FACULTY OF ENGINEERING AND ARCHITECTURE

SUSTAINABLE THERMO-FLUID ENERGY SYSTEMS RESEARCH GROUP – DEPARTMENT OF ELECTROMECHANICAL, SYSTEMS AND METAL ENGINEERING

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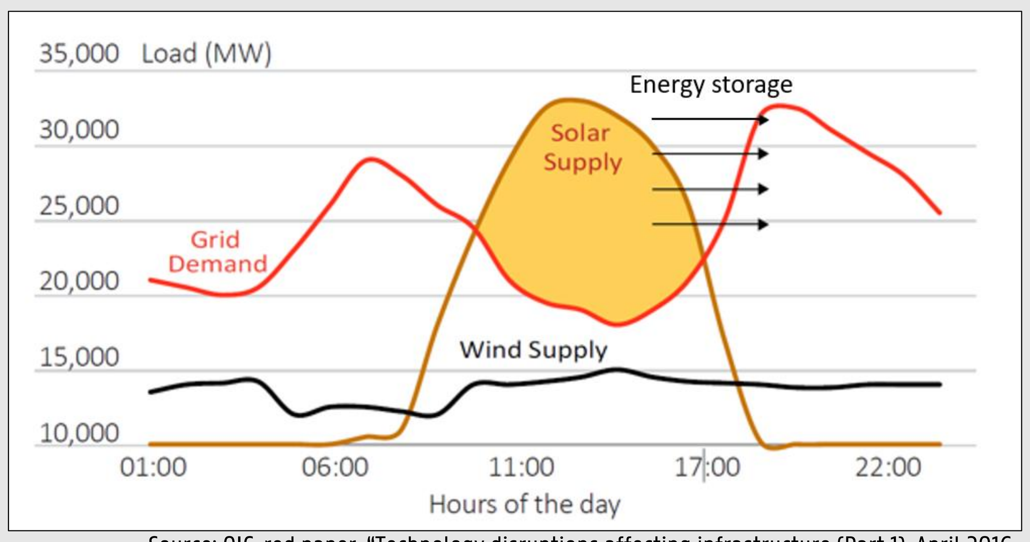
# EFFICIENCY POTENTIAL OF METHANOL FUELLED SPARK IGNITION ENGINES FOR GENSET APPLICATIONS

## Energy system transition

Global warming forces countries to increase their share of renewable electricity production at the cost of fossil fuel powered generators.

- The renewable energies must be able to meet the grid demand that fluctuates not only on a daily basis, but also on a monthly and yearly basis.
  → Flexibility of production is necessary
  → Big challenge given the intermittence of certain renewable energies dependent on hourly and seasonal weather conditions.

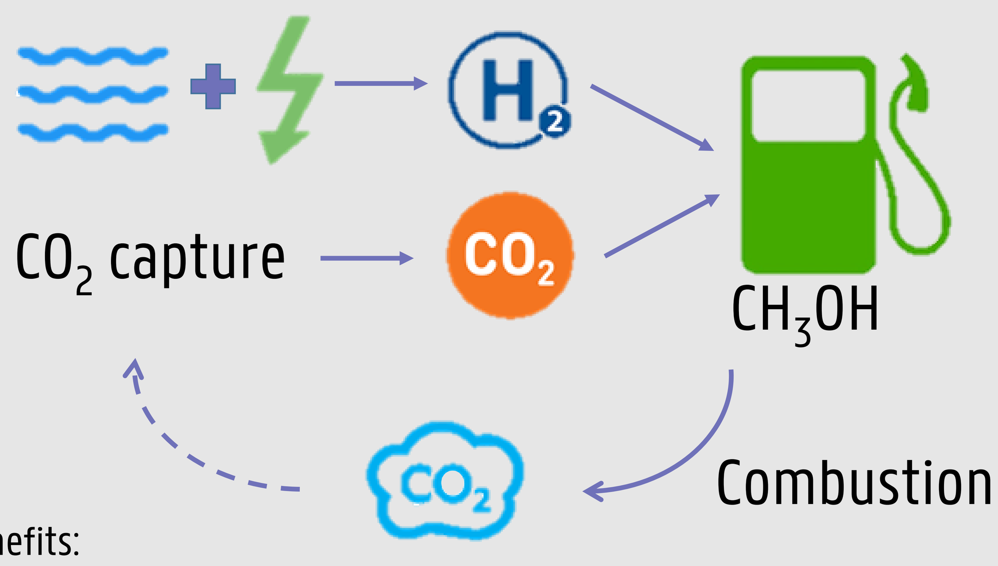



Source: QIC, red paper, "Technology disruptions affecting infrastructure (Part 1), April 2016

→ **Need for energy storage!**

## Chemical storage or "Power-to-Fuel"

Excess electricity in times of low grid demand is used to synthesize fuels which can then later be re-used in times of high grid demand. Methanol is the simplest type of synthetic fuel that is liquid at ambient pressure and temperature.



