Sustainable Organic Fuels for Transport - SOFT

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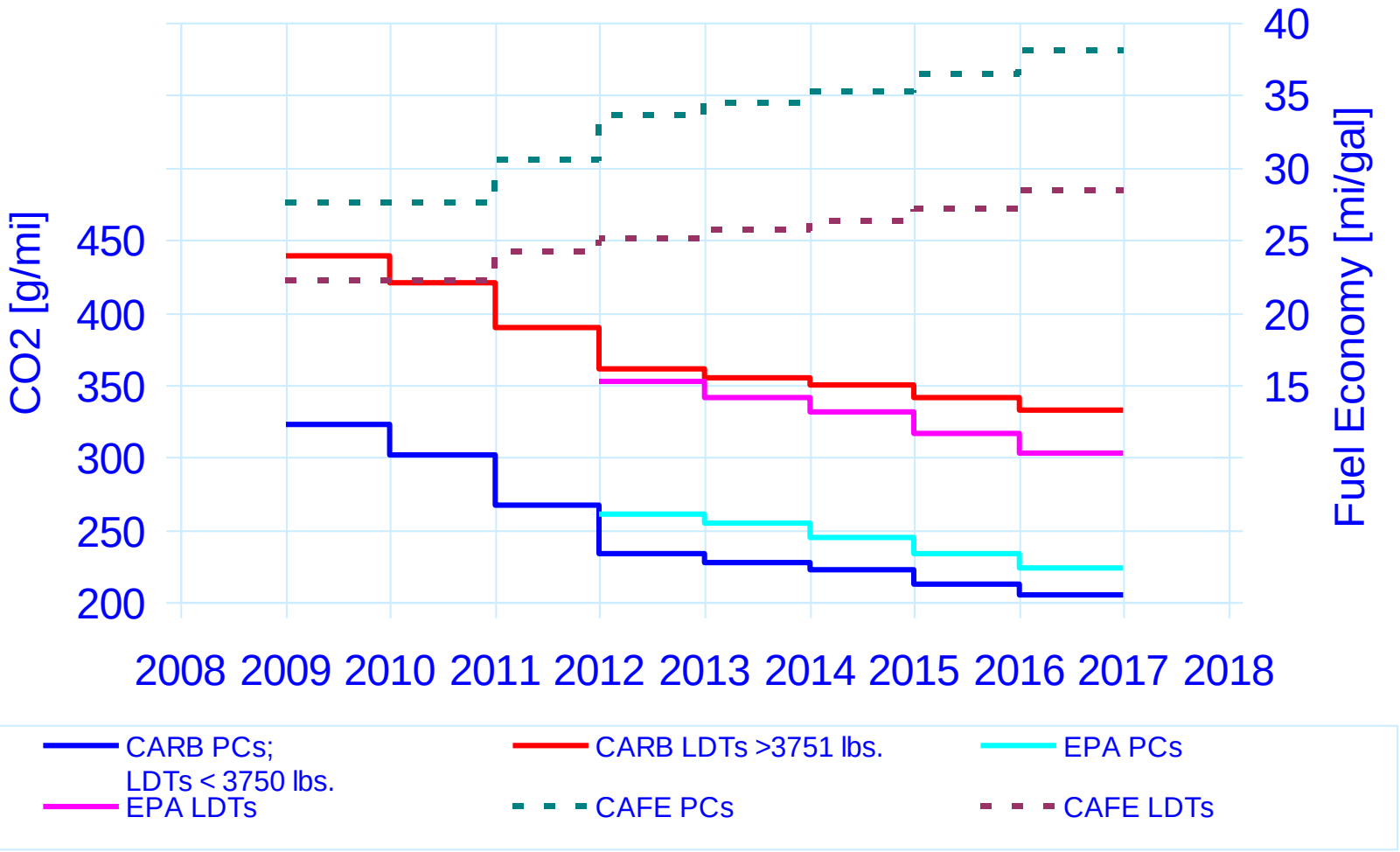
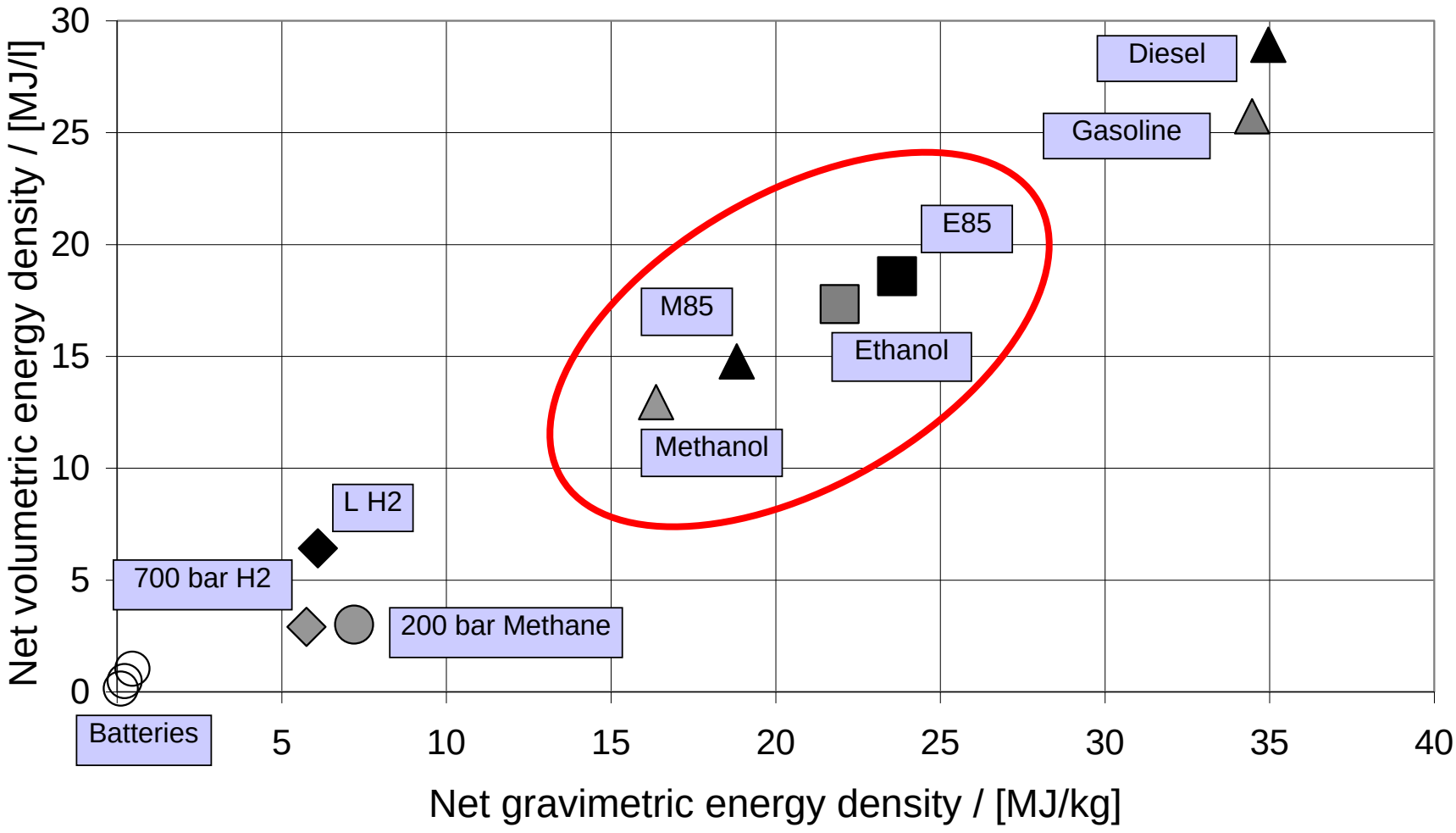
Greenhouse Gas Emissions - Standards



