UNIVERSITEIT GENT

FACULTY OF ENGINEERING AND ARCHITECTURE

Methanol as an engine fuel

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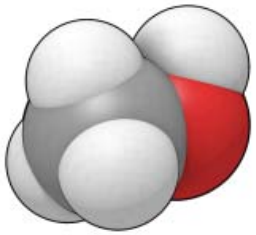


WHY METHANOL?

UGent ICE research focus: background

Starts from a vision on long term energy supply
and energy carrier for transportation

- Long term energy supply: selection of candidates based on

- **Sustainability**, of energy source and of harvesting technology (includes e.g. recyclability)

- **Scalability**, i.e. abundance of energy source, and of resources needed for building the harvesting technology

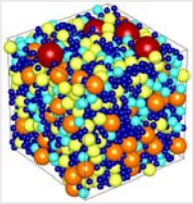
- Example: CSP (concentrated solar power) vs. PV

UGent ICE research focus: background

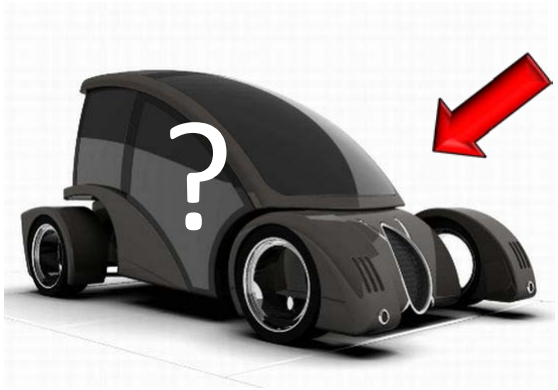
- Long term solution for transport?
  Options for energy carrier and powertrain?

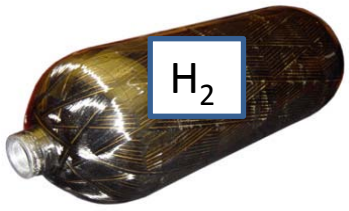
- **Sustainability**: closed cycle for energy carrier and powertrain materials

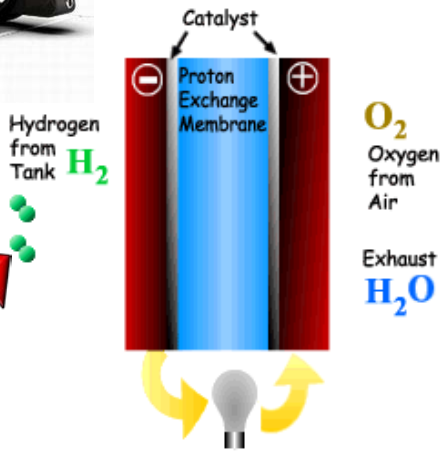
- **Scalability**: resources for energy carrier and powertrain

