"SAME DEUTZ-FAHR VISION AND EXPERIENCE WITH PURE (100%) - ESTERIFIED (RME/FAME) AND NON-ESTERIFIED (RSO), VEGETABLE DIESELFUELS FOR AGRICULTURAL TRACTORS".

Hannover , November 14th, 2011

SAME DEUTZ-FAHR

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INDEX

- **INTRODUCTION _** ***Biodiesel used***
- **RME _** ***B100 project (since 2007 above 90 Kw)***
- **RSO _** ***100 tractor program (April 2001 – October 2005)***
- **RSO _** ***- Natural power Deutz-Fahr project (2007 – 2009)***
- **CONCLUSION _**

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INTRODUCTION *- Biodiesel*

INTRODUCTION - *Biodiesel*

1st GENERATION BIODIESEL:

- Biodiesel that can count on food crops <u>as commodities.</u>

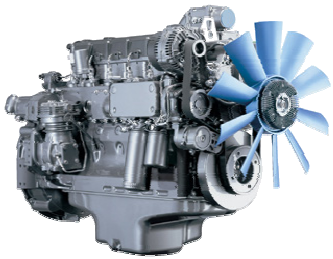
RAPESEED
2,5 – 3 ton/ha of seed
(European average)

Pure rape seed oil *(RSO)*
~1 ton/ha
(European average)

STANDARDS

- RME according with EN14214.
- RSO according with DIN V51605.

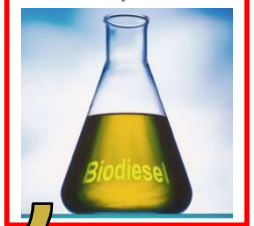
Directly



Transesterifacation chemical process

100% RSO
+
13% Methanol
+
1,5% NaOH

Glycerine
+



RME
~1 ton/ha
(European average)

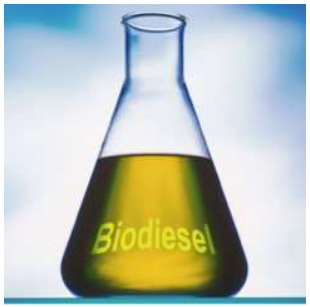
Directly

INTRODUCTION - *Biodiesel*

1st GENERATION BIODIESEL:

- **Biodiesel that can count on food crops <u>as feedstock.</u>**

RME production



1 ton/ha

Agricultural diesel consumption (*)

2 Mton/year (ITALY)

10'000'000 ha cultivated/year

<u>(only for agricultural needs)</u>

