How can alcohols contribute to a fossil-independent non road machinery fleet?

Goal: The project will document the conditions under which alcohol fuels for non road machinery have the greatest potential to contribute to the transition to a fossil-free society. The project shall document estimated values (means and spread) for the following variables, and describe how sensitive the results are for assumed external factors:

- **Cost per kWh fuel** per year. Both total cost and divided per the stakeholder. The financial conditions from “well to wheel” will be penetrated and reported.
- **Environmental impact per kWh of fuel**. The environmental impact is calculated primarily for the climate impact expressed as CO_2 equivalents, but also other variables can be included.
- **Performance for variables that are difficult to describe in monetary terms** (e.g., driveability and local environmental impact)

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Swedish Energy Agency

THE SWEDISH KNOWLEDGE CENTRE FOR RENEWABLE TRANSPORTATION FUELS

Background

- Work vehicles, such as tractors and wheel loaders use ~14 TWh of fossil fuel annually.
- Fossil Diesel dominate
- Many alternatives to fossil fuels - Biogas and biodiesels have been extensively studied, alcohols less so (in this context)
- Consequences (econ., env.) of introducing alcohols as fuel for work machines
- Will study driving forces and restrictions on the way towards broader establishment.

Scenarios

- Production
  - **Fossil Diesel** and **Biodiesel** (HVO) from Preem's refinery in Gothenburg
  - Södra's pulp mill in Mönsterås, **methanol** from forestry
  - Agroetanol's plant in Norrköping, **ethanol** from agriculture
  - SEKAB's plant in Domsjö, **ethanol** from forestry

- Use
  - Agriculture:
    - Skara, Västra götaland county. Rationale: The county with the most agricultural companies
    - Tractor 75 – 130 kW
  - Forestry:
    - Skellefteå, Västerbotten county. Rationale: The land (Norrland) with the biggest forest production
    - Forwarder 75 – 130 kW (10-15 ton)
  - Construction:
    - Södertälje i Stockholm county. Rationale: The county with the most sold "yellow machines"
    - Wheel loader, 75 - 130 kW (8-10 ton)

Powertrains

- Used in a Diesel engine
  - As an additive to Diesel
  - Used in a ”dual fuel” configuration, where (fossil/bio) diesel initiate combustion, whilst the alcohols supply most of the energy. Different engine (need to handle two fuels etc.)
  - As a main component, with added ignition improver, MD95/ED95. Different engine (built based on the alcohols)
- As M85/E85 in a motor run according to the Otto cycle
- Not yet commercial engine concepts (PPC, HCCI)
- Fuel cells

Human toxicity

- Direct consumption
  - Methanol can cause acidos, damage eye sight and the central nerve system.
  - Can be lethal at fairly low concentrations (30 ml). So can Diesel
- Chronic exposure
  - Methanol not known to be cancerogenic or teratogenic.
- Vapour
  - Vapour limits are lower for methanol (200 pm) and higher for ethanol (1 000 ppm) compared to petrol (300 ppm)
  - Self contained breathing apparatus should be used at fires
- El
  - Alcohols conduct current → risk for electric shocks if fuel in contact with electric current

Ecotoxicity

- Soluble in water.
- Decomposes rapidly in soil, groundwater and surface water
- Degradation consumes oxygen if available. May lead to oxygen deficiency.
- Methanol and ethanol are not considered toxic in themselves to aquatic animals and plants
- If ethanol is included in a mixture with gasoline (such as E85) it can help to reduce the viscosity of the gasoline and thus help to spread it more easily.