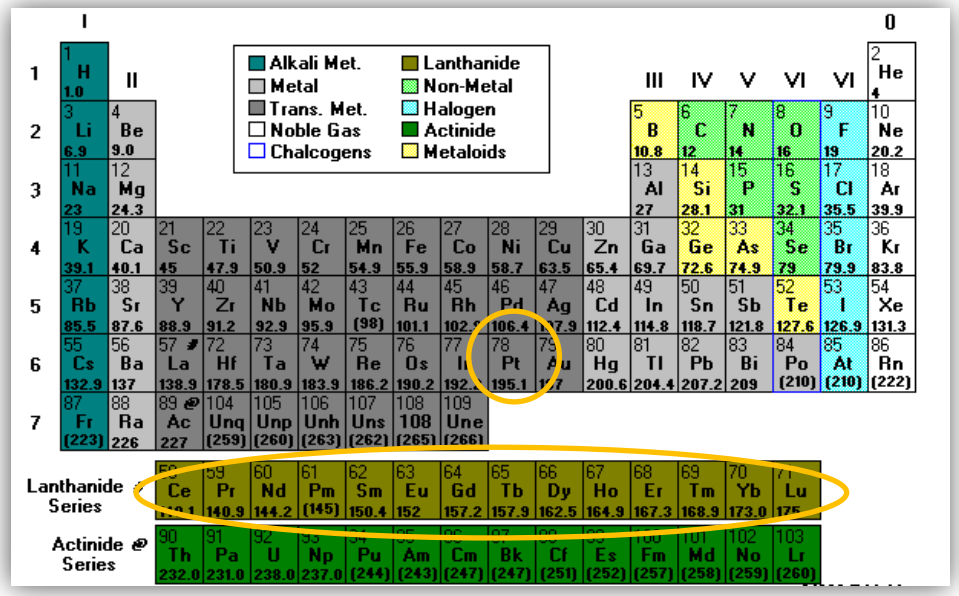


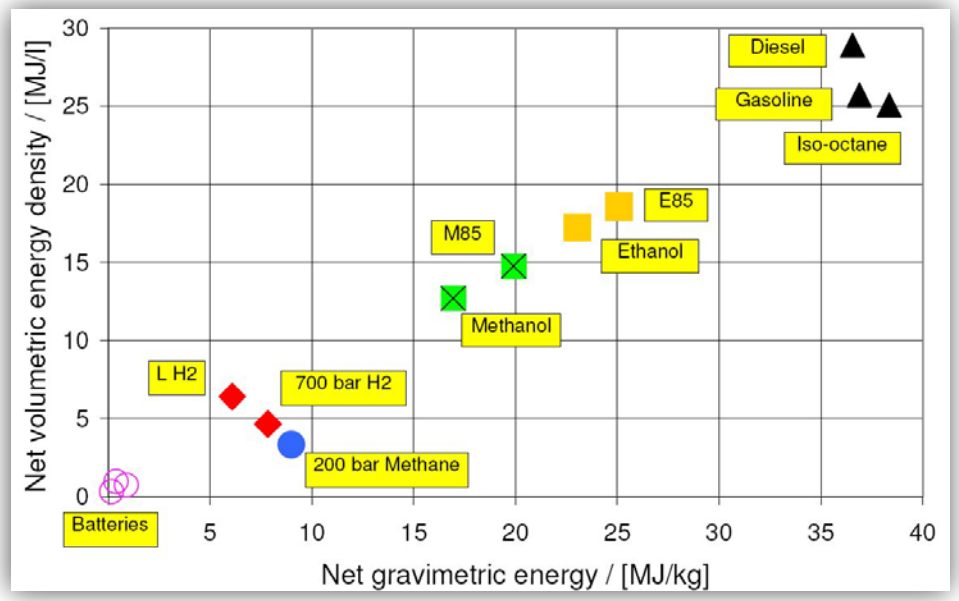
- **Compact**: need sufficient energy & power density


?


H_2


Catalyst
Proton Exchange Membrane
Hydrogen from Tank H_2
O_2 Oxygen from Air
Exhaust H_2O


Alkali Met.
Metal
Trans. Met.
Noble Gas
Chalcogens
Lanthanide
Non-Metal
Halogen
Actinide
Metaloids
Lanthanide Series
Actinide Series

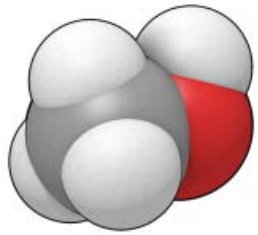

Net volumetric energy density / [MJ/l]
Net gravimetric energy / [MJ/kg]
Diesel
Gasoline
Iso-octane
E85
Ethanol
M85
Methanol
L H2
700 bar H2
200 bar Methane
Batteries

Truly sustainable transportation?