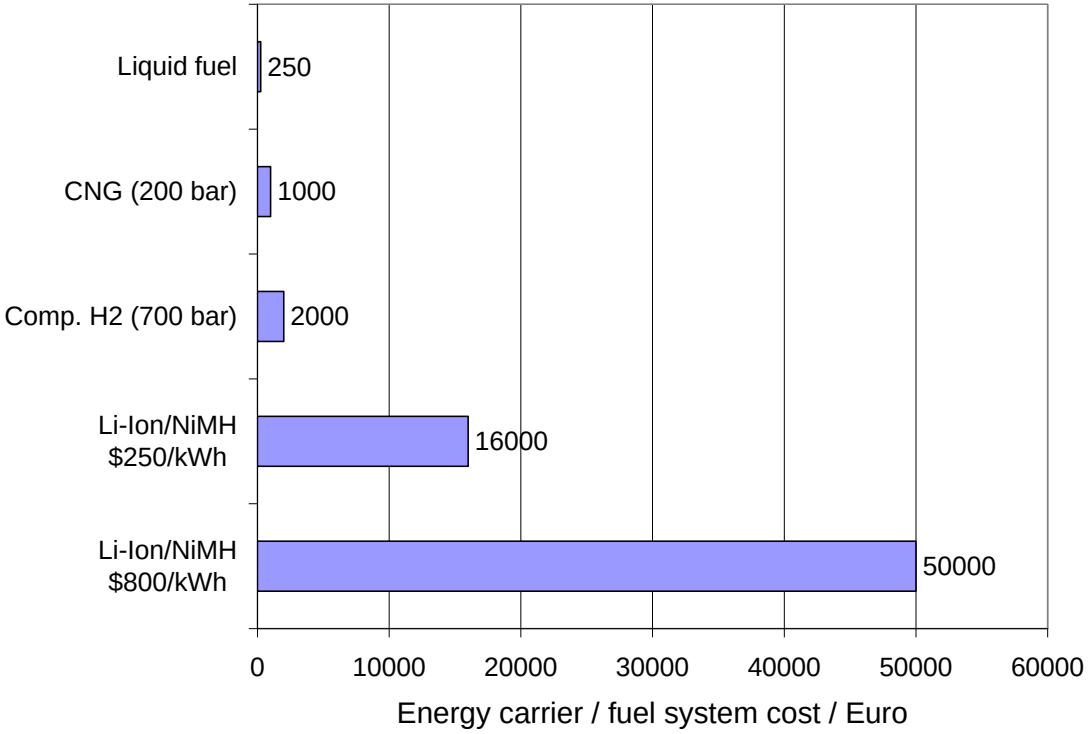
Options For Reducing GHGs

- Higher Efficiency Powertrains
  - Gasoline
  - Diesel
- Hybridization
- Battery Electric Vehicles
- Hydrogen Fuel Cell Vehicles
- Low Carbon Fuels
  - Gaseous
  - Liquid

Fuels and Energy Carriers



Fuel System and Powertrain Costs



Cost per kW

	Current ($/kW)	Medium Term ($/kW)
Gasoline	10-15	15-20
Diesel	15-20	20-30
Hybrid	25-40	20-35
Fuel Cell	500-1000	Target 60

Source: Jackson, N., I.Mech.E. Cost-Effective Low Carbon Engines Conference, London. Nov. 2006.