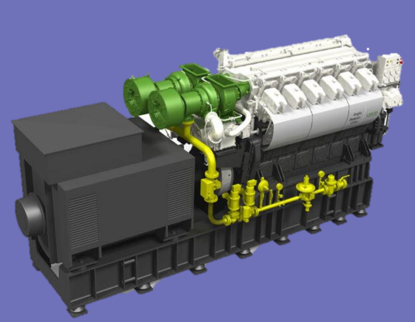

Benefits:

- Closed loop carbon cycle
- Long-term storage (seasonal fluctuations)
- High-capacity storage
- Low-cost upscaling possibility
- Easily imported/exported

## "Fuel-to-Power"

Use Internal Combustion Engine to convert this fuel back to electricity.

→ Fast start-up time
→ High modularity
→ High brake thermal efficiency
→ High power density
→ Fuel flexible



Methanol is an excellent candidate for high efficiency SI engines

- High Research Octane Number (RON)
- High Heat of Vaporization (HoV)
- High Laminar Burning Velocity (LBV)

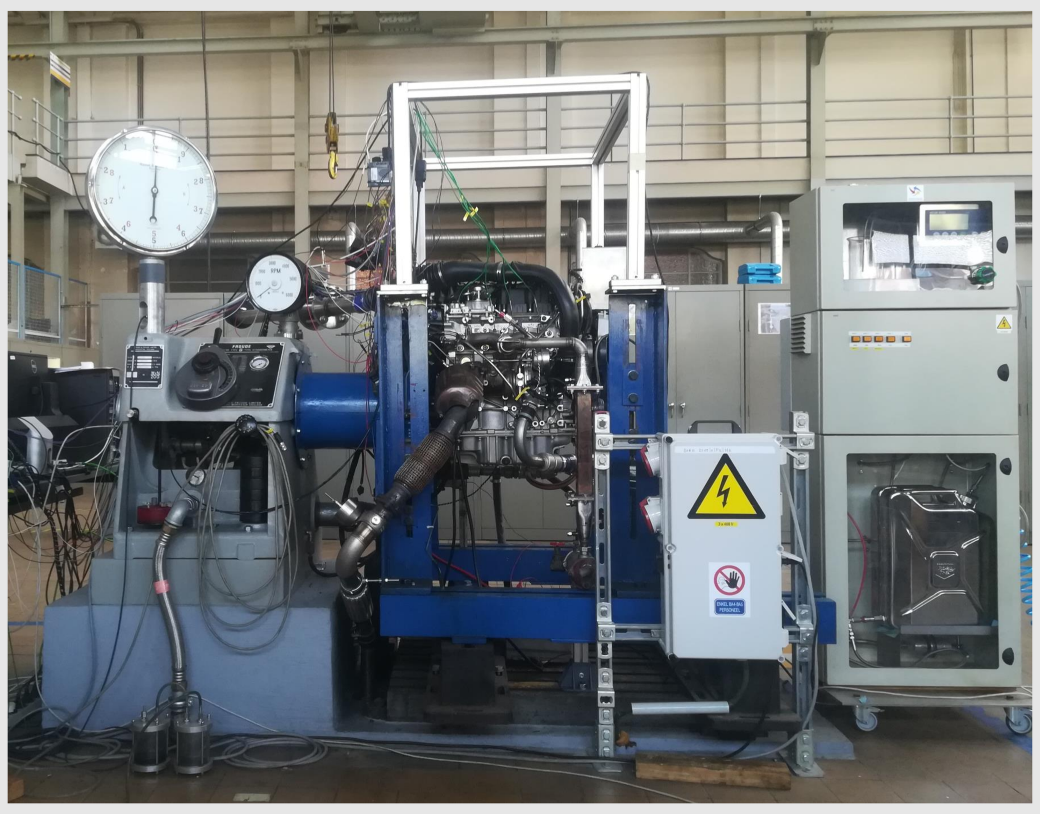
| Property | Gasoline | Ethanol | Methanol |
|---|---|---|---|
| Chemical formula | Various | $C_2H_5OH$ | **$CH_3OH$** |
| LHV (MJ/kg) | 42.74 | 26.95 | **20.09** |
| Specific $CO_2$ (g/MJ) | 73.95 | 71.22 | **68.75** |
| RON (-) | 97.1 | 109 | **109** |
| HoV (kJ/kg) | ~350 | 838 | **1100** |
| LBV at 358 K (cm/s) | 46 | 53.3 | **54.8** |

## Methanol Fuelled Spark Ignition Engines

**Research question: How efficient can we make a SI combustion engine run on methanol at full load?**

**Starting point: Volvo T3 engine**

- Swept volume: 1596 cm³
- CR 10:1
- Direct Injection Spark Ignited



This study analyses the effects of five control parameters on brake thermal efficiency and brake mean effective pressure for a fixed speed of 1700 rpm.