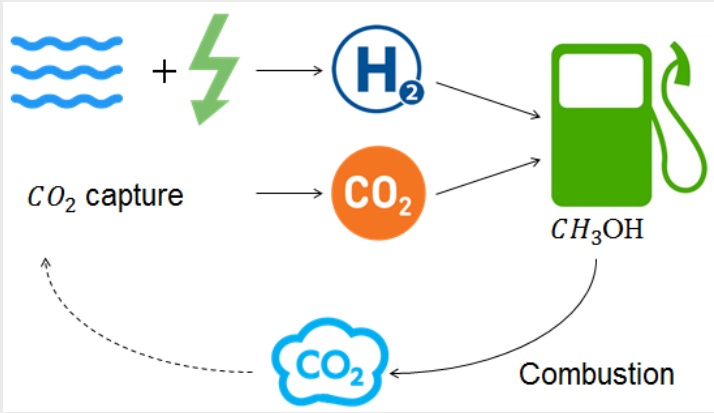
- Energy carrier: need for renewable (solar), **liquid** fuels
  - Efficient, so practical and cheap distribution and storage
- Powertrain: internal combustion engine
  - Cheap to produce
    - From abundantly available, recyclable materials
  - Fuel flexible
  - High power density
  - High ratio efficiency/cost
  - Still potential for efficiency improvement

Keep the engine, change the fuel

The case for methanol

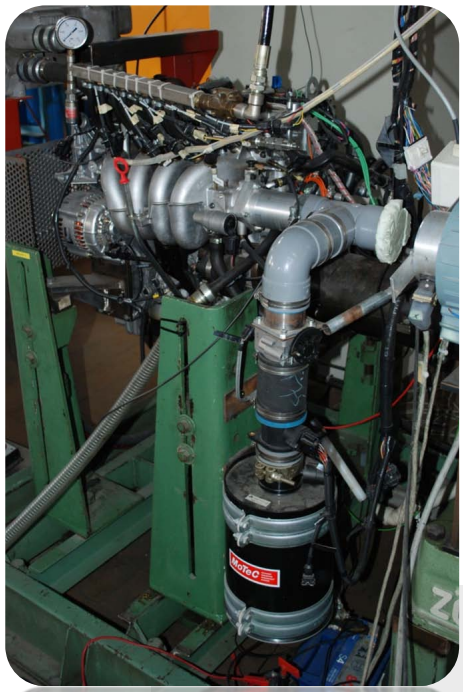
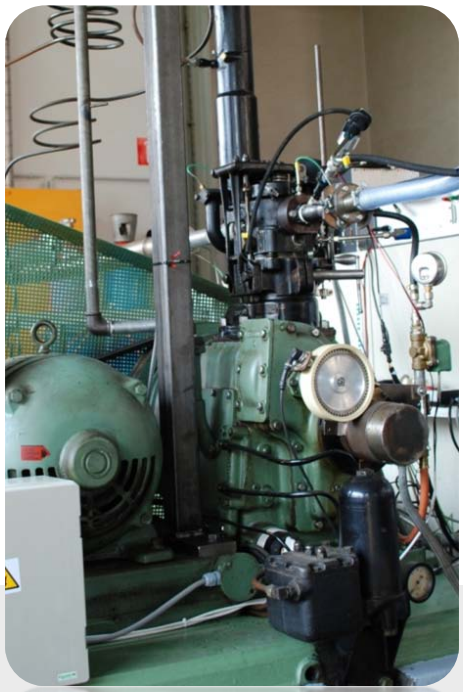


- Can be produced in different ways
  - Biomass, fossil fuels
  - *Synthesize using renewable energy:* $H_2 + CO/CO_2 \rightarrow CH_3OH$
- Liquid
  - Cheap tanks, cheap distribution
  - Miscible with gasoline and ethanol
  - *Evolution* of infrastructure possible



- Also building block for synthetic hydrocarbons (MTO)

