The CAST Proposal

Renewable Synthetic Liquid Fuels for Compatible Affordable Sustainable Transportation

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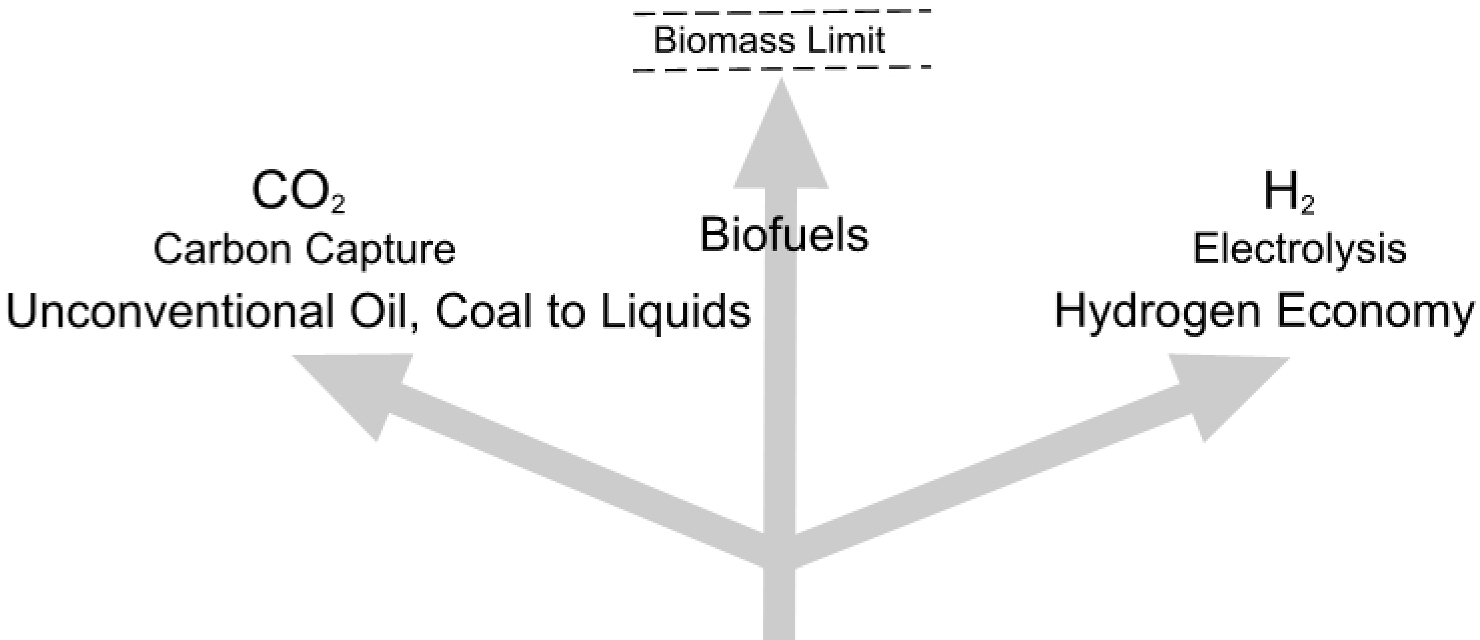
Outline

- Renewable energy is needed for deep cuts in CO_2
- Vehicle makers and buyers could not afford Battery Electric Vehicles or Fuel Cell Vehicles
- Fuel companies could afford to produce renewable synthetic liquid fuels
- These would provide Compatible Affordable Sustainable Transportation

Sustainable Transportation ?



The World at the Crossroads

Transport Options

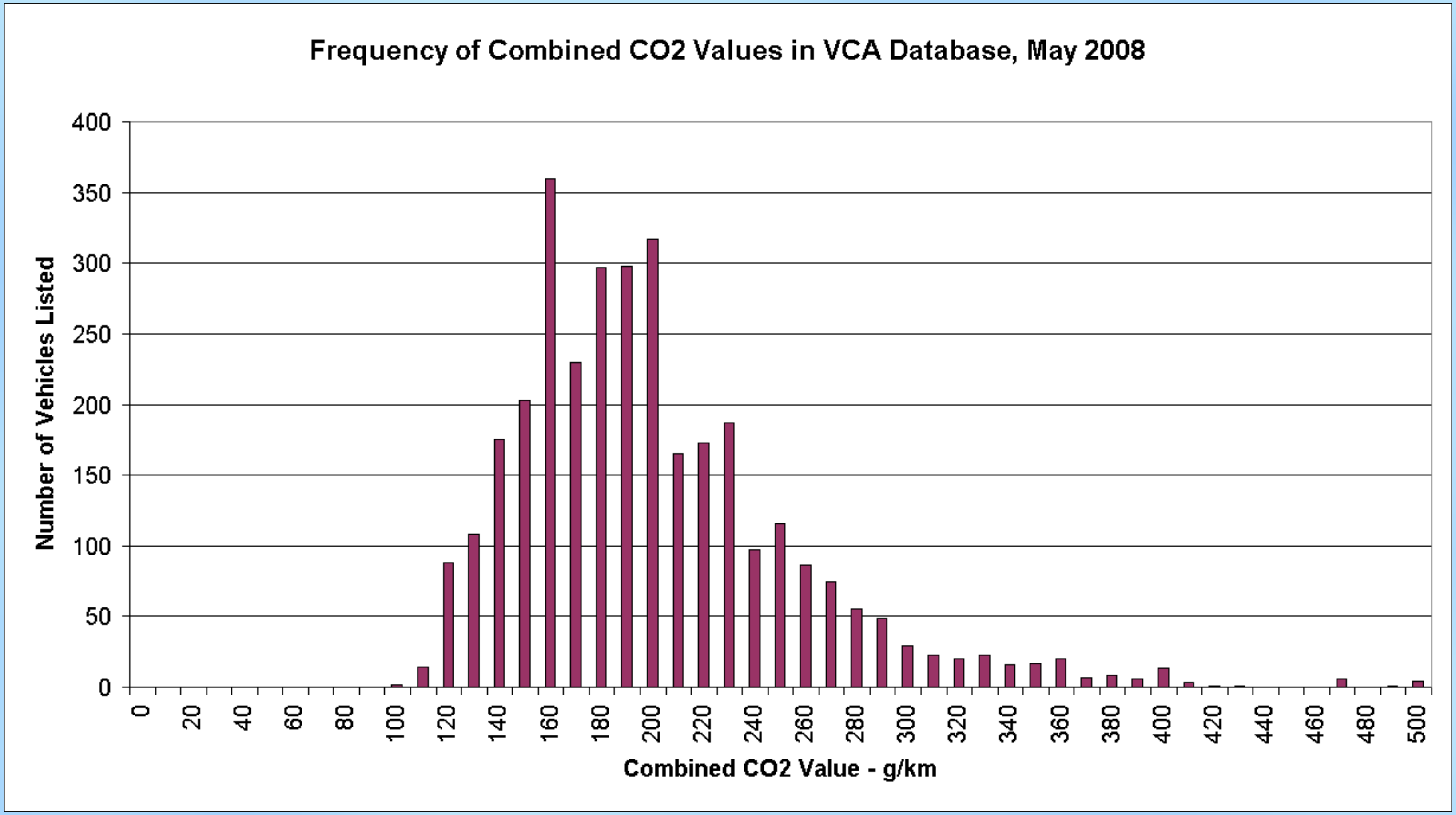
- Unconventional Oil & Coal to Liquids would increase GHG emissions and not be sustainable
- H_2 would be incompatible for all, unaffordable for cars & very difficult for trucks, ships and planes
- Biofuels are subject to the Biomass Limit (~ 10-30% of transport fuel for developed countries)