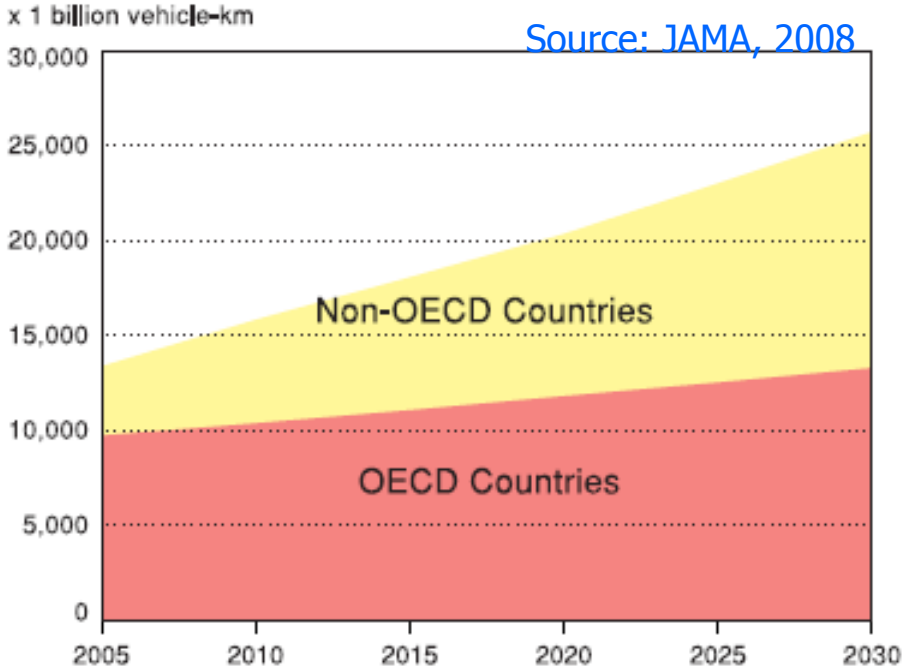
Using scarce / expensive materials does not give volume benefits.

Unaffordable low-carbon vehicles do not reduce CO_2 emissions.

Hydrogen infrastructure costs for US estimated at $\$1 \times 10^{12}$

Projected Growth in Transport

- The number of vehicles on the road is expected to increase by a factor of 4 by 2050.
- 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



Source: JAMA, 2008

Tata Nano

Alcohol Fuels - Happening Now, But …

- Production of liquid fuel from biomass creates an energy carrier with a high degree of flexibility, but…
- Recent studies have highlighted problems caused by biofuels which limit the amount of fuel which can be produced in a sustainable manner.

Table 2.1: Illustrative GHG savings and payback times for biofuel feedstock causing land change[13]

Fuel chain	Assumed country of origin	GHG saving excluding the impacts of land-use change	Carbon payback (years)	
		%	Grassland	Forest
Palm to biodiesel	Malaysia	46%	0 – 11	18 – 38
Soya to biodiesel	USA	33%	14 – 96	179 – 481
Sugarcane to bioethanol	Brazil	71%	3 – 10	15 – 39
Wheat to bioethanol	UK	28%	20 – 34	80 – 140

Source: Gallagher Review, UK

Where Do We Get Them From?

- Up to the BioMass Limit (different for each country) – from BioMass:
  - *using carbon collected and re-cycled by the biosphere;*
  - *producing ethanol and methanol (via gasification) – where feed stocks are properly sustainable.*
- Beyond the BioMass Limit – via synthesis using feed stocks from the atmosphere and the ocean:
  - *using carbon collected and re-cycled artificially together with renewable hydrogen;*
  - *producing sustainable synthetic methanol:* $CO_2+3H_2 \rightarrow CH_3OH+H_2O$;
  - *this can be thought of as chemically liquefying hydrogen using* CO_2;
  - *the pragmatic implementation of the hydrogen economy.*