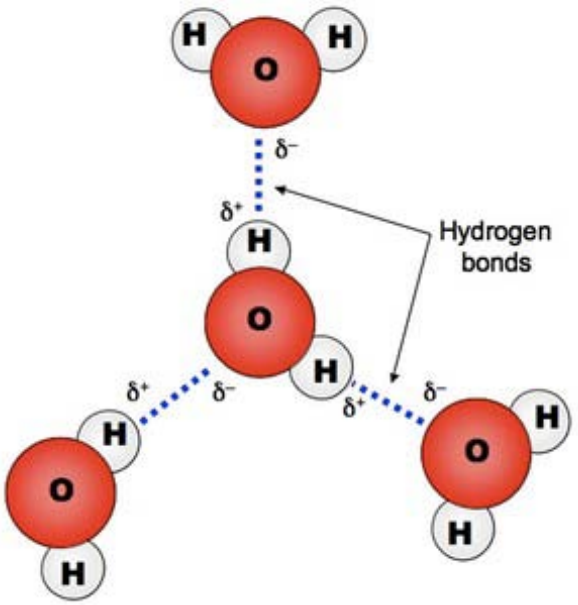
→ Has been a focus for UGent since 2009

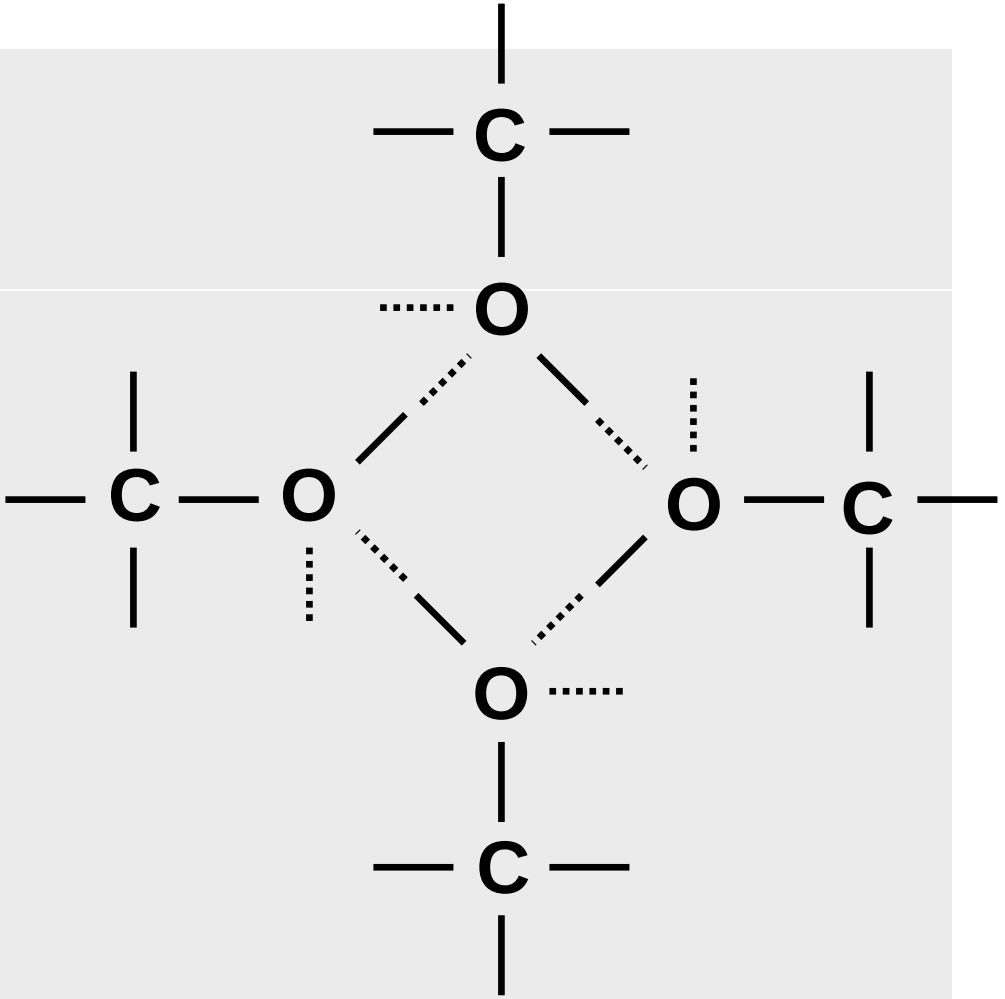
Ghent University engine tests

METHANOL ENGINE POTENTIAL

Water



Methanol



Like water, also polar.

