

Meeting the Demand for Low Carbon Fuels in the Transport Sector

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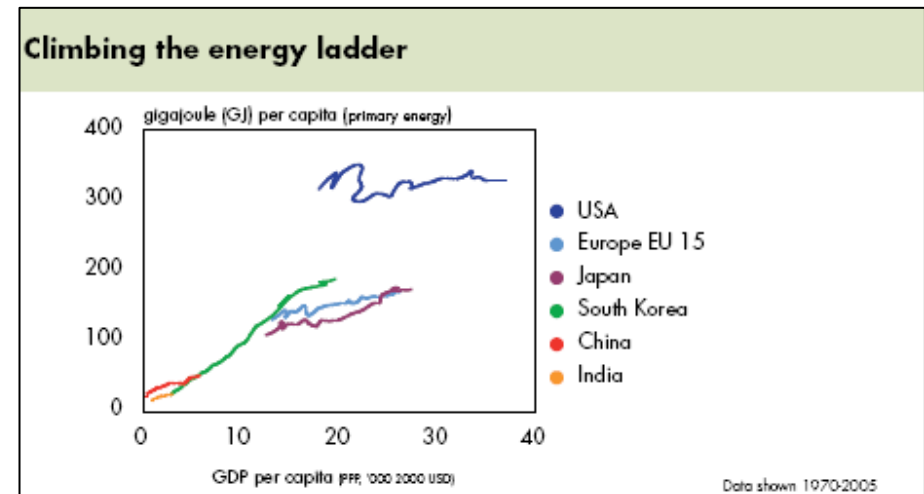
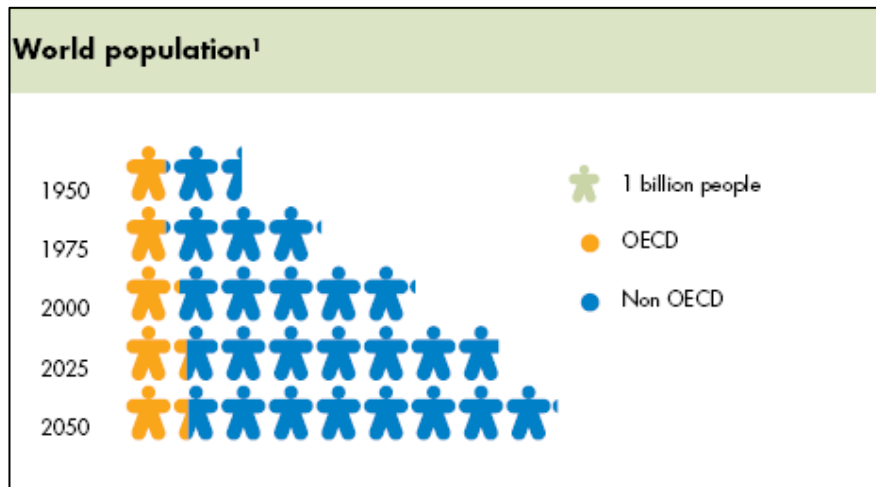
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The “three hard truths” globally will impact future energy supply and demand

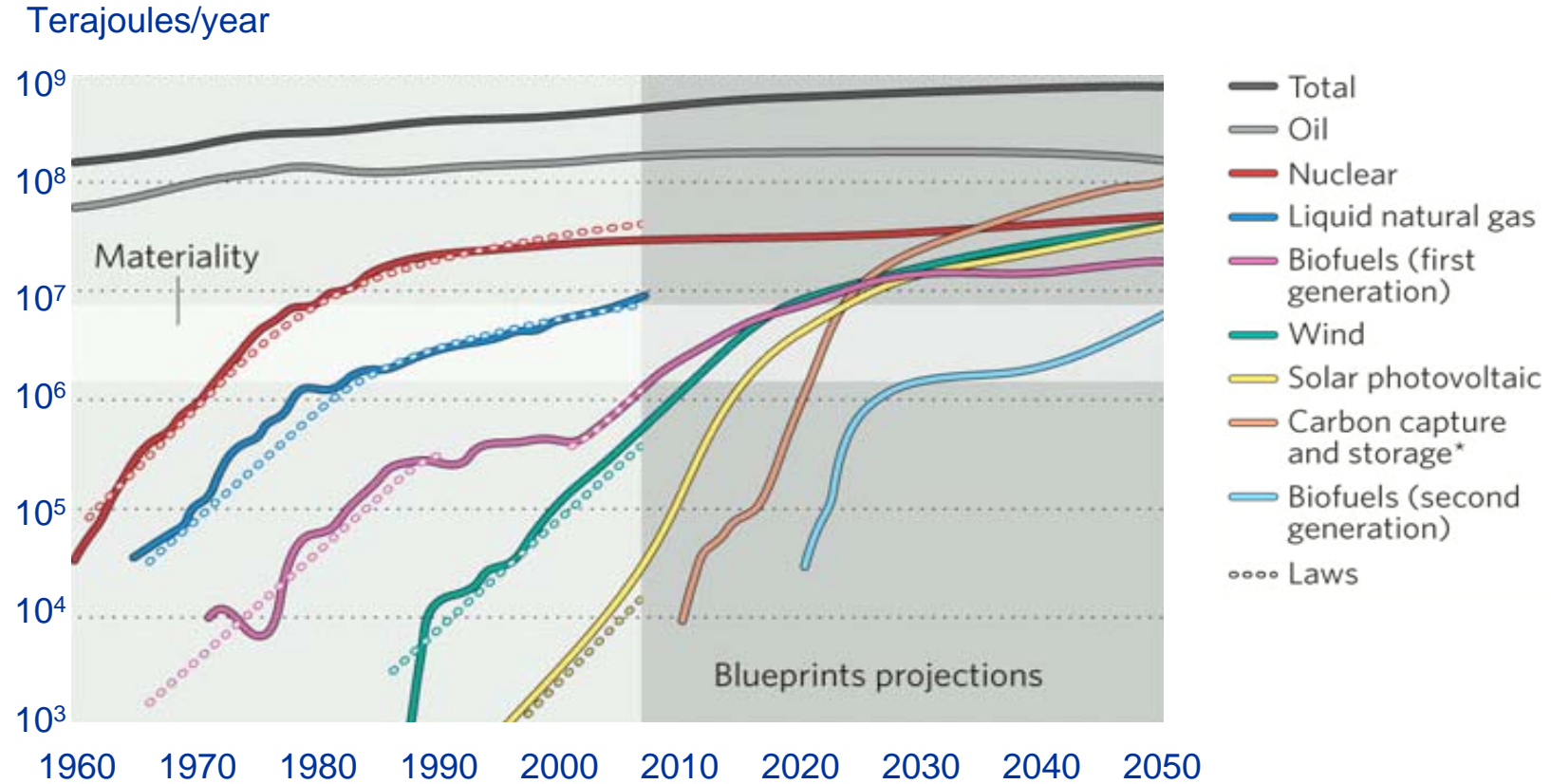
- 1: Step-change in energy use
- 2: Supply will struggle to keep pace
- 3: Environmental stresses are increasing