Transport Vehicles and Fuels

Aircraft, ships, trains and trucks require high energy hydrocarbon fuels to achieve their design payloads and ranges, and account for about 50%

Cars are less demanding in payloads and ranges, and account for the remaining 50%

CO_2 Values for Cars Available in the UK



With oil-based fuels, less than 100 gCO2/km is costly and less than 130 fleet average would be even more costly

Renewable Sources for Transport

Biomass

Renewable electricity from the following:

- Hydro and geothermal - limited to certain sites

- Marine current and wave power - not yet shipping

- Wind turbines and photovoltaics, of which the former give much lower cost electricity

Sustainable Energy/Fuel Options for Cars

Renewable electricity stored in batteries, driving electric motors - BEVs

Renewable electrolytic hydrogen, stored at high pressure, converted in fuel cells to electricity, driving electric motors - FCVs

Renewable electrolytic hydrogen, combined with captured CO2 to produce synthetic fuels such as methanol, used in internal combustion engines - ICEVs

Operating Criteria - BEVs

Compared with hydrocarbon fuels, batteries have energy densities lower by about 100 x

This limits the vehicle range, especially in 'real world' usage

Yet the recharge time is not minutes but hours

Hence Plug-In Hybrid EVs and Extended Range EVs, with ICEs and powerful generators