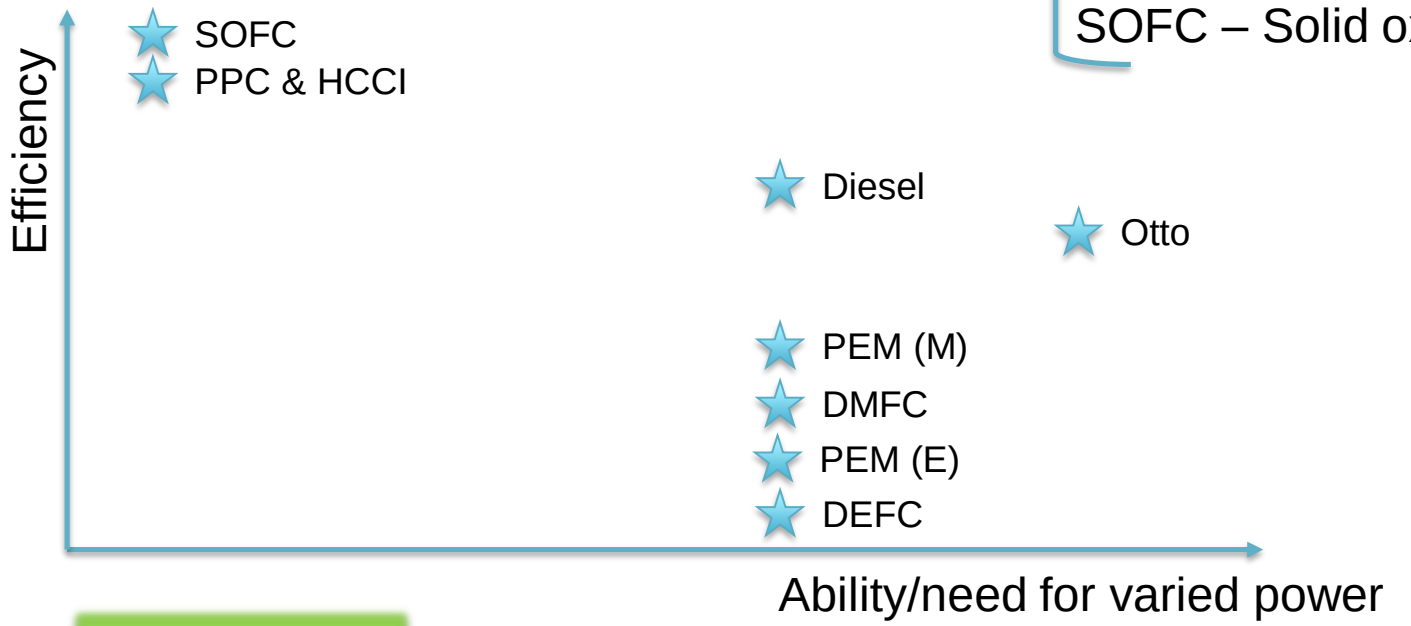
Risk assessment

- Methanol and ethanol are commonly used chemicals, with identified risks and well established practices for how to handle them
- However, when used as a fuel in new sectors that experience does not exist at an individual level
- It is therefore crucial with efficient information dispersal of how to handle alcohols, and in which respects they differ from Diesel
- Handling culture needs to be adopted
- Some risks can be reduced by using additives (denaturation, colouring) to reduce risks

Use & powertrains

Combustion engine
- Diesel – Diesel cycle
- Otto – Otto cycle
- PPC – Partially premixed combustion
- HCCI – Homogenous charge compression ignition

Fuel cells
- PEM – PEM fuel cell
- DMFC/DEFC – Direct (methanol/ethanol) fuel cells
- SOFC – Solid oxide fuel cells



Tractor, plowing

Wheel load, loading

Harvester, loading

Three cases used arbetsplatser och förutsättningar

Sector / Machine	Case no	Local tank volume	kWh/h	Power, KW
Forestry/ Forwarder	#1, small scale	333/450 L	91	75-130
Agriculture/Tractor	#2, medium scale	10 000 L	78	75-130
Construction/Wheel loader	#3, large scale	32 000 L	116	75-130

Tabell 1. Data från Christian Wetterberg et al, Utsläpp från större dieseldrivna arbetsmaskiner, Rapport – miljö, teknik och lantbruk 2007:03

Typical case 1 is relatively small-scale and can suit forestry where the contractor takes fuel on his pickup out to his machine in the forest. Obtaining fuel from the **farm cistern** or **fuel station**. But it may also suit a smaller contract but also agriculture. For transport to the workplace, own transport capacity is used in the form of pick-up / pickup truck. Refuelling in fields from **450 liters** diesel tank for HVO or **333 liters** tank for ED / MD 95

Typical case 2 is meant to suit small construction as well as agriculture. From the fuel manufacturer, the propellant is transported to larger buffer depots in the field or directly to the permanently established **farm tank** containing **10 0000 liters**.