Hence:

- High heat of vaporization
  - Great for engine efficiency, emissions and performance
  - But challenge for cold start
- Corrosive to some metals

Unlike water: it burns!

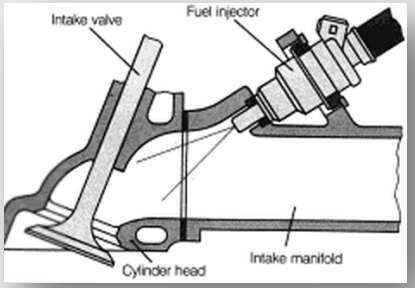
- Quickly → good for efficiency
- Even diluted → good for efficiency&emissions

Potential in “world standard gasoline engine”

I.e. gasoline engine using port fuel injection

UGent: converted 2 engines to allow operation on alcohols

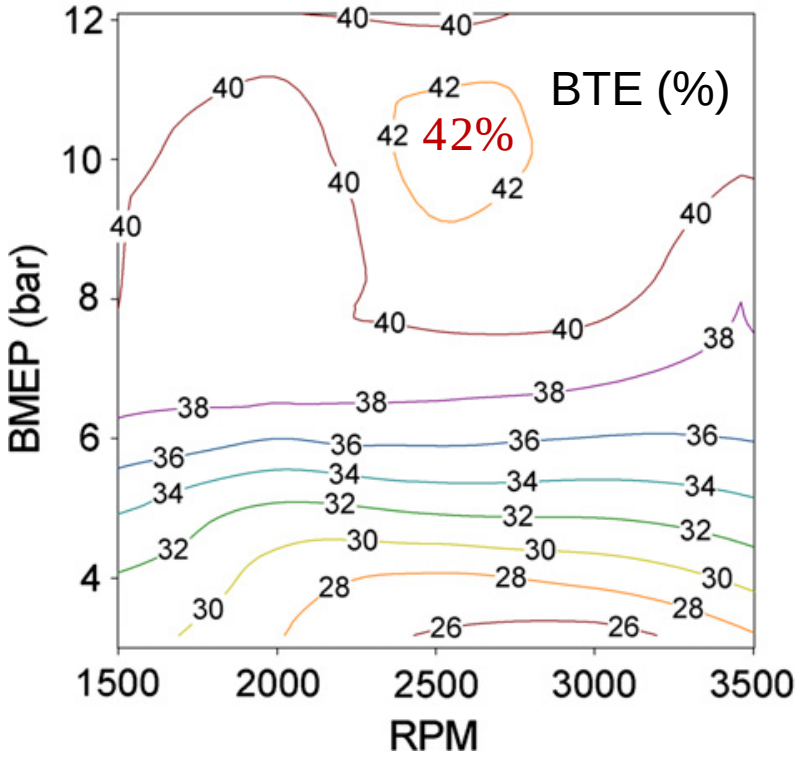
- With same operating strategy:
  - Relative efficiency benefits methanol vs. gasoline order of 10%
  - Reductions of engine-out NO_x levels of 5–10 g/kWh
- Alternative load control strategies (dilution)
  - Relative additional efficiency benefits of 5%
  - Also lower NO_x