ENERGY TECHNOLOGY CHANGE TAKES TIME

Global production of primary energy sources.

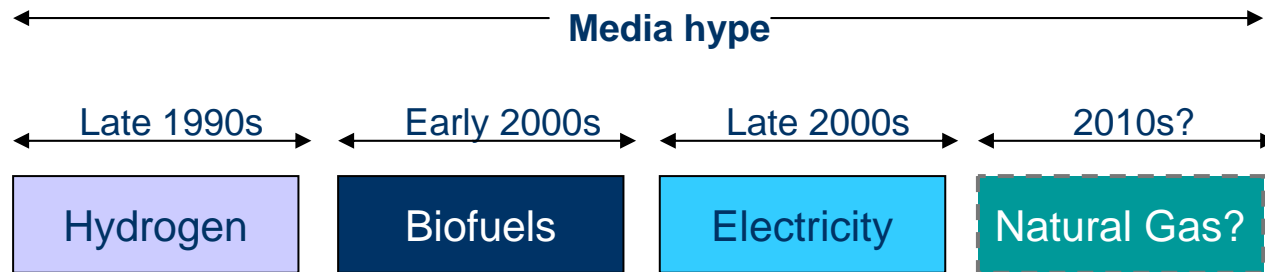


Source: Historic Data: Energy Balances of OECD Countries (IEA, 2009), Energy Balances of Non-OECD Countries (IEA, 2009). Projections: Shell International, from the article: *No quick switch to low-carbon energy* by Gert Jan Kramer & Martin Haigh *Nature* 462, 568-569(3 December 2009)

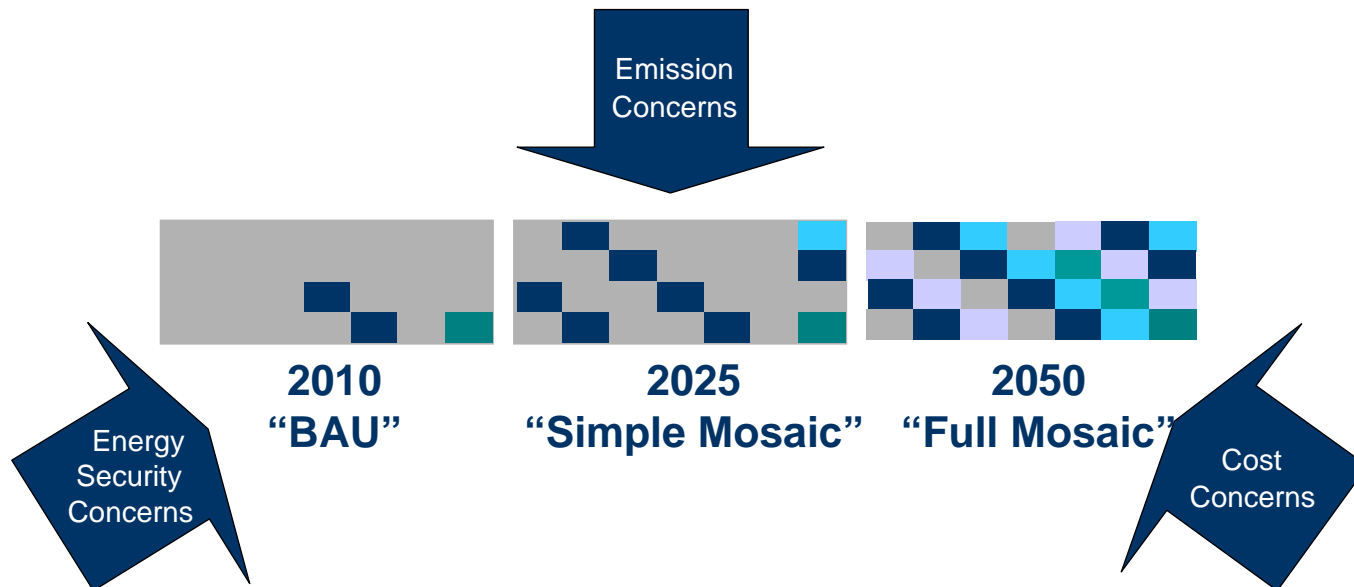
*Coal and natural gas used in power generation with carbon capture and storage



The continuing search for the replacement of liquid hydrocarbons in road transport yields no silver bullet