Typical case 3 is intended to be suitable for larger construction and a larger agricultural sector. Buffer depot and **temporary refuelling point** in the form of a tanker trailer or container-based filling station that holds 27,000 - 33,000 liters, 32000L

Sveriges första mobila tankstation för fossilfritt bränsle, HVO100, finns vid Ebbepark i Linköping. Foto: Ann-Louise Larsson

Foto Magnus Persson Malte Fuel & Wash AB

1. Small scale

2. Medium scale

3. Large scale

Persson f.N.B. AB

Economical parameters:

- **Interest:** 5 %
- **Depreciation time:**12 years for cisterns, 5 years for other equipment
- **Maintenance**: Diesel / HVO 1,5 %; Alcohols 2 % of investment cost

Assumptions

- Transportation:
  - For transport to cisterns of 15 m^3, the freight in Central Sweden (Skara / Södertälje) is about 0.30 SEK / liter and in the north as Skellefteå about 0.65 SEK / liter. For small-scale pickup transports, no charge is included
- Storage:
  - Small scale, 450/330 L Price 31 000/120 000 SEK (Diesel / Alcohols)
  - Medium scale, 10 000 L Price ~300 000 / 357 000 SEK
  - Large scale, 32 000 L Price [redacted] / 505 000 SEK
- Emergency Rescue Service (example):
  - Basic fee 3 000 SEK plus case handling about 8 hours x SEK 910
- Tank Inspection (example):
  - 10 kbm 11,740 SEK and 32 kbm 17 130 SEK at a time.

Forwarder

2 shift = 14 h / day

	Diesel	HVO	Methanol	Ethanol
Days per tank	3.7	3.4	1.3	1.7

Agricultural tractor

8.33 h / day

	Diesel	HVO	Methanol	Ethanol
Days per tank	239	220	116	151

Wheel loader

	Diesel	HVO	Methanol	Ethanol
Days per tank	407	375	198	257

Post production costs

	Diesel	HVO	Ethanol	Methanol	
Small scale					
Forwarder, SEK / kWh	0,02	0,02	0,05	0,06	231 645 kWh/y
Tractor, SEK / kWh	0,10	0,10	0,31	0,41	38 991 kWh/y
Wheel loader, SEK / kWh	0,02	0,02	0,07	0,10	162 892 kWh/y
Medium scale					
Forwarder, SEK / kWh	0,04	0,04	0,13	0,18	
Tractor, SEK / kWh	0,29	0,29	0,90	1,20	
Wheel loader, SEK / kWh	0,07	0,07	0,22	0,29	
Large scale					
Forwarder, SEK / kWh	0,06	0,06	0,19	0,25	
Tractor, SEK / kWh	0,41	0,41	1,28	1,70	
Wheel loader, SEK / kWh	0,10	0,10	0,31	0,41	