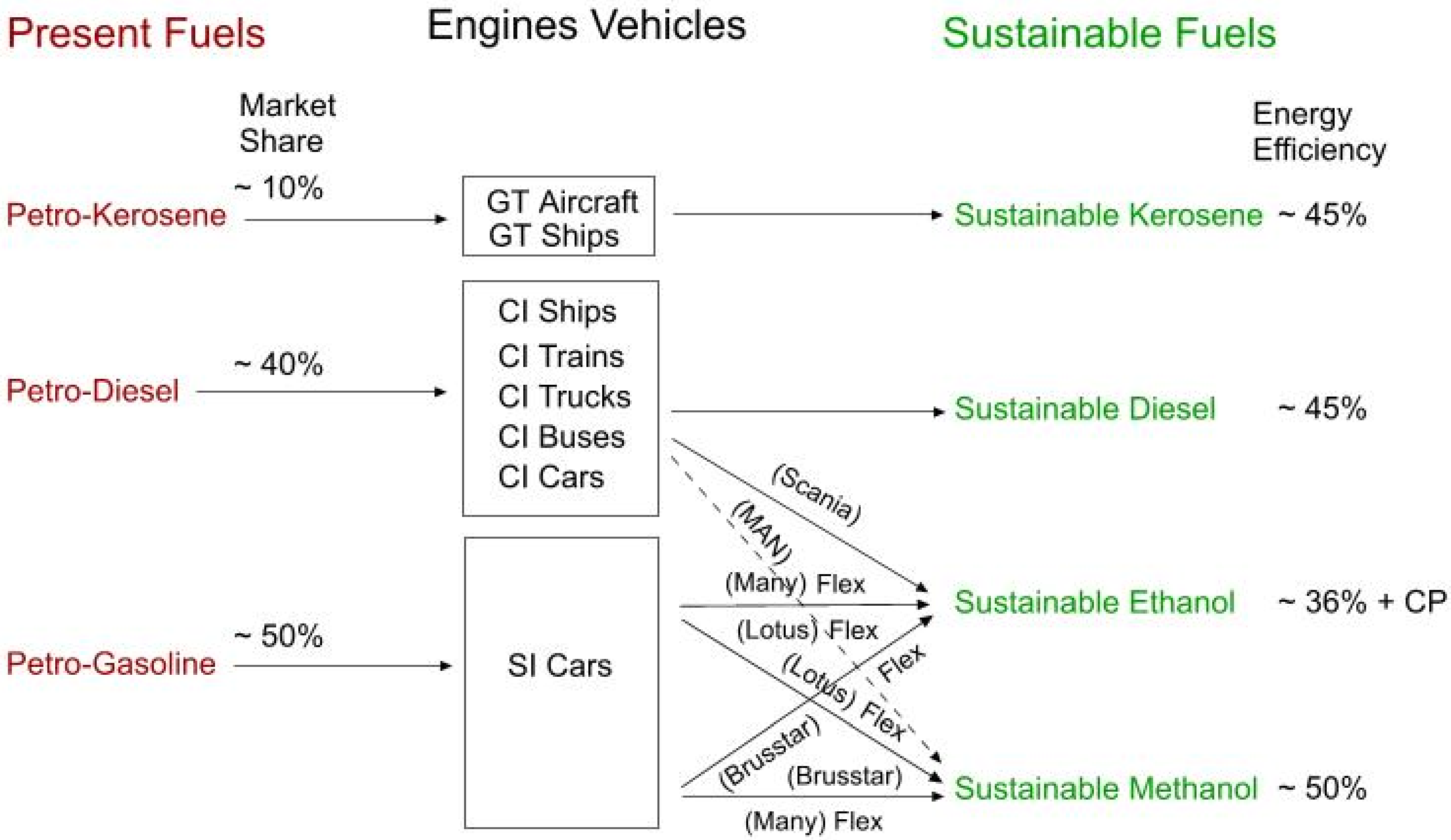
Operating Criteria - FCVs

Compared with hydrocarbon fuels, hydrogen at 700 bar has a volumetric energy density lower by 5 x

This limits the vehicle range, especially in 'real world' usage

Hence Fuel Cell Vehicles are usually hybrids, with high-power batteries, for regenerative braking

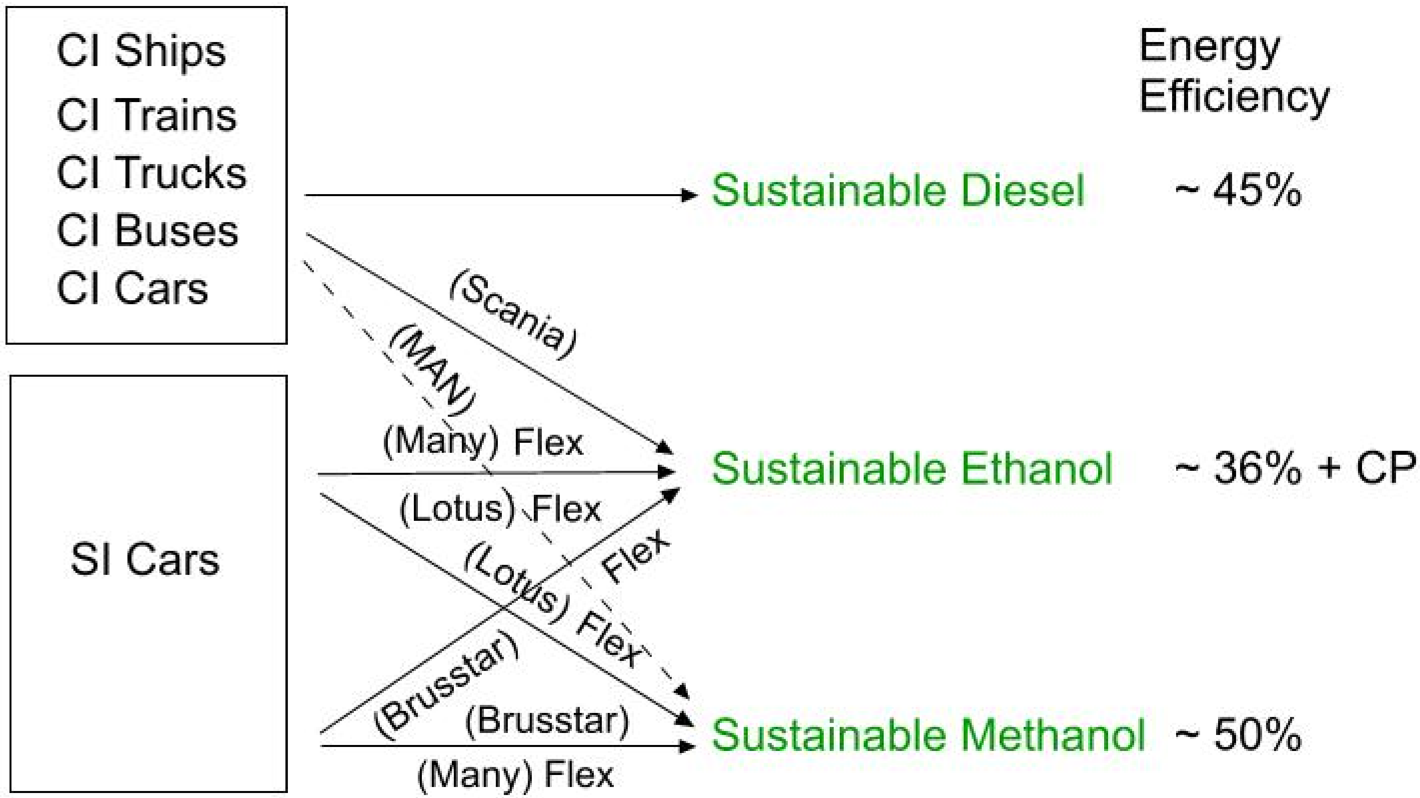
Compatible Affordable Sustainable Transportation



GT = Gas Turbine, CI = Compression Ignition, SI = Spark Ignition, CP = Co-Products

Compatible Affordable Sustainable Transportation

Engines Vehicles — Sustainable Fuels



Compatible 1: Keep ICEs

- Piston-type for most surface vehicles
- Gas Turbines for most aircraft
- They are easy to produce, have high specific outputs and still have considerable potential
- They contain few scarce materials, so have low energy and money costs
- Replacement of the existing vehicle plants and fleets would be hugely costly and leave vast 'stranded assets'