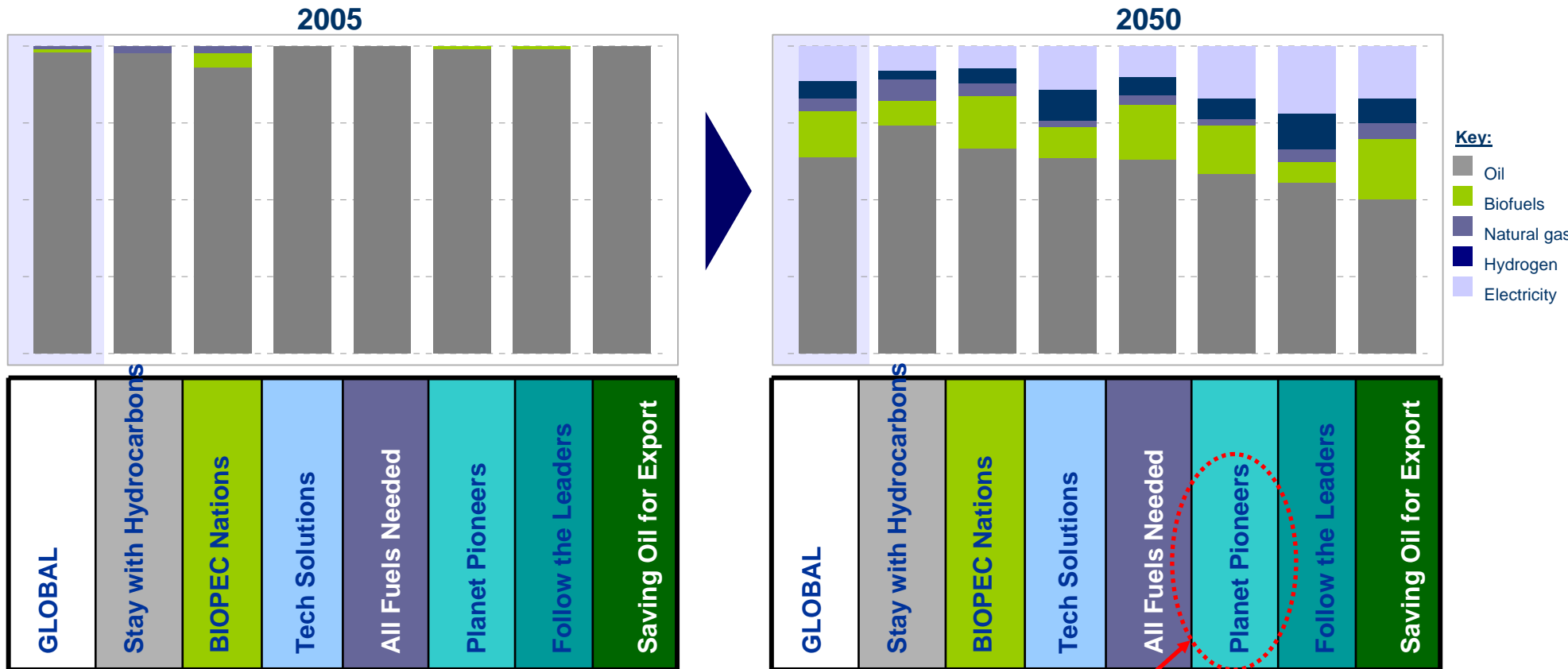


The "real" answer?





Global averages can mask a variety of country or archetype differences



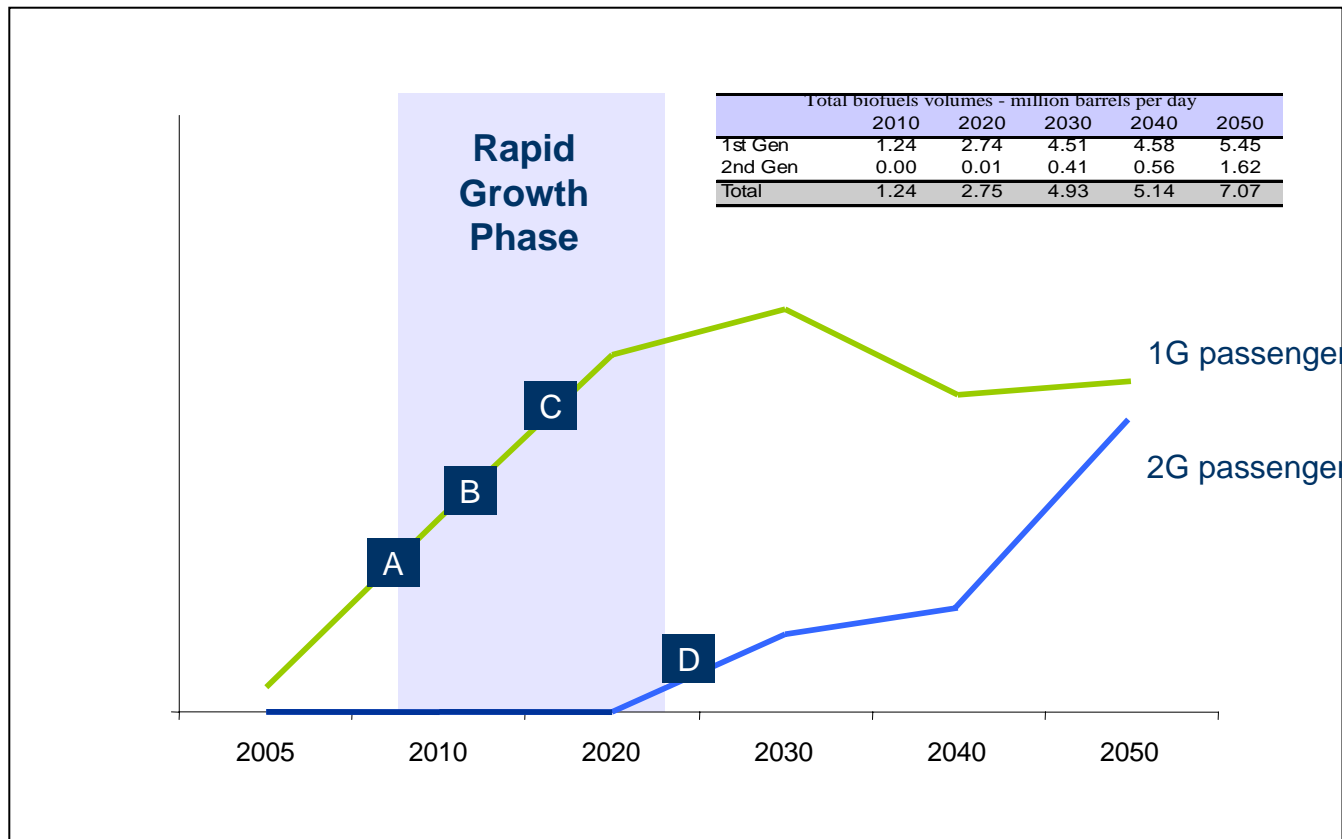
e.g. US, Germany, UK, NL, France, Scandinavia.

