastructure
- Technology enabler (e.g. advanced after-treatment)

.... and

- Potential for further benefits through engine developments in efficiency and other key areas.
- Bridge to renewable energy sources

Different Geographic drivers

- OECD – “zero sulphur” and advanced aftertreatment, benefits of 20-30% blends not clearcut. However, 100% could enable engine efficiency improvements
- Developing Countries – Serious concerns about urban air pollution, emissions benefits significant from 20-30% blends

Stakeholders

- Government and Regulators

- US Department of Energy
 - Participation in DOE workshop (Oct 2002) on F-T diesel designation
 - Fulfils criteria pertinent to designate F-T diesel fuel as alternative fuel (under Sec. 301[2] of the Energy Policy Act of 1992)
- EU Commission DG TREN (Directorate General Transport and Environment)
Currently assessing alternative fuels

- OEMs

- Collaborative studies on GTL, e.g Volkswagen, Bosch etc

- Consumer Groups

- 100% GTL - Early targets commercial fleets, operating within city environs
 - Buses, Taxis, Light and heavy duty delivery vehicles etc
 - Home base refueling (not retail stations)
- GTL blends – Premium diesel for private motorist
 - Demonstrable emissions benefit

GTL Fleet Trials in the US (1)

[1] California

Partners Yosemite Waters
DOE NREL
SCAQMD
Johnson Matthey
Shell
International Truck and Engine



Purpose

- Demonstrate that technologies are robust under real operating conditions
- Evaluate scientifically the emissions reductions that can be achieved
- To provide key data to legislators, commercial users and the public, for important air quality decisions and legislation

Timing Q1 2003 – Q2 2004

[2] CARB Certification for SMDS Gasoil

Participants California Air Resources Board
Southwest Research Institute
Shell

Timing Ongoing

GTL Fleet Trials in the US (2)

[3] California

Partners California Department
of Transportation
Shell

Purpose Durability, compatibility

Key Findings

- No leaks of fuel from any of the vehicles –on changing to GTL & back again
- No increases in maintenance for any of the vehicles
- Fleet operator very happy with the performance of the fuel

Timing Completed 2002

[4] California

Partners Ralphs Grocery
ATL
SCAQMD & CEC
DOE NREL
Ricardo
Cummins
Cleaire
Shell

Purpose

- Similar to Yosemite water trial, but in engines modified to optimize combustion of GTL fuel.

• **Timing** Q4 2003 – Q3 2004



GTL Fleet Trials in Europe

[1] Berlin VW-Shell Trial

Participants Volkswagen
Shell

Timing May 2003 – Oct 2003

German Chancellor Gerhard Schröder launched the trial, part of a joint research & development programme looking at new road vehicle technologies and fuels.



[2] London Bus Trial

Participants London General
EvoBus (UK) Ltd
DaimlerChrysler
Shell

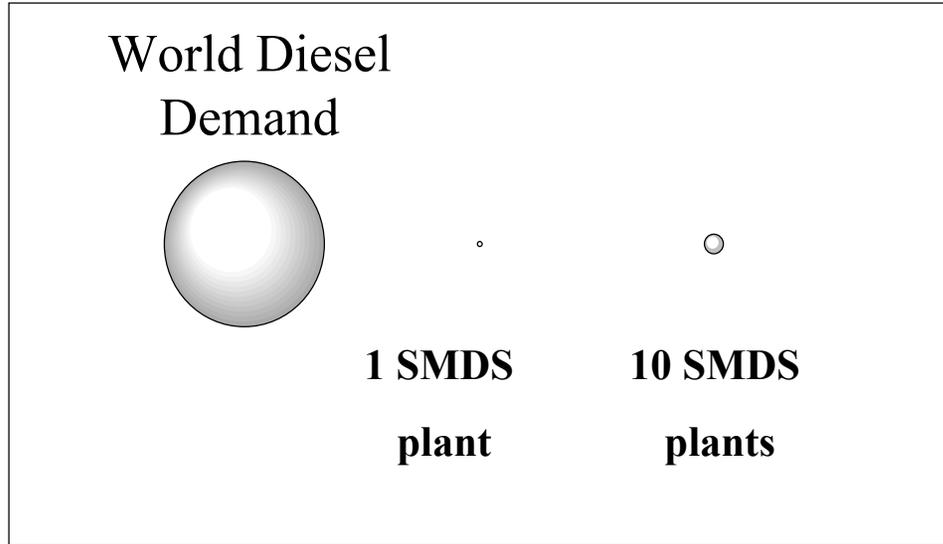
Timing July 2003 – Sept 2003

Trial of Shell GTL fuel launched by UK Green Fuels Minister David Jamieson MP on 8th of July, in cooperation with Daimler Chrysler and 'London General'.