Compatible 2: Keep liquid fuels

- CHO liquids are easy to produce, have high energy densities & alcohols can mix with gasoline
- They can be stored in low cost tanks
- They can be transported by pipelines and by sea and road tankers
- They can be dispensed by self-service
- Replacement of the existing fuel plants would be hugely costly and leave vast ‘stranded assets’

Choice of Sustainable Fuels

- Kerosene and FT Diesel have feedstock and energy efficiencies 1.2 – 1.4 x lower than Methanol, but are needed for aircraft and ships

- Ethanol and Methanol are well suited to road transport, both light duty vehicles (cars) and heavy duty vehicles (buses & trucks)

- E100 from sugar cane etc. is the most likely fuel for developing countries and M100 from biomass and captured CO2 for developed countries

Vehicles for developing economies

- The number of vehicles on the road is expected to increase dramatically.
- The increase will be driven by increasing prosperity in the developing world and by the production of ultra-cheap cars such as the $2500 Tata Nano
- These cars will use cheap powertrains and cheap fuel systems

The Tata Nano

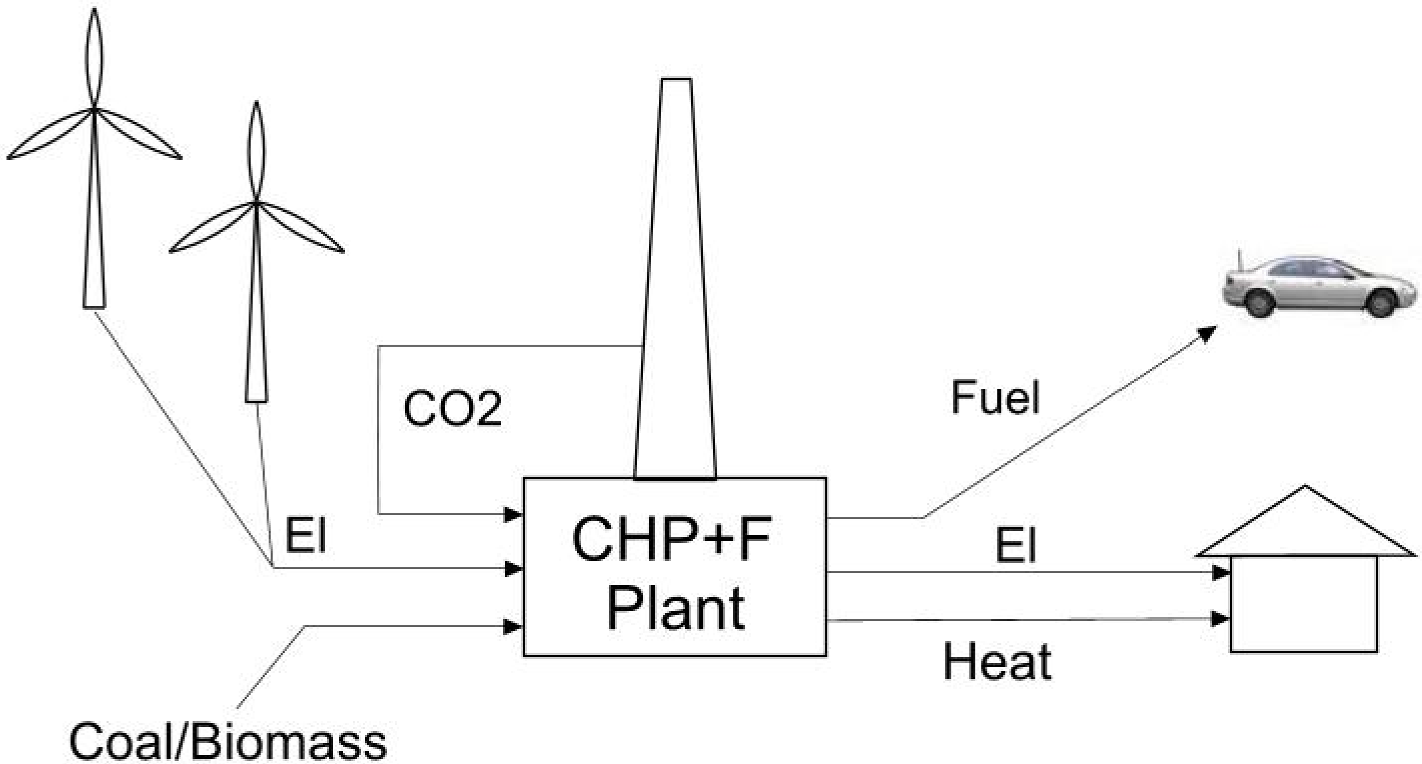
Affordable Vehicles because:

- Dedicated and FFVs for sustainable fuels must sell sufficiently fast for...
- Such vehicles to gain 100% market shares for...
- A fast and complete transition to increased fuel security and reduced GHG emissions

Affordable Fuel and Vehicles

- Fuel companies are professionals and closer to the resource depletion and climate change challenges
- Fuel plants are bought by corporates, using low-cost capital, and run up to 95% of the time
- Most light duty vehicles are bought by individuals, using higher-cost capital, and run ~ 5% of the time
- So fuel companies are best placed to deliver most of the sustainable transportation solution