Beyond the Biomass Limit: Sustainable Methanol

Energy in

Hydrogen from electrolysis of water

$$H_2O \rightarrow H_2 + \frac{1}{2}O_2$$

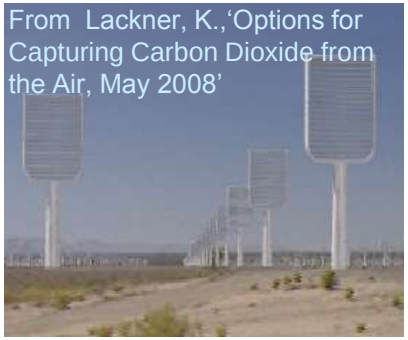
Carbon out

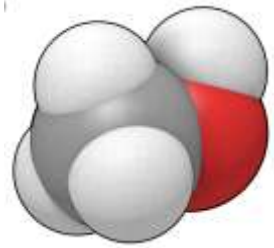
Synthetic hydrocarbons and products

Methanol synthesis

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$

CO_2 consumption





Fuel use

$$CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O$$

CO_2 capture

Carbon in

CO_2 from fossil fuel burning power plants

Atmospheric CO_2

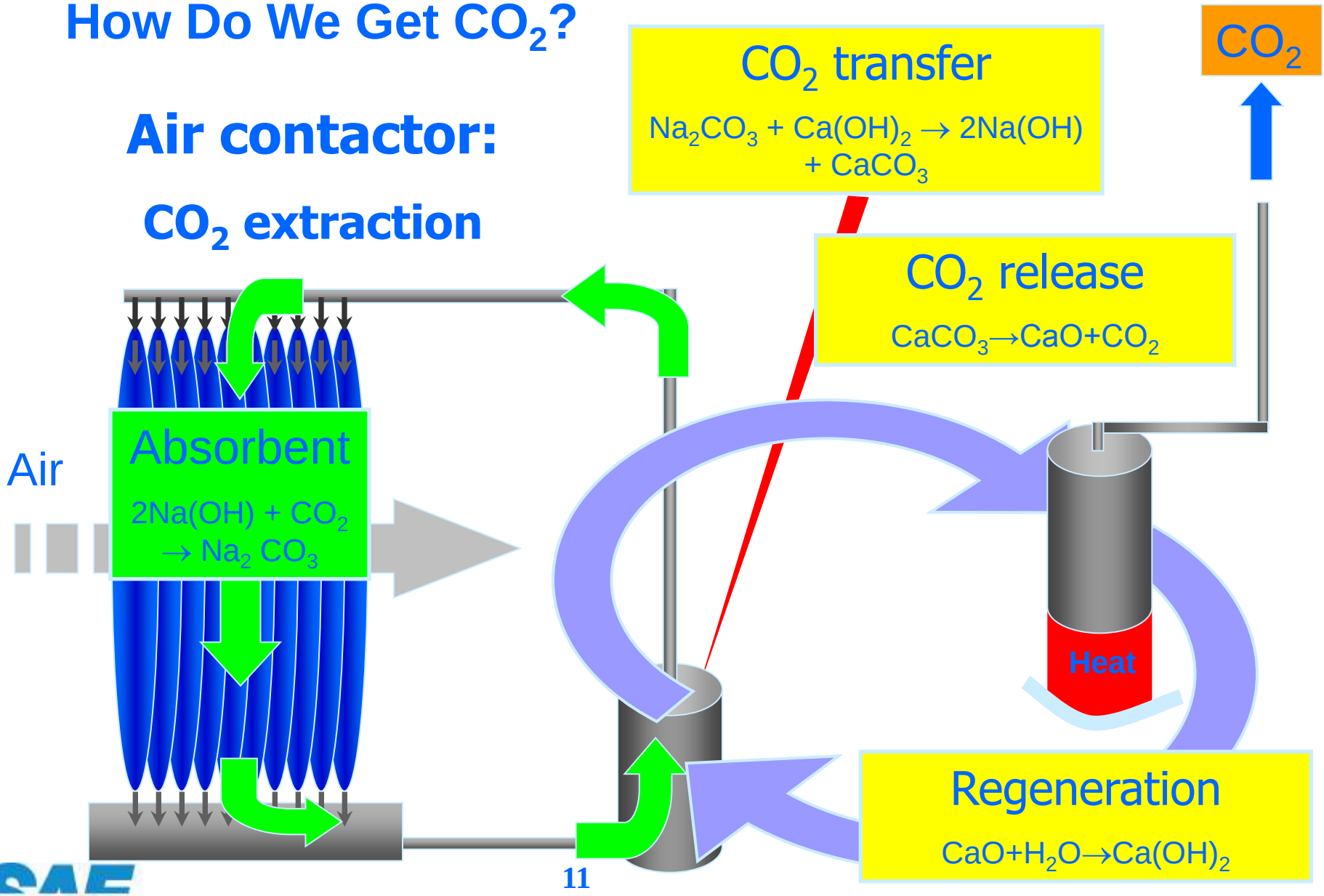
CO_2 emission

Adapted from Olah et al., *The Methanol Economy*

How Do We Get CO_2?