Large, developed markets keen to reduce CO₂ and dependence on oil products. Have standing/weight to set trends in alternative fuels.



Two key growth enablers for biofuels are regulation and technology (in both feedstock and 2G manufacturing)

Global penetration of biofuels volumes

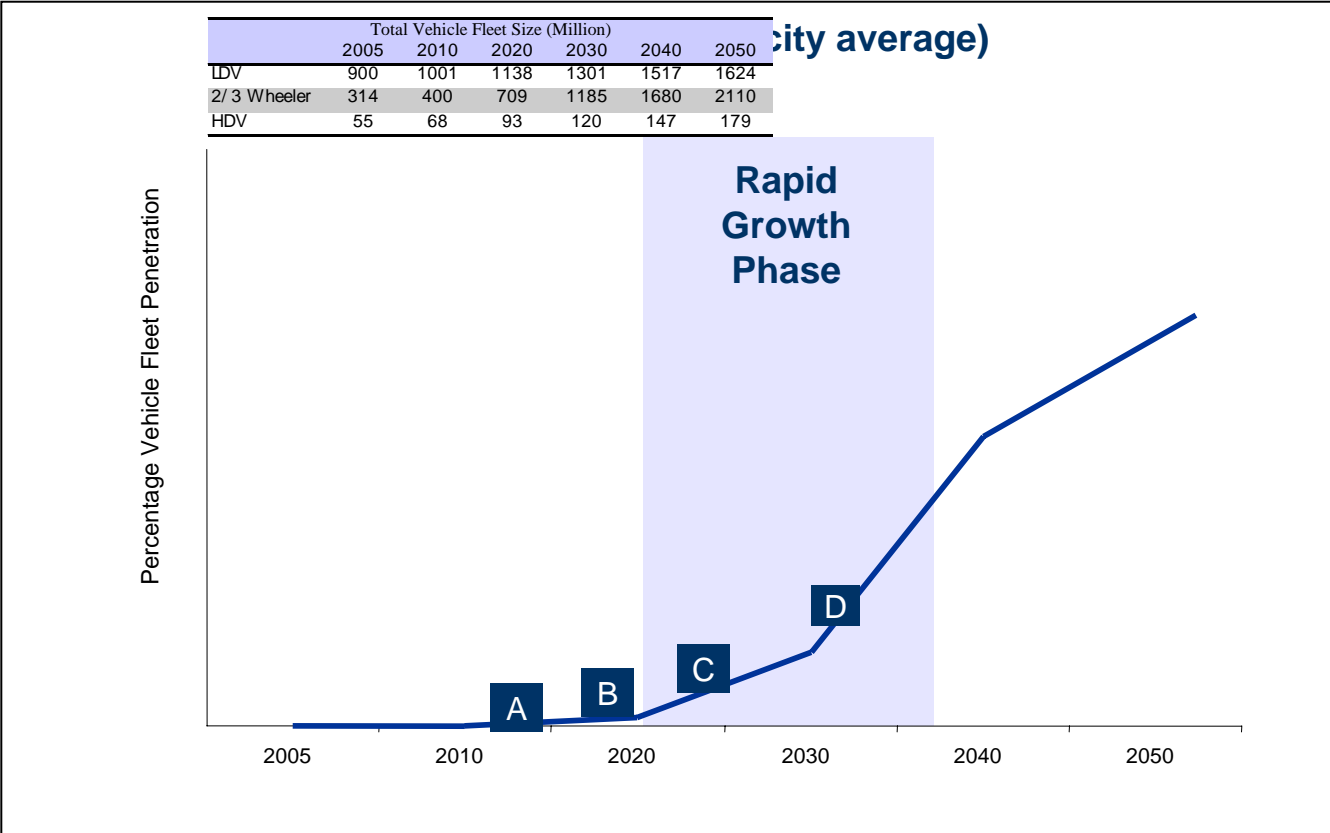


- A** Adoption of biofuel mandates
- B** Fuel specifications raised in EU to E10 and B7
- C** Development of GHG based legislation, incl. ILUC etc.
- D** Development of 2G feedstock production and conversion process technologies



Even with breakthroughs in battery technology, transport electrification growth needs to overcome other factors