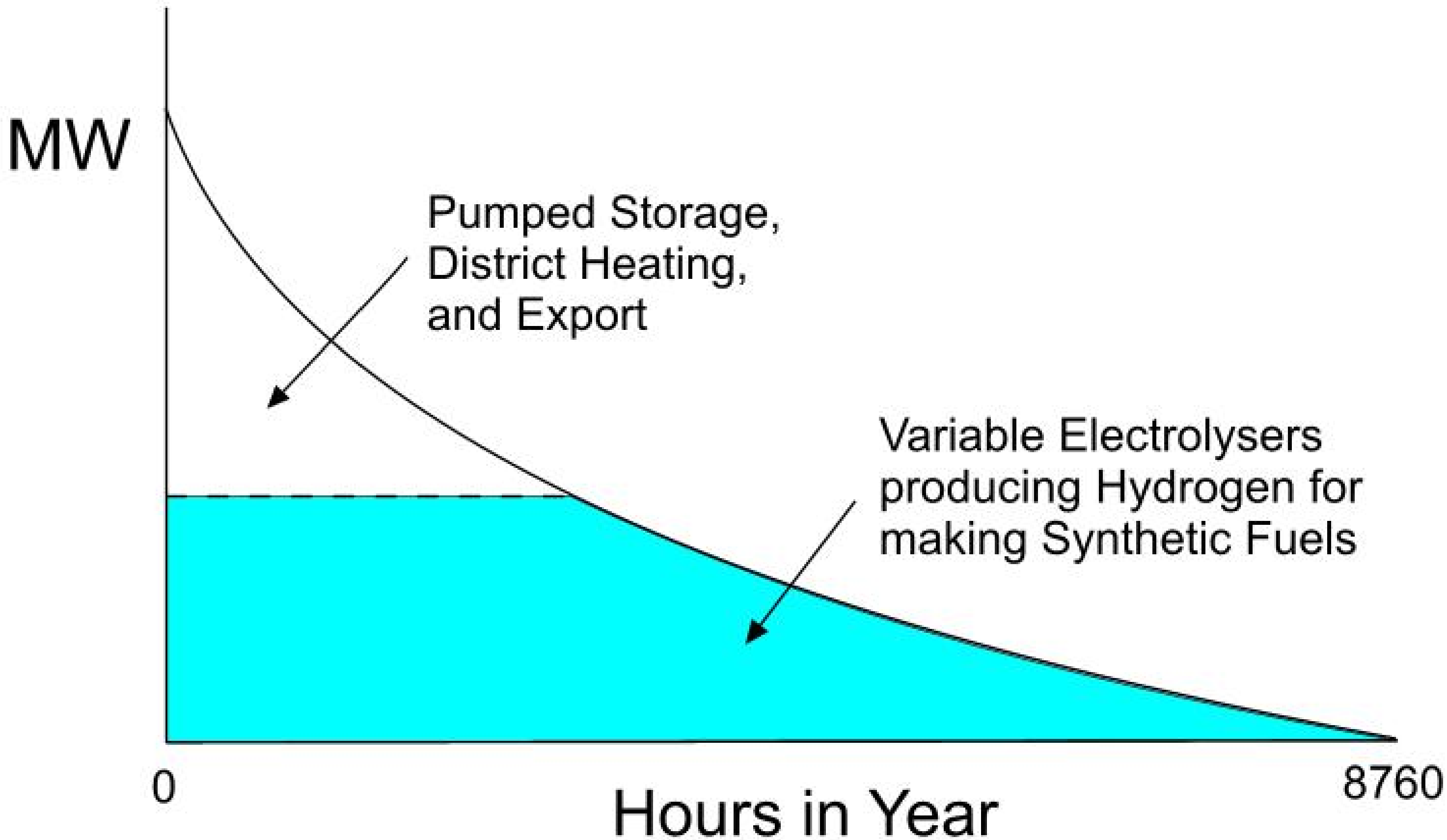
Combined Production of Heat, Power and Fuel



Carbon Sources for Fuels

- Biomass, but this is often limited by land, water and nutrients to only 10-30% of fuel demand
- CO_2 from power station fluegas, but this will decline as fossil fuels are phased out, leaving that from those burning biomass and waste
- CO_2 from the air. This is essentially unlimited and will be needed for 70-90% of fuel demand