Air contactor:

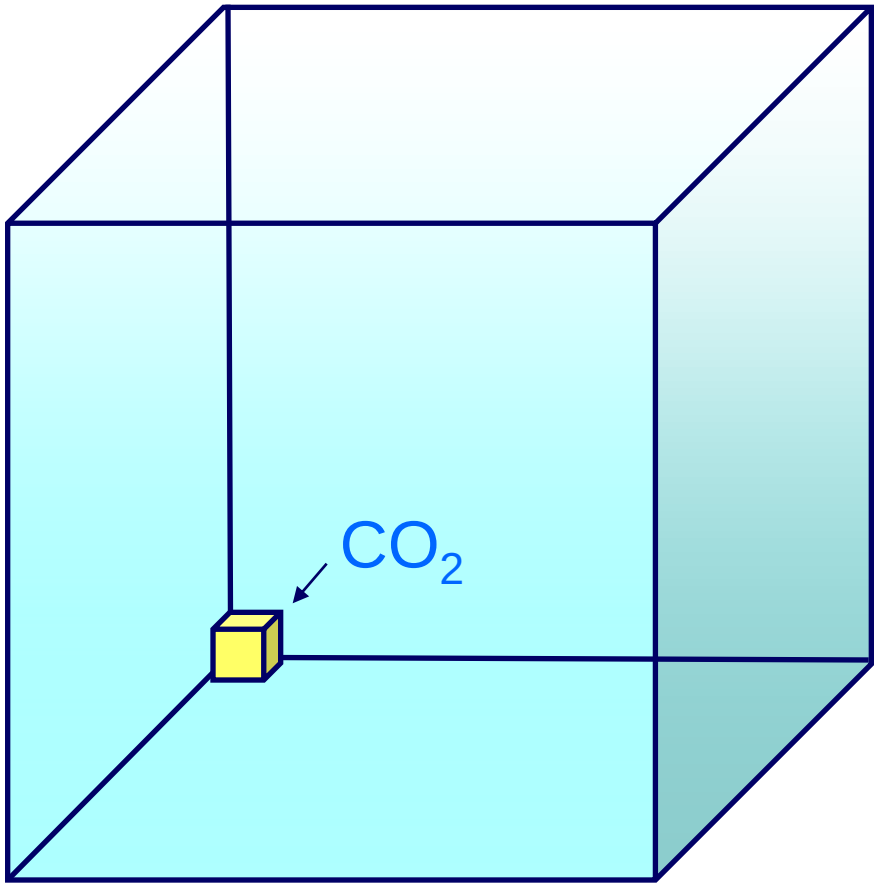
CO_2 extraction



Based on: Lackner, K.,'Options for Capturing Carbon Dioxide from the Air, May 2008'

How Much CO_2 is in the Atmosphere?

- 385 ppm = 0.0385%
- a small, but non-negligible amount!
- Synthesis of methanol from hydrogen and atmospheric CO_2 is happening **now**
  - in submarines!
  - Using Plant Flue Gas at Mitsui Chemical's Osaka Works