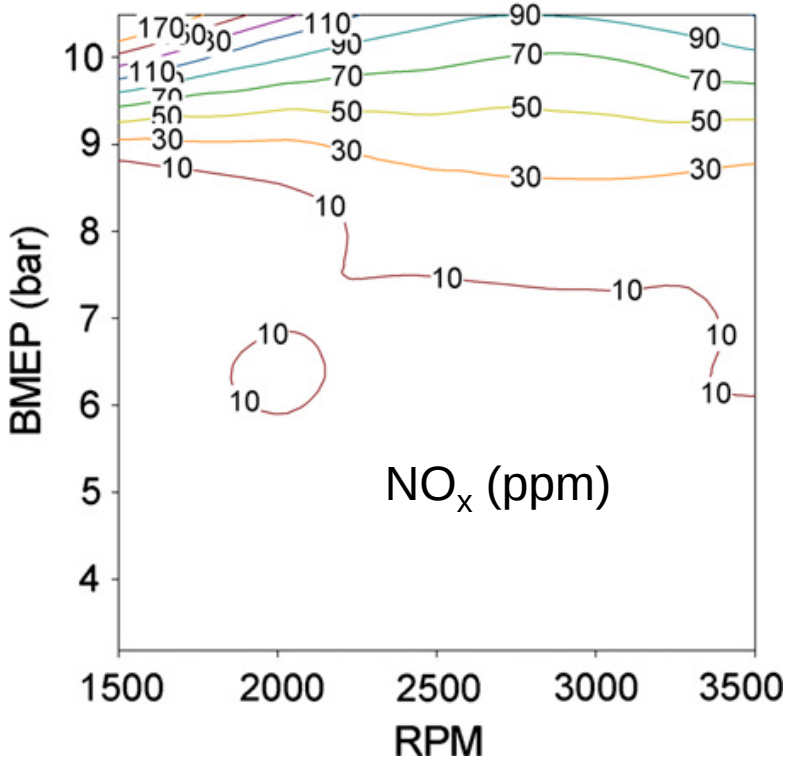
Potential in “dedicated engine”?

We have some idea…

- Converted a VW turbodiesel to methanol PFI spark-ignition operation
- Reproduced EPA work (Brusstar et al.) and expanded to lower loads
- Expected faster, more stable combustion
  - High CR, turbocharged
  - Hence, more dilution tolerance
  - Hence, lower in-cylinder temperatures
  - Hence, better efficiency, lower emissions



Diesel-like peak efficiency
Part load efficiency gains up to 20% (compared to throttled operation)

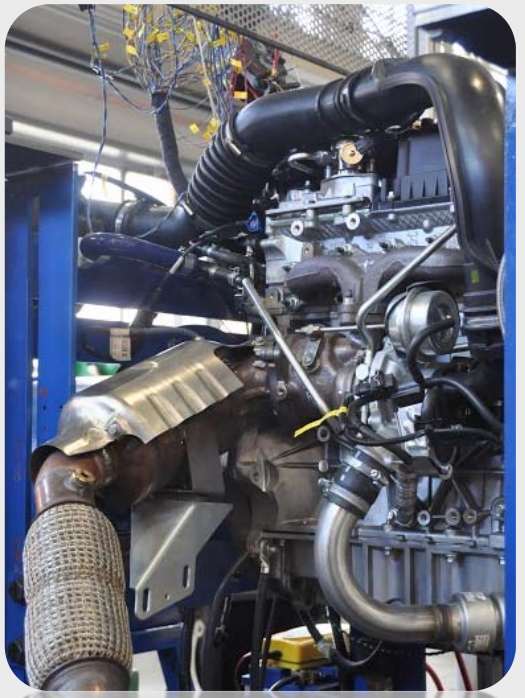


Vast engine-out NOx reductions (ppm)

Diesel-like efficiencies while using cheap aftertreatment systems

Potential in state-of-the-art gasoline engines

- Naturally aspirated Direct Injection (DI) engine Hyundai 2.4L at Argonne Nat. Lab
  - Tested methanol vs. gasoline +ethanol, butanol, E85, M56
  - Stock ECU – load limitations
  - Low-mid load: 2.7 %pt efficiency increase on methanol vs. gasoline
  - High load: 5.6 %pt (eff.=40%, i.e. -20% CO_2)
- Turbocharged DI: Volvo 1.6L “T3”
  - In progress… initial tests already showed up to 5 %pt higher efficiency (+18% relative), NO_x -35%