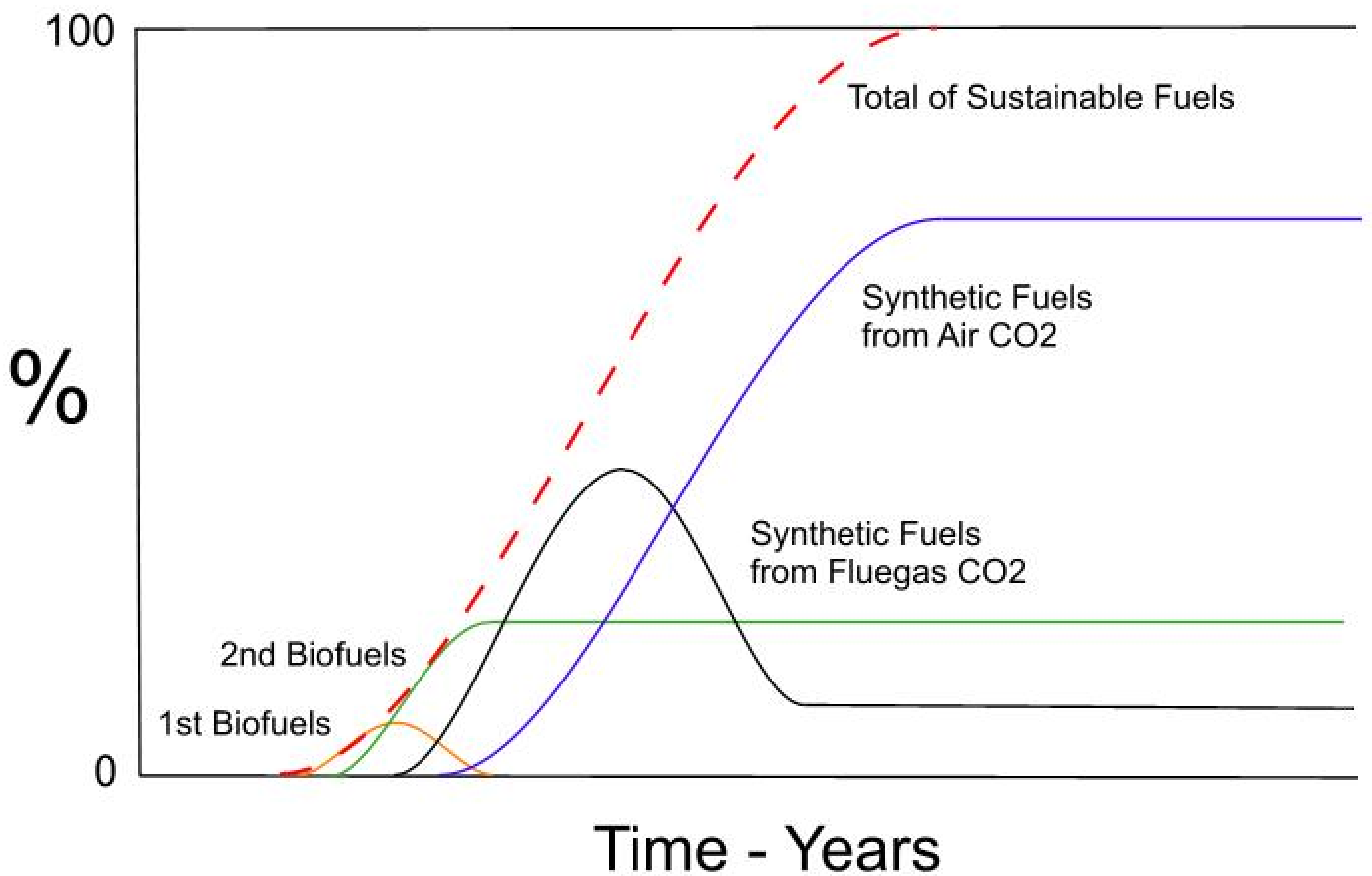
Wind Power Production and Use



Hydrogen for Synthetic Fuels

- Produced by electrolysis with renewable electricity - mainly from wind turbines
- Present world transport fuel demand is ~ 3 TW
- Assuming a fuel synthesis efficiency of 50%, the required energy input is ~ 6 TW
- Global wind power (>= 6.9 m/s at 80m) is ~ 72 TW, plenty for this and other uses and for growth

Transition to Sustainable Fuels



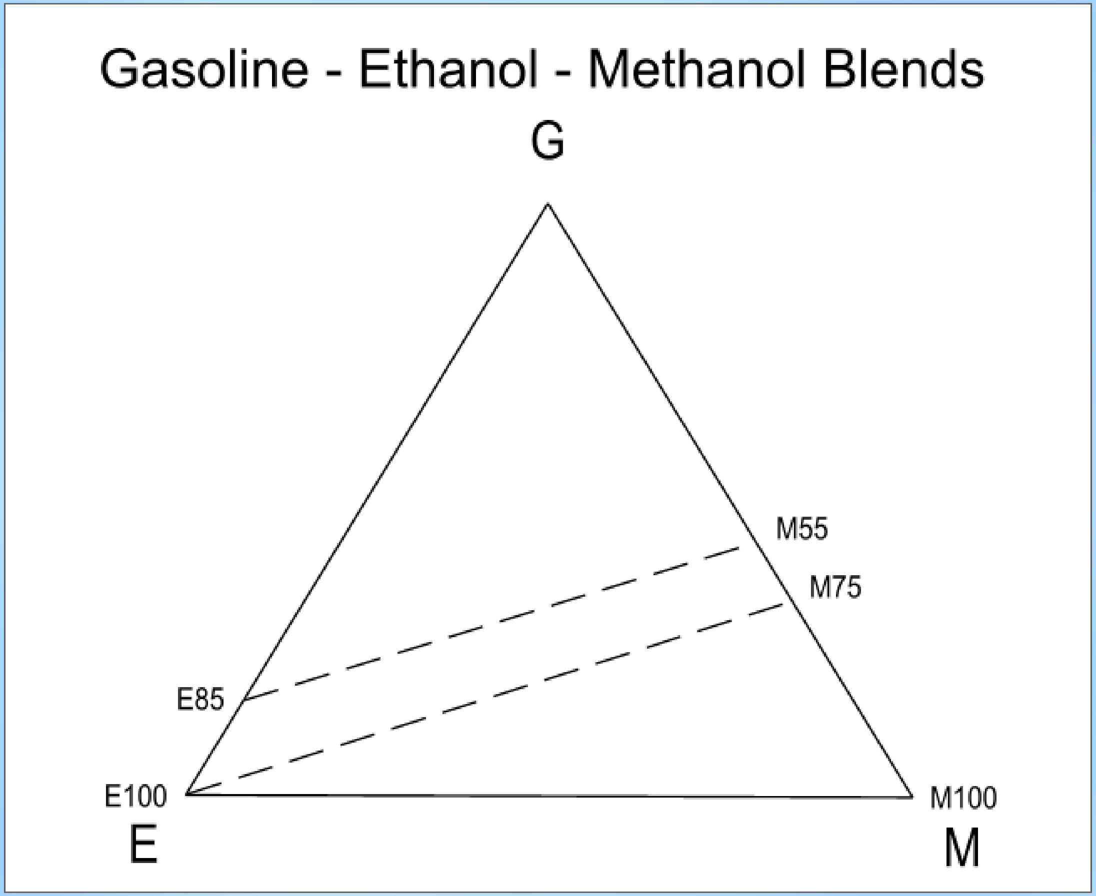
Transition to Sustainable Fuels

Gasoline could be replaced in developed countries by synthetic methanol, and in developing countries by bio-ethanol

Flex-Fuel, Total-Flex and Tri-Flex Vehicles require only enhanced maps for the ECU and sometimes a fuel sensor for about $ 200

Tri-Flex vehicles could be developed and produced to a single specification for sale and use worldwide

Vehicle Fuel Requirements



3 Grades: E85-M55, E100-M75, M100

Transition to Sustainable Fuels

For existing standard vehicles, methanol and ethanol may be used in low-blends – up to e.g. 17 to 23%