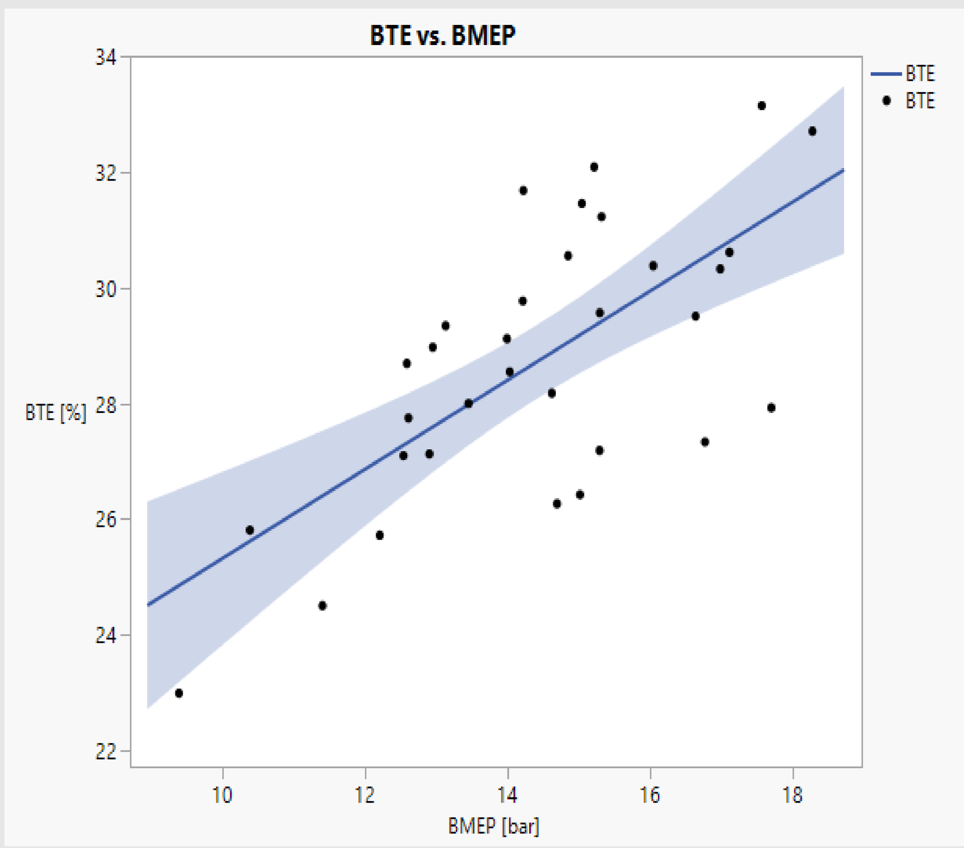
Control parameters:

- # Boost pressure
- Intake valve opening timing
- Exhaust valve opening timing
- EGR valve opening
- Backpressure valve opening

Box-Wilson (Central Composite) Design

| Design Variable | -2 | -1 | 0 | +1 | +2 |
|---|---|---|---|---|---|
| # Boost pressure [bar] | 0,34 | 0,405 | 0,47 | 0,535 | 0,6 |
| IVO [°ca aTDC] | -24 | -11,5 | 1 | 13,5 | 26 |
| EVO [°ca aBDC] | -14 | -2,75 | 8,5 | 19,75 | 31 |
| EGR valve opening [%] | 0 | 25 | 50 | 75 | 100 |
| Backpressure valve opening | 40° | 52,5° | 65° | 77,5° | 90° (WOT) |

Results




Conclusion

- Efficiency still increases with power and is limited by the excessive peak in-cylinder pressures at high load, being higher than 100 bar.
  → Thermodynamic limit of SI engines = "Knock" not reached yet for this engine.
  → Full potential still unknown
  → **Leave the "physical world" and enter the world of simulations!**

## Engine simulation using GT-Power

**Step 1) Set up a benchmark model of the Volvo T3 engine**

Include in-house models for alcohol fuelled engines;