Global PHEV % of total vehicle fleet

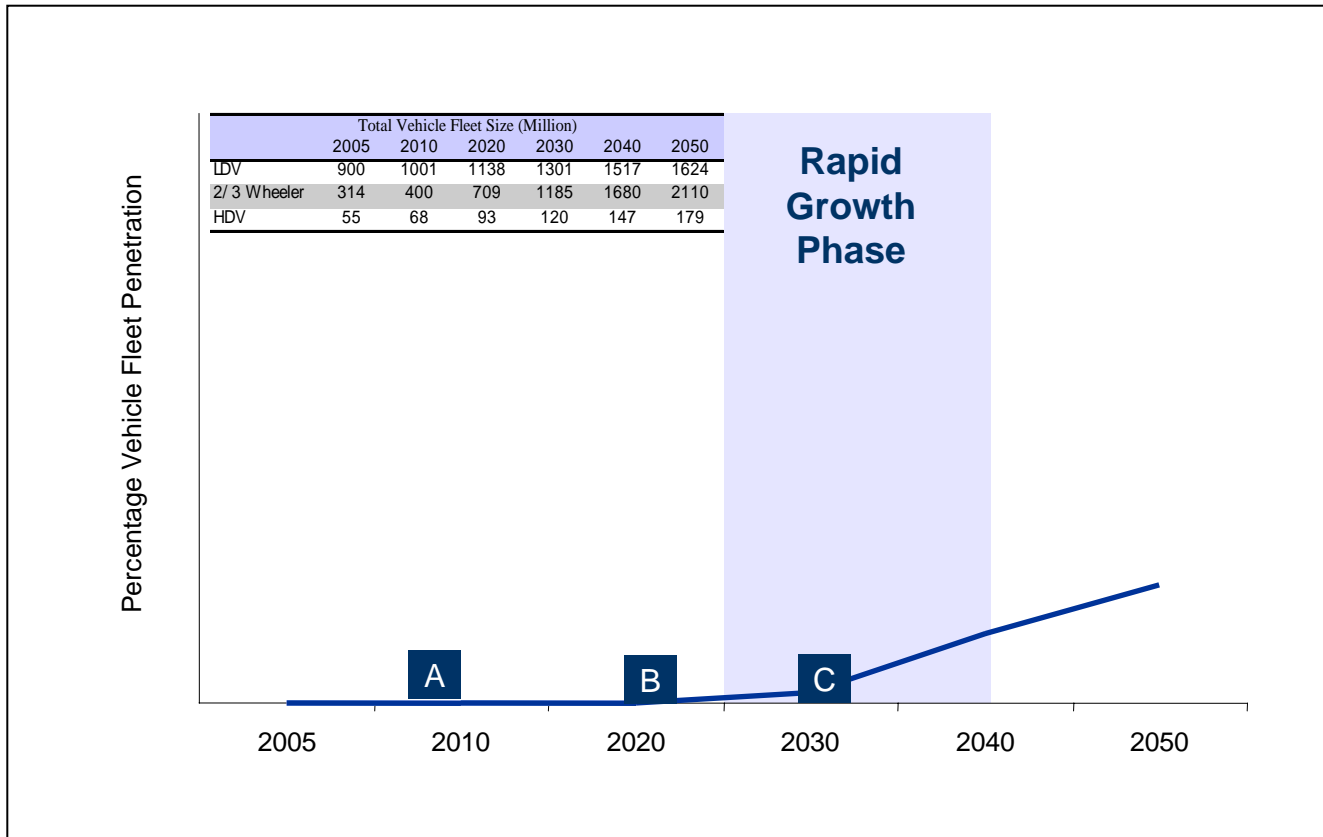


- A** Economic incentives offered to early adopters (not in all markets).
- B** Smart metering and tariff structuring implemented to balance generation load.
- C** Additional electricity capacity (network and generation stock) investment ~ 2025 once transport needs ~5% of additional electricity.
- D** Limited supply of lithium in geographically uncertain regions overcome



Significant numbers of fuel cell vehicles expected once OEMs and fuel suppliers build customer acceptance

Global FCV % of total vehicle fleet

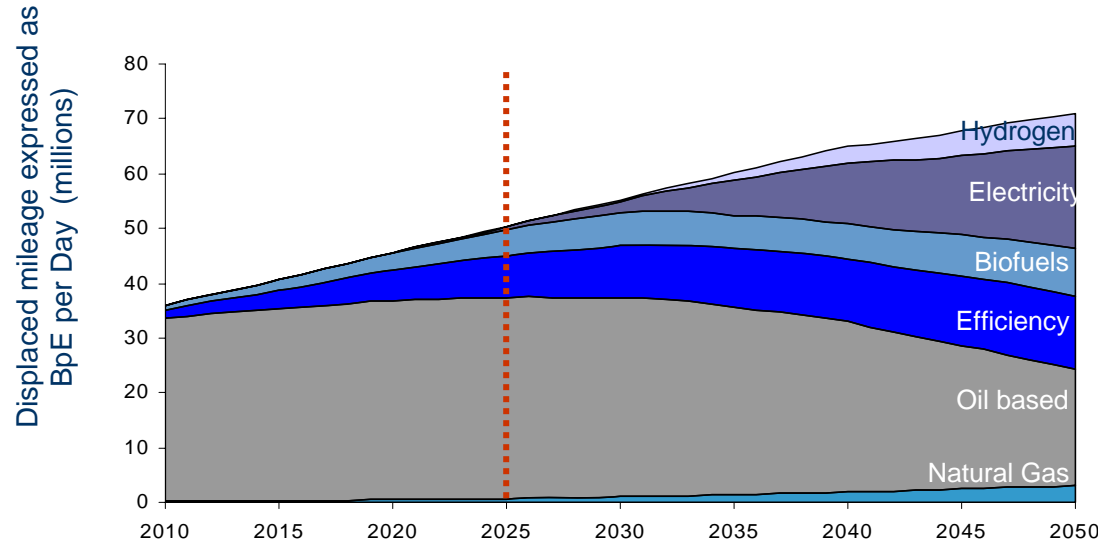


- A** Public Private Partnerships
“Lighthouse” projects and market preparation
- B** Start of commercialisation:
Series production of FCV starts.
- C** Expansion of hydrogen supply infrastructure; transition phase to reach material market share.