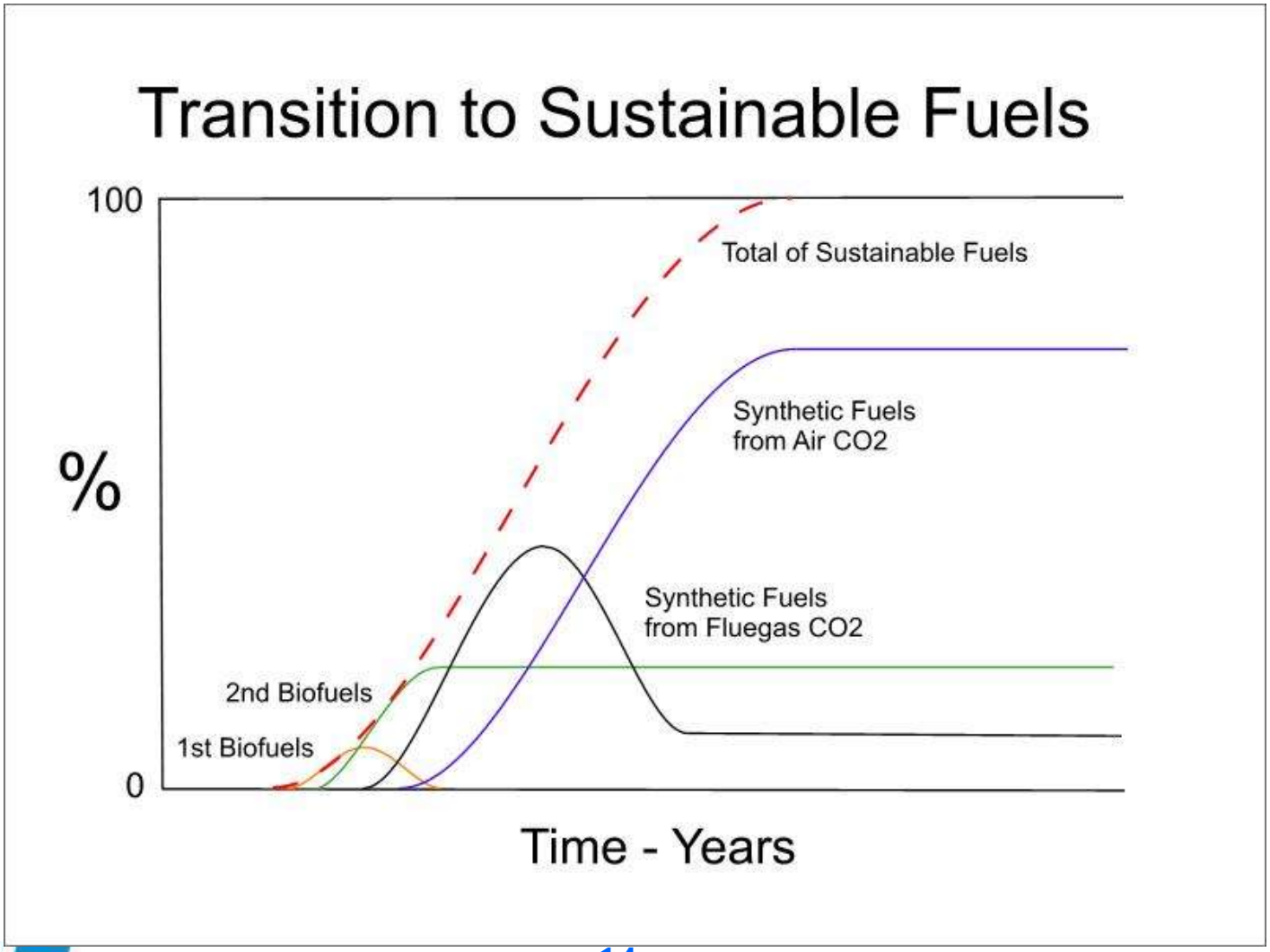
How Much Can We Get / What Might it Look Like?

- 60m x 50m collector can extract 3 kg CO_2 / sec.
- 90,000 tons / year
- equivalent to the fossil CO_2 produced by 4,000 people or 15,000 cars
- 250,000 units would process all anthropogenic CO_2 emissions
- Don't sequester the CO_2
- Use it as a feed stock.
- As part of a closed-carbon fuel cycle.

Source: Broecker, W.S.,'Global warming: take action or wait?'. Chinese Science Bulletin, 2006, vol. 51, no. 9, 1018-1029.

From: Lackner, K.,'Options for Capturing Carbon Dioxide from the Air'