The Future -GTL Gasoil production

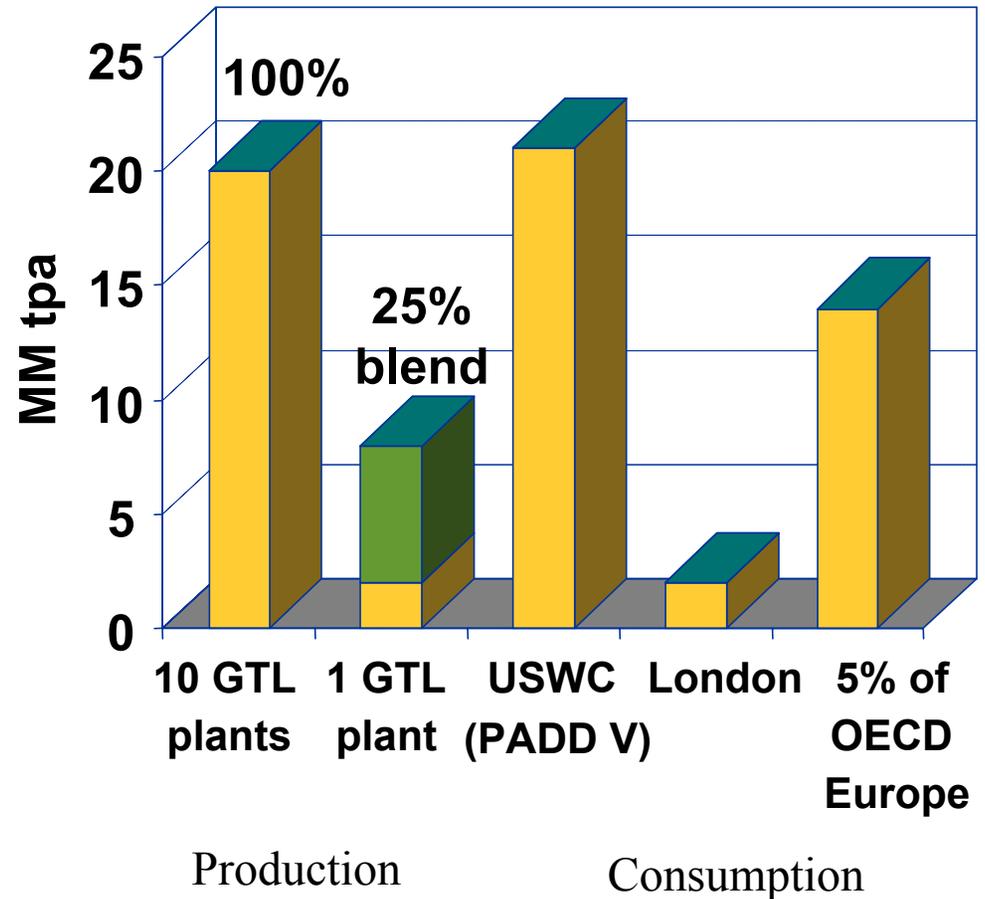
Small globally.....



10 large scale GTL plants

- ~2.5% of world diesel demand, or
- Diesel demand of US West Coast or
- ~8% of diesel demand of OECD Europe

But significant locally



The Futurebut already present today at some retail sites



Shell Pura Diesel in Thailand

- A blend of normal diesel, Shell GTL and an additive package
- Product proposition
 - Engine clean-up
 - Reduced black smoke
- In Shell retail outlets at a price premium
- Launched in Bangkok in Jan 2002, went nationwide in Feb



Shell Diesel 2004 in Greece

- A blend also formulated using Shell GTL
- Product Proposition
 - Reduced black smoke in the taxi fleet in advance of the Olympics
- Launched in Athens in July 2003

Conclusions

- Gas to Liquids, an integral part of the Shell's future fuels strategy
- GTL is an essential component of the niche fuels scene
- Customer acceptance is key, but often overlooked
 - Advantages in keeping familiar vehicles and infrastructure
- GTL has advantages in several key areas
 - Energy diversification, Vehicles emissions, Infrastructure compatibility etc.
- Field trials are a good route to engage with stakeholders
 - Governments, OEMs, Consumer Groups