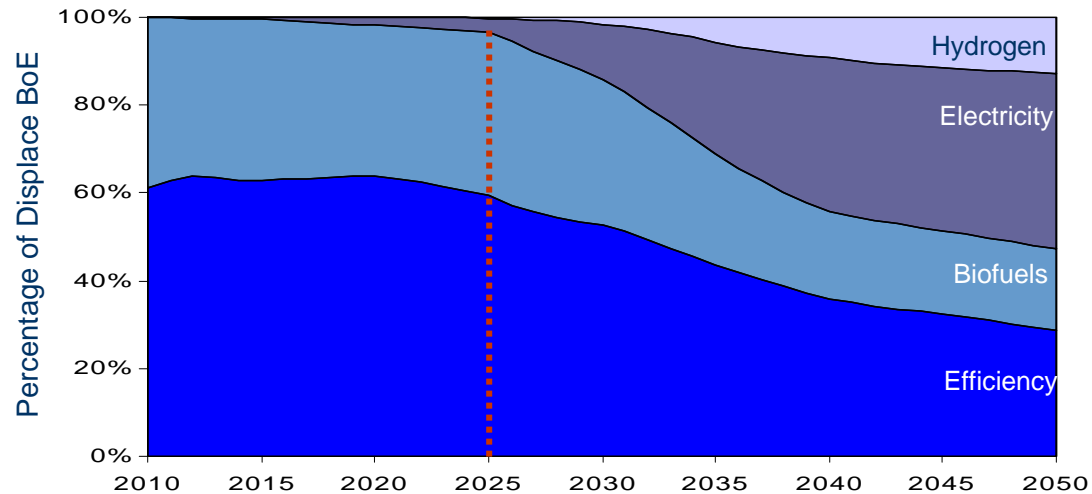


Biofuels is likely to remain the only material low CO₂ fuel option for the next 10-15 years

Road Transport Fuels (2010 to 2050)



Displacement of Oil (2010 to 2050)



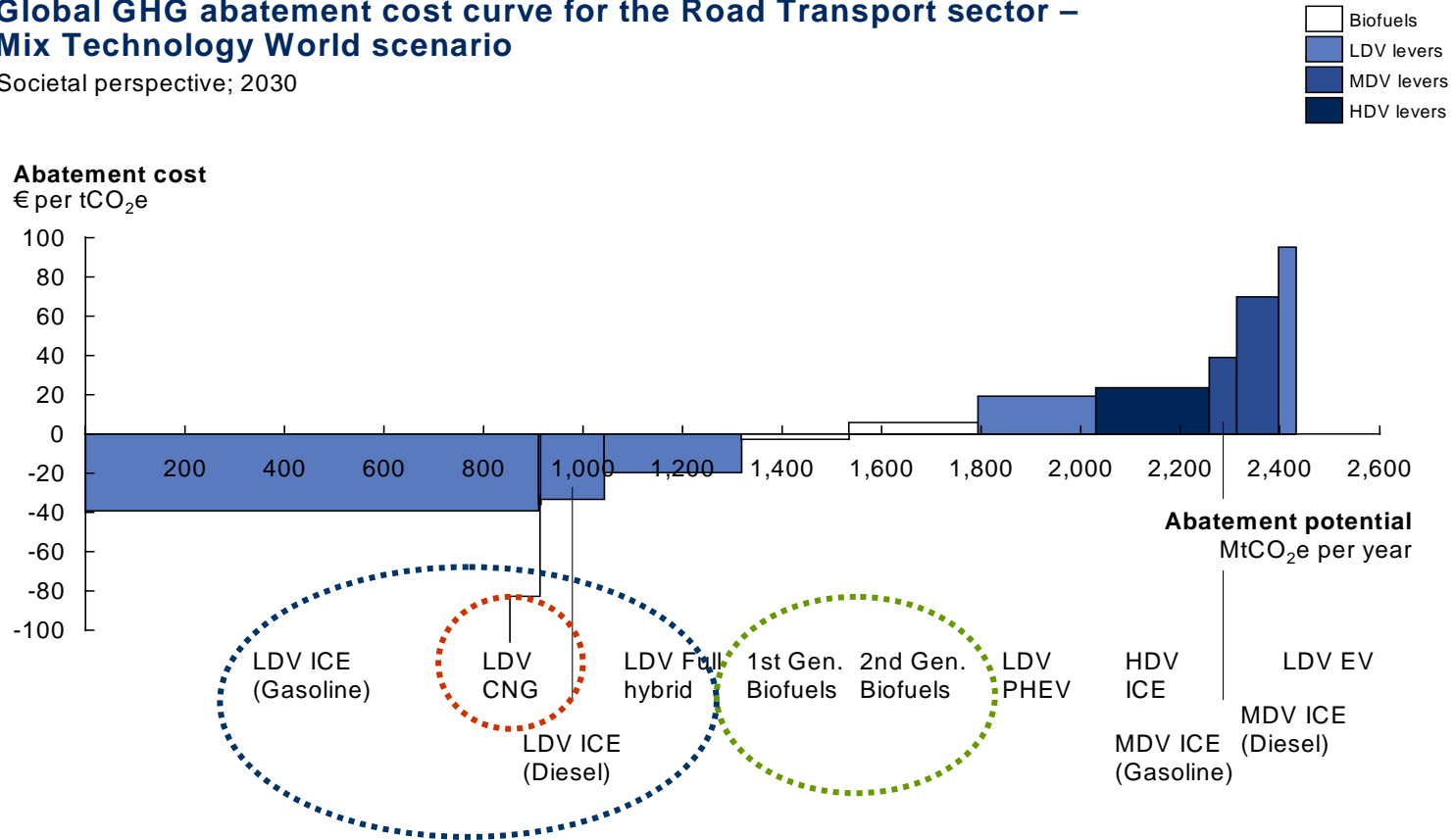


McKinsey work confirms efficiency, CNG (niche) and biofuels as the lowest cost options to abate CO₂

Exhibit 8.6.4

Global GHG abatement cost curve for the Road Transport sector – Mix Technology World scenario