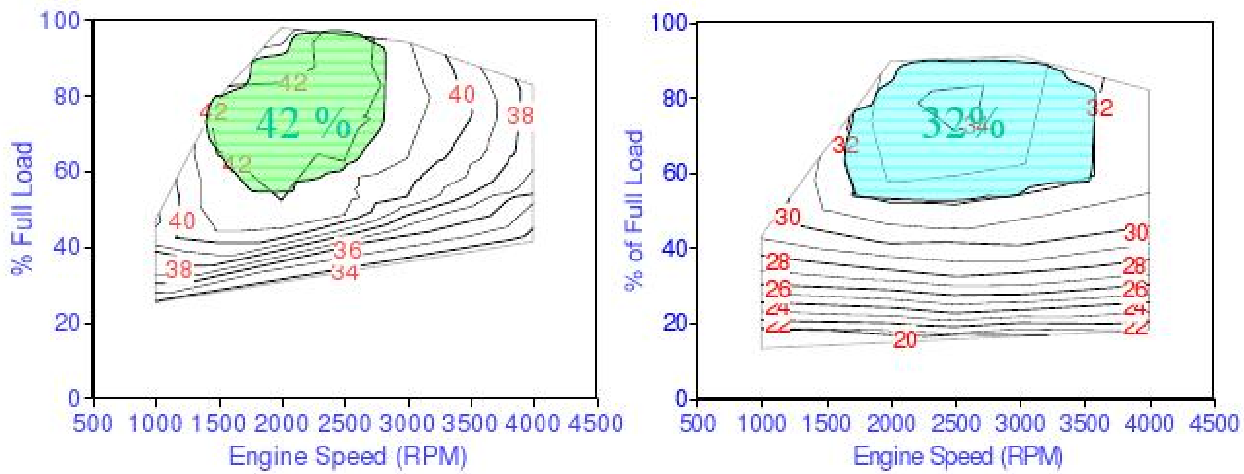
For existing E85 Flex-Fuel Vehicles, methanol may also be used – up to e.g. M55

For existing E100 Total-Flex Vehicles, methanol may also be used – up to e.g. M75

Lotus has developed SI engines using E0-100 (flex-fuel) and E/M 0-100 (tri-flex)

Brusstar (EPA) has developed high efficiency SI engines using E/M100 and E10-100 (flex-fuel)

Efficiency: Methanol



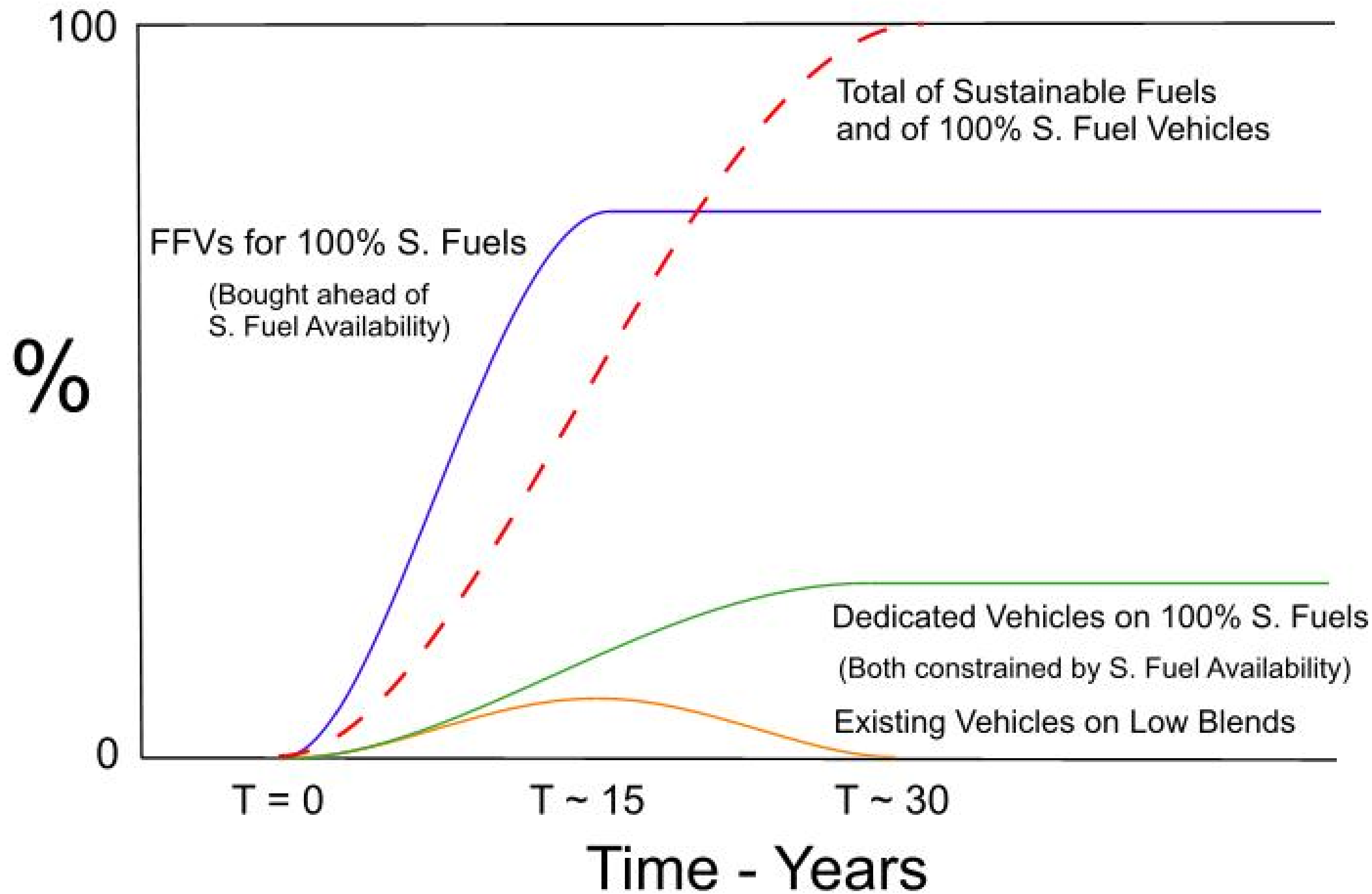
Methanol Gasoline

33% higher efficiency with methanol
Broad region of high efficiency

Transition to Sustainable Vehicles

- TotalFlex cars in Brazil can already use E22-100
- Lotus have demonstrated E/M0-100 (Tri-Fuel)
- M100 gave 33% higher efficiency in EPA project
- M85 was used by Ford and GM FFVs in the 1980s
- M100 was used by MAN and GM buses in the 1980s