LCA

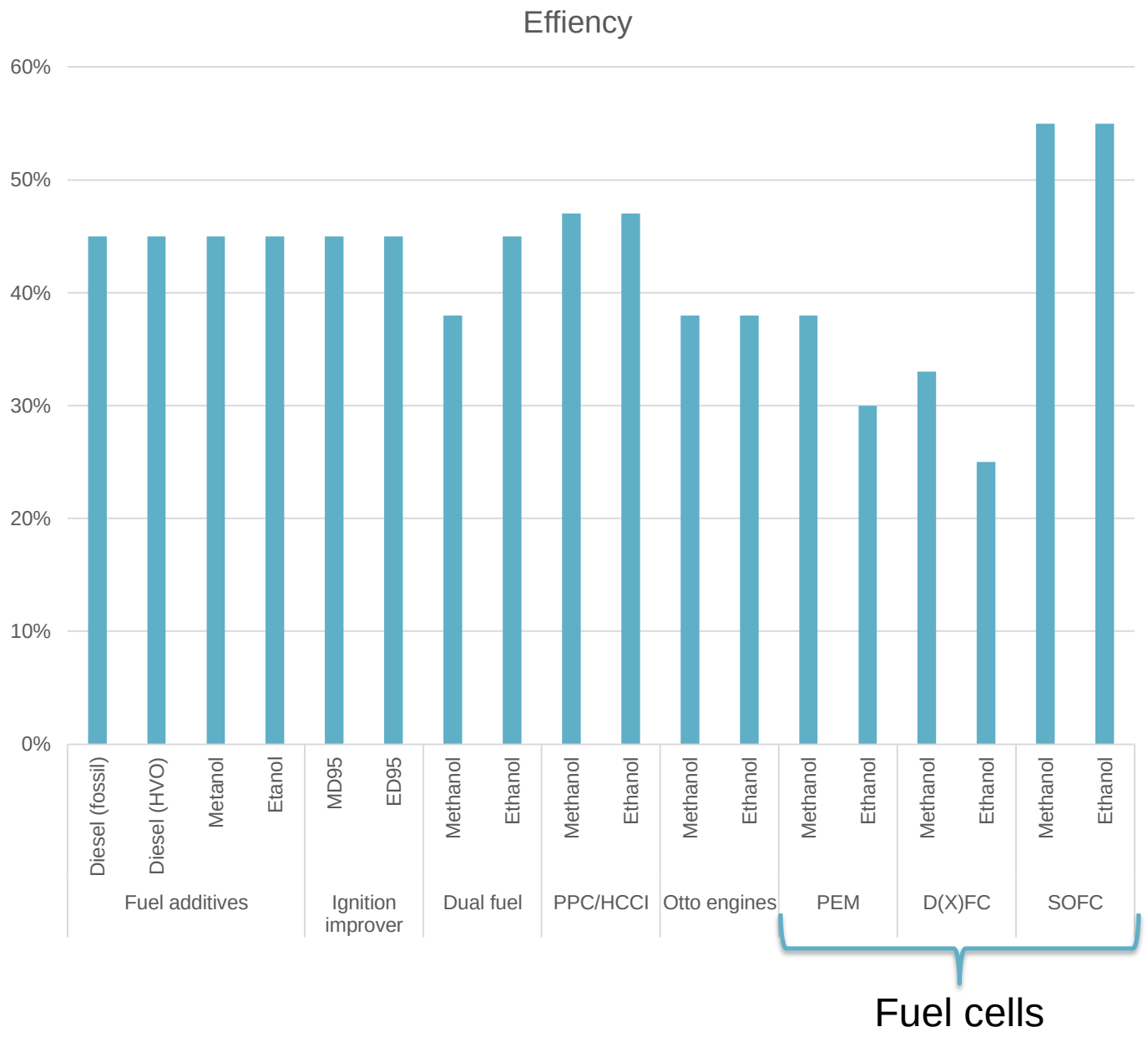
- Functional unit 1 kWh out of engine
- Type of LCA Allocation
- Allocation Energy
- Delsystem
  - Production
  - Distribution
  - Powertrain components
  - Use

Climate impact

Dominated by

1. the fossil intensity of the production
2. the thermal efficiency in engine

Fuel distribution & vehicle components of less importance



Conclusions (i)

- Commonly used chemicals, with identified risks and well established practices
- But important to put in education efforts to highlight characteristics that differ from Diesel’s.
- Limited impact of fuel spills.
- Fire risks comparable to petrol, but higher than Diesel. Small fires (~vehicle) relatively easier to handle, large fires relatively harder to handle
- Fuel mixtures might pose bigger risks than pure fuels

Conclusions (ii)

- Alcohols likely to work better with high local consumption
  - Added costs spread over more fuel consumption kWh
  - Same/similar environmental benefit
  - Fuel use in the highest in forestry, might be the sector where it is easiest & most useful to introduce