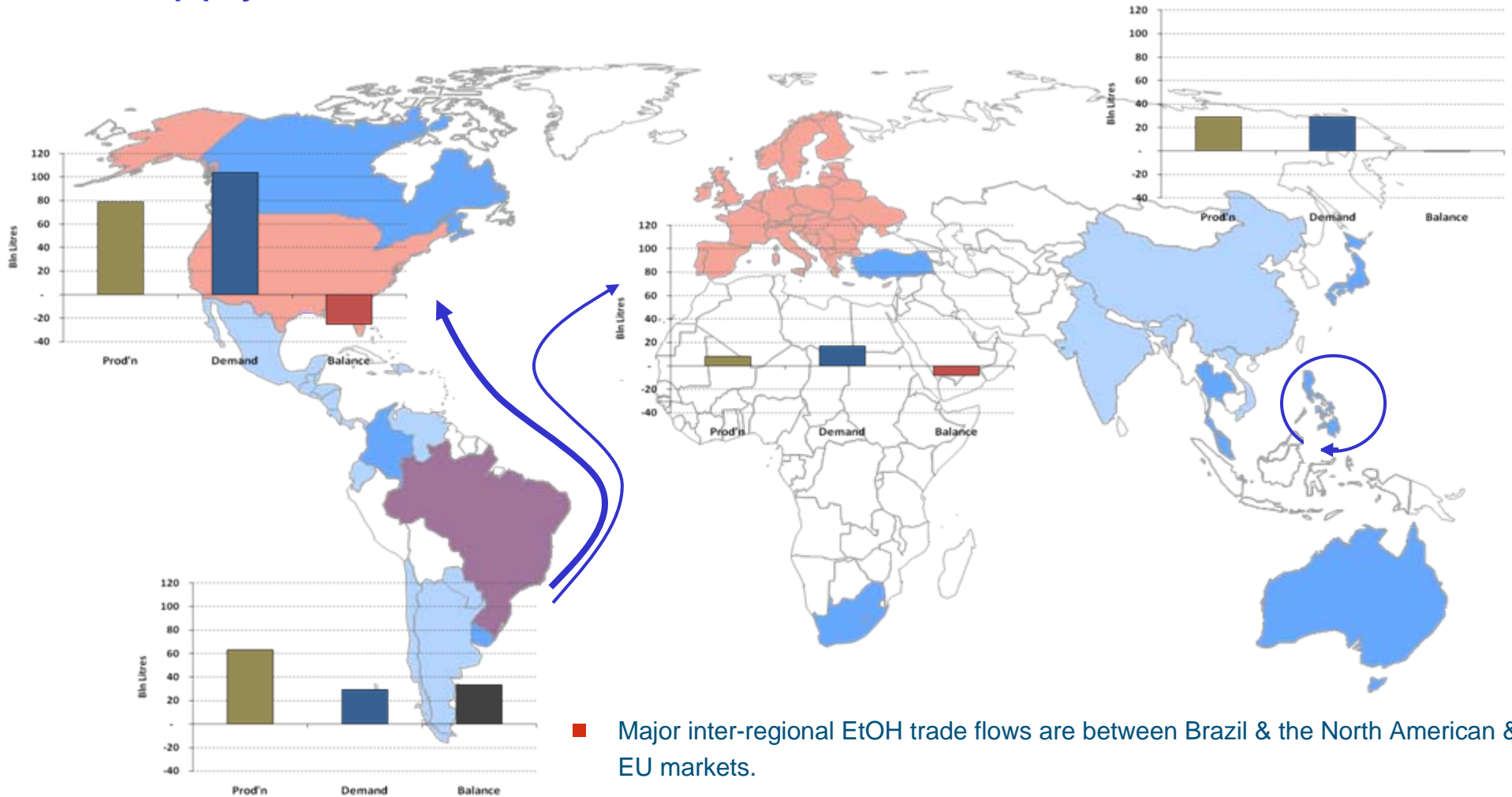
Societal perspective; 2030



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €100 per tCO₂e in a penetration scenario if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0



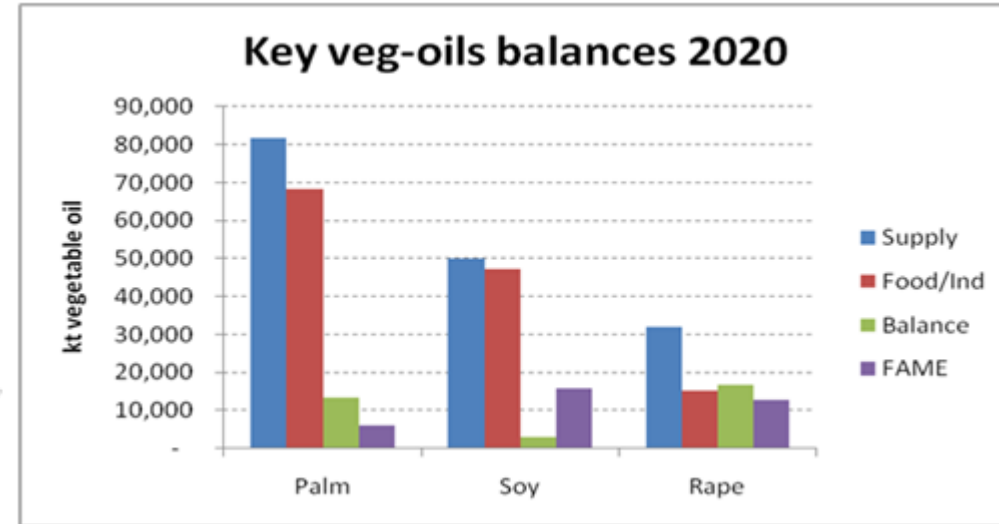
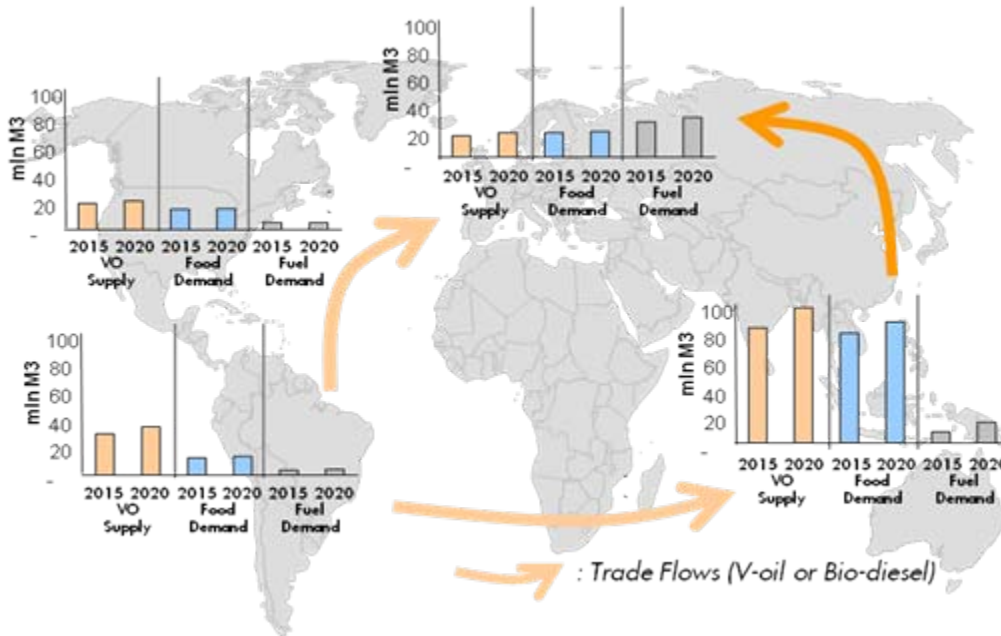
Supply demand balances - EtOH