Transition of Vehicle Fleet

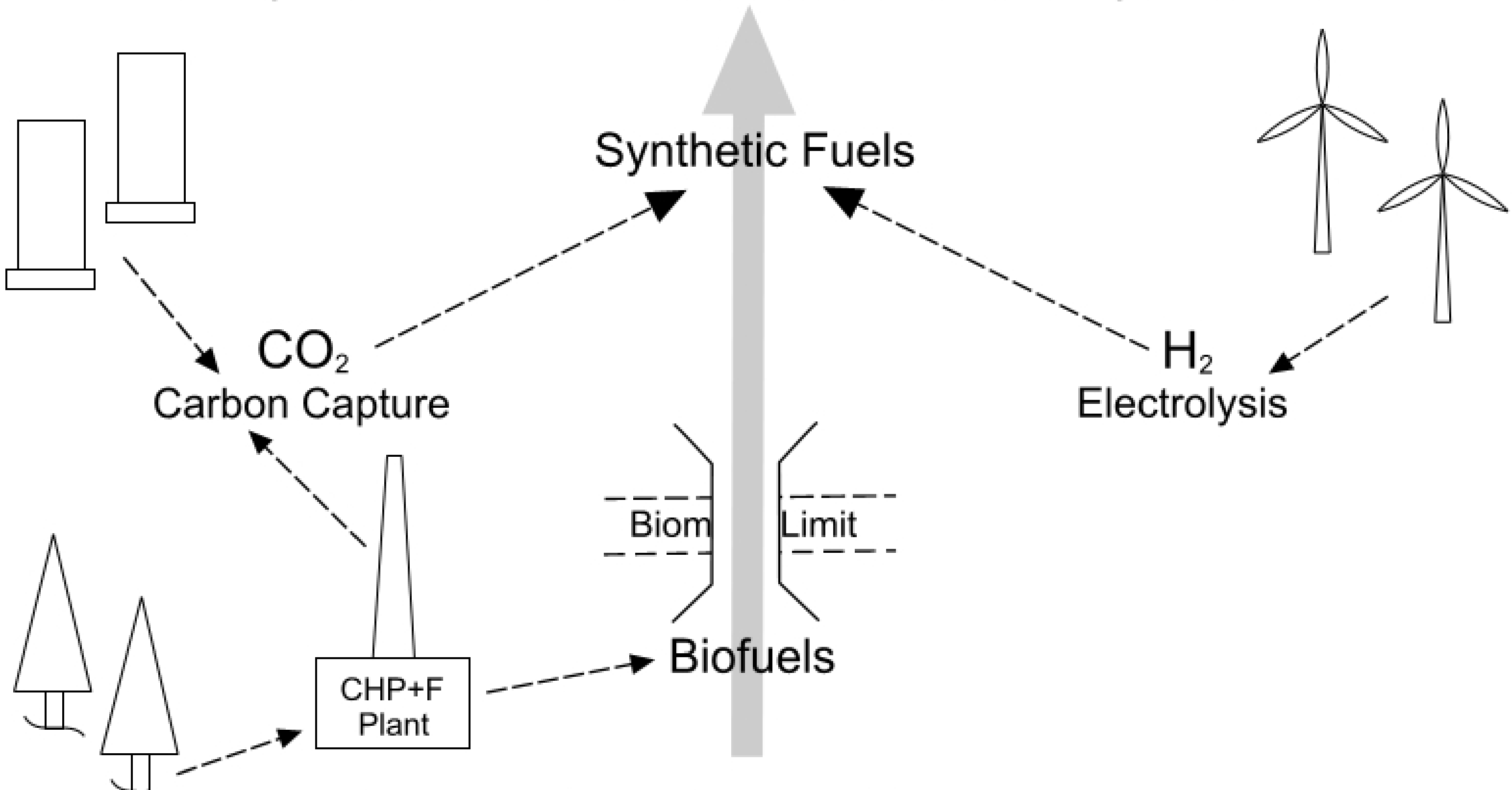


Transition Times

- LDVs could be replaced with FFVs in ~ 15 y
- HDVs could be replaced with E/M100 Vs in ~ 30 y
- To avoid 'stranded assets' the sustainable vehicle transition time should be at least ~ 30 y
- This is independent of the fuel and vehicle options

CAST

Compatible **A**ffordable **S**ustainable **T**ransportation



The Way Ahead Is Clear

Compatible Affordable Sustainable Transportation

- **Compatible** with the world’s transport fuel infrastructure and vehicle plants and fleets
- **Affordable** by fuel suppliers, vehicle makers and vehicle buyers
- **Sustainable Transportation**, all fuelled from renewable sources
- Hence the fastest transition to maximum fuel security and minimum GHG emissions

Delivering CAST

The major investments would be made – as now - by fuel suppliers – to maintain and increase production

Oil would require recurrent and ever-increasing sums, whereas – once the demand capacity had been met – synthetic fuels from renewable electricity would not

Instead they would enable CO_2 targets to be met with the existing vehicle fleets and their production plants

The CAST Proposal document
– on which this presentation is based -
may be obtained via:

http://www.energypolicy.co.uk