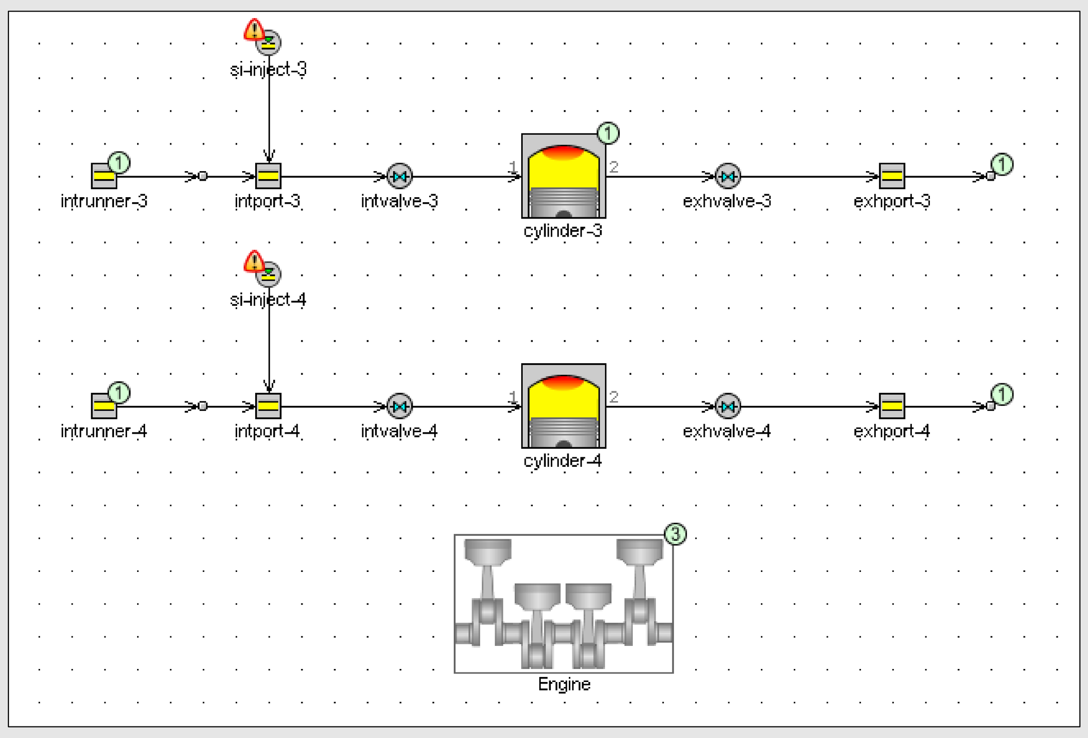
- Combustion model
- Knock model
- Heat transfer model

**Step 2) Validate the model with measurements**

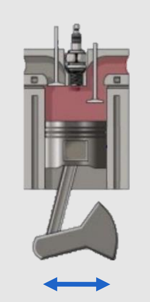
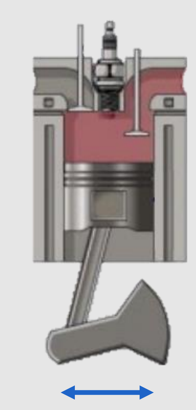
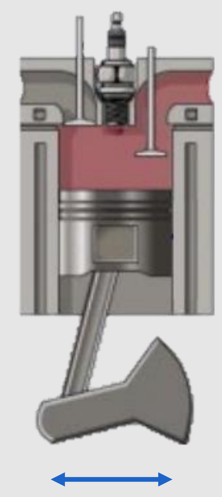
**Step 3) Upgrade the existing engine to reach higher peak efficiencies**

- Possible upgrades:
  - Peak pressure increase
  - CR increase
  - Water injection
  - Variable valve actuation

**Final step) Find the highest efficiency a 1.6L engine can reach**




## Scaling Laws

| | | |
|---|---|---|
|  B = 79mm |  B = 170mm |  B = 300mm |
| $\eta_{max} = 38\%$ | $\eta_{max} = 43\%$ | $\eta_{max} = 45\%$ |
| $@\ P = 54\ kW$ | $@\ P = 120\ kW$ | $@\ P = 600\ kW$ |
| Optimization parameters: | Optimization parameters: | Optimization parameters: |
| $A_1$ | $B_1$ | $C_1$ |
| $A_2$ | $B_2$ | $C_2$ |
| $A_3$ | $B_3$ | $C_3$ |
| $A_4$ | $B_4$ | $C_4$ |

Goal: Investigate and quantify common terms

→ Set up scaling laws
→ **How big can we go?**

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