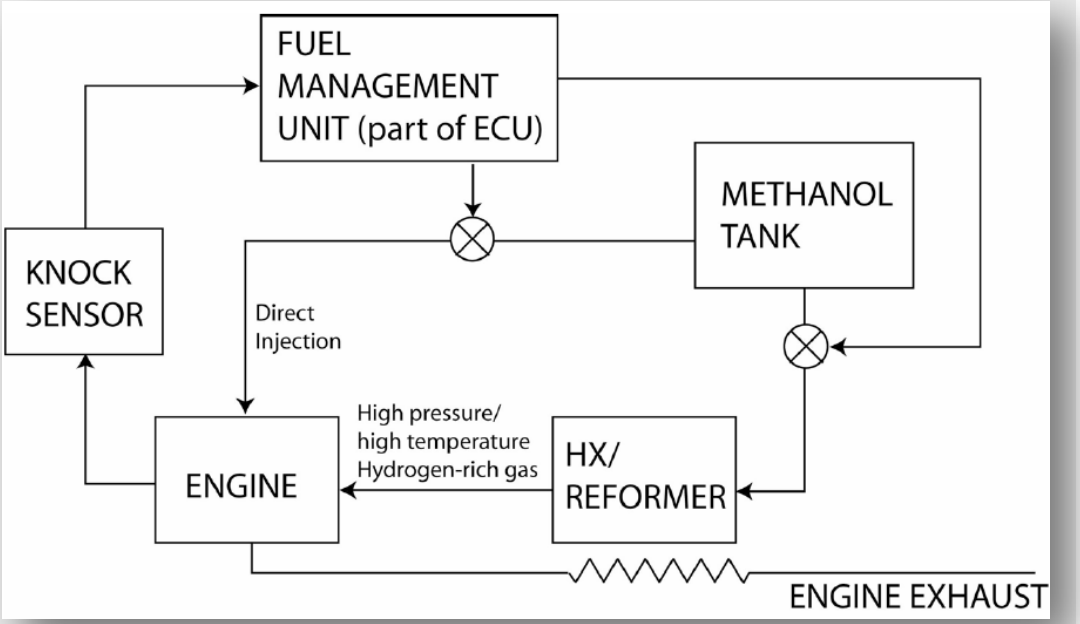


Outlook: fuel reforming using exhaust heat

Proposed by M.I.T.

- Methanol very suitable for exhaust energy recovery
- “potential engine efficiency ~ 55-60%”
- i.e. rivalling fuel cells

UGent PhD just started

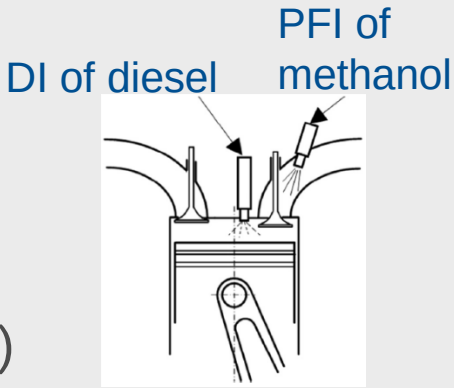


Ultra-High Efficiency Methanol Engines with Advanced Exhaust Energy Recovery, L Bromberg, K Cedrone, DR Cohn, 20th International Symposium on Alcohol Fuels (ISAF)

How about diesel?

LeanShips: Low Energy And Near to zero emissions Ships

- EU Horizon 2020 Mobility for Growth ‘innovation action’
- 46 partners, 8 demonstrator platforms
- UGent: WP05 leader “Demonstrating the potential of methanol as an alternative fuel” (6 partners)
  - Conversion of high speed marine diesel engine to dual fuel operation with methanol
  - LCA of methanol in shipping for 2 case studies
  - Tools for dissemination and market uptake (pilots)



Conclusions

- The case for methanol as energy carrier has been made
  - Produced in large quantities today
  - Can be produced from renewables – “electrofuel”
  - Liquid – easily&efficiently distributed&stored
  - …
- Additionally, methanol is a great engine fuel!
  - Not discussed yet: can be blended in – see Prof. Jamie Turner
  - Increased performance, increased efficiency, decreased emissions

Potential for the high efficiencies of diesel engines,
with the low emissions of gasoline engines,
and with greater performance than both!

Thank you for your attention!

& thanks to drs. Richard Pearson (ex-Lotus), Jamie Turner (U-Bath), Thomas Wallner (ANL), Jeroen Vancoillie (ex-UGent), Louis Sileghem (ex-UGent), …

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