- Major inter-regional EtOH trade flows are between Brazil & the North American & EU markets.
- East balances itself with trade flows between major producers like Thailand, Pakistan, Philippines and major consumers like Aus.
- Role of Africa is unclear, but potential (e.g. Mozambique, West coast) is high



Supply/demand balances - Biodiesel



- All based in terms of 1G feedstock flows.
- Assumes no significant impact from 2G feedstocks by 2020
- Drivers of volume of oils are different price signals will increase required volumes of Palm & Rape, Soy is more driven by protein demand & is expected to be tight.



Conclusion

- Significant regional variations means no “one size fits all” solution, both at the country level or at a more granular regional level within a country.
- Vehicle efficiency improvements are very necessary and drive decline in liquid fuels in mature markets.
- Biofuels has greatest short to medium term potential to reduce road transport CO₂ emissions.
- Electrification and Hydrogen FCVs could become important later, but technical barriers still to be overcome.
- National fuel mixes will be driven by country specific factors. Policy should create a stable platform and encourage all growth of low carbon transport options



PROPOSED SHELL COSAN JOINT VENTURE

- Brazilian sugar cane – lowest CO₂* and cost competitive of today's biofuels
- Joint Venture Agreement with Cosan proposes \$12 billion joint venture
- 2 billion litres of ethanol production capacity per year – with room to grow
- Robust sustainability principles, standards and operating procedures



Ethanol fuel in Shell's retail network



Automated sugarcane harvesting

European Union Renewable Energy Directive Annex V





IOGEN ENERGY: CELLULOSIC ETHANOL FROM STRAW

- Shell and Iogen Corporation 50:50 equity partners in Joint Venture company Iogen Energy since 2002
- Joint technology programme developing the processing technology to make 'cellulosic' ethanol from lignocellulose (straw) using enzymes
- World's first commercial demonstration cellulosic ethanol plant opened in 2004 (Ottawa, Canada):
 - Produced more than 500,000 litres in 2009
 - Month long retail demonstration in Ottawa, June 2009
- CO₂ emissions of enzymatic cellulosic ethanol from straw could be up to 90% less than gasoline
- Full-scale commercial plant under assessment
- Iogen Energy included in proposed Cosan deal





CODEXIS: DEVELOPING NEW ENZYMES

- Shell has held a 14.7% equity stake in Codexis, California since 2007
- Joint technology development programme to 'evolve' natural enzymes into improved variant enzymes capable of performing to specification
- Codexis is working closely with Shell and Iogen Energy to enhance the efficiency of enzymes used in the Iogen cellulosic ethanol production process
- Researching new enzymes to convert biomass directly into components similar to gasoline and diesel





VIRENT: SUGARS TO HYDROCARBONS

- Equity investment and joint technology development programme to convert plant sugars directly in to a range of high performance liquid transport fuels including gasoline and diesel, since 2007
- Uses catalysts to convert plant sugars into hydrocarbons
- Sugars can be sourced from crops and non-food sources
- Fuels have higher energy content than conventional biofuels and deliver better fuel efficiency
- Could result in biofuels that can be used at high blend rates in standard gasoline engines
- Potentially eliminates requirement for specialized infrastructure, new engine designs and blending equipment
- Pilot plant began production of biogasoline in November 2009





GOVERNMENT SUPPORT FOR ADVANCED BIOFUELS

- In the short term, government policies, incentives and financial support accelerate development from lab to commercial deployment
- Government support should:
 - Promote cost-effective sustainable low CO₂ components and use common 'well-to-wheels' CO₂ calculations
 - Not pick technology 'winners' and focus on sustainable CO₂ reduction
 - Structure incentives to link and align with regulatory policy mechanisms governing commercial deployment of low carbon technologies
 - Avoid using penalties based on inexact science E.g. ILUC
 - Provide certainty for private investment in technology demonstration and ensure support for demonstration projects is for the fixed length of the development /demonstration project
 - Ensure funds go beyond R&D and include assistance for commercial scale demonstration
 - Promote free trade