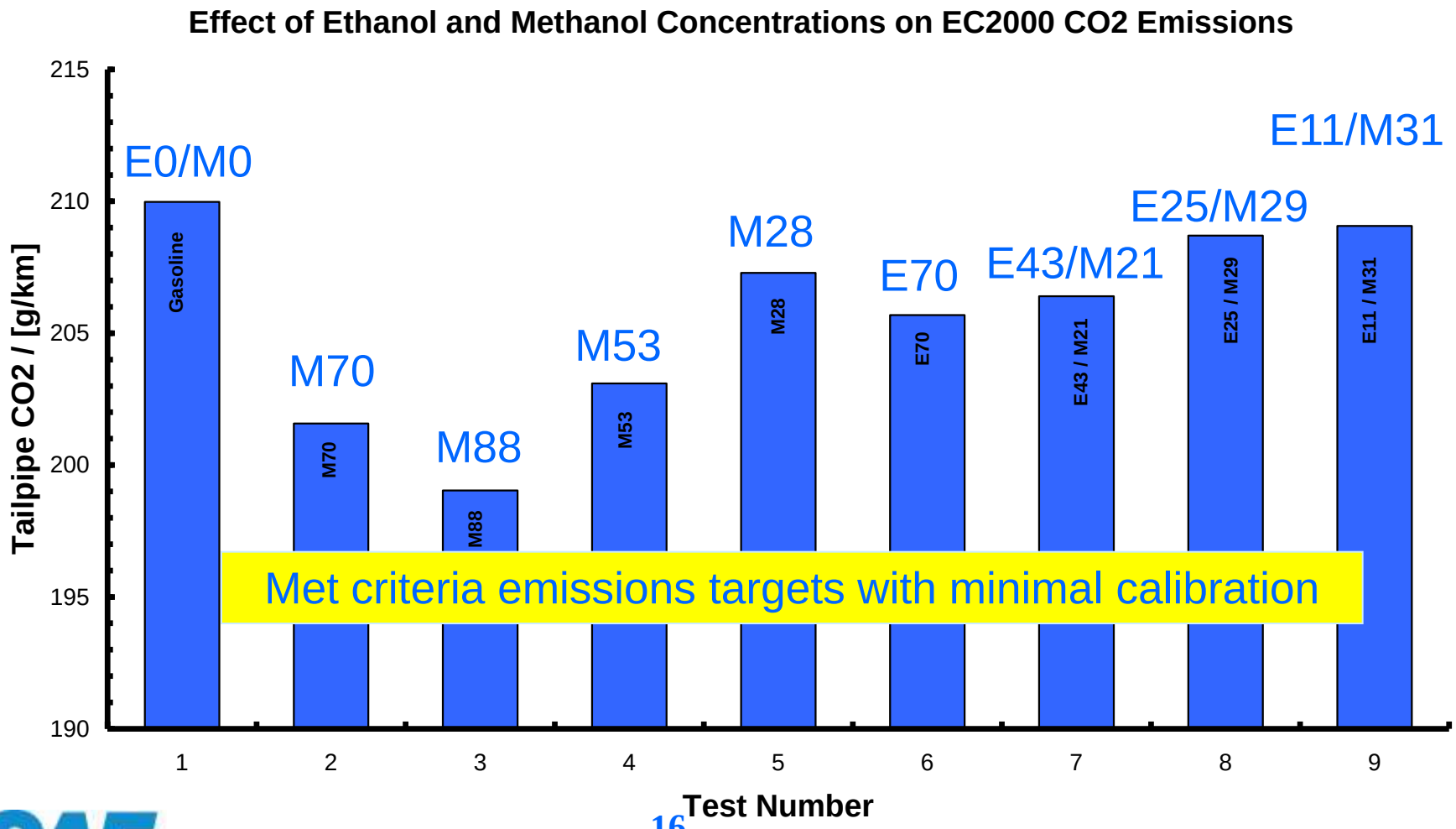
Transition to SOFT - Evolution Not Revolution



Vehicle Transition – Lotus Tri-Fuel Exige 270E

- Will run on any combination of gasoline, ethanol, and methanol.
- Achieves emissions compliance on all three fuels.

Lotus Exige 270E Tri-Flex-Fuel Development: CO_2



Leveraging the Stakeholder Capital

- Put the burden of producing affordable efficient vehicles on the vehicle manufacturers.
- Put the burden of de-carbonizing transport fuel on the upstream production and supply companies:
  - *this will always be profitable as demand is ever-present and growing;*
  - *$2.25 trillion spent on oil world-wide in 2007.*
  - *the average oil price over 2008 was $99.57 (EIA).*
- Cars are used 5% of their lifetime and are purchased with expensive capital.
- Customers have the option to defer new vehicle purchase.
- They cannot easily defer the purchase of the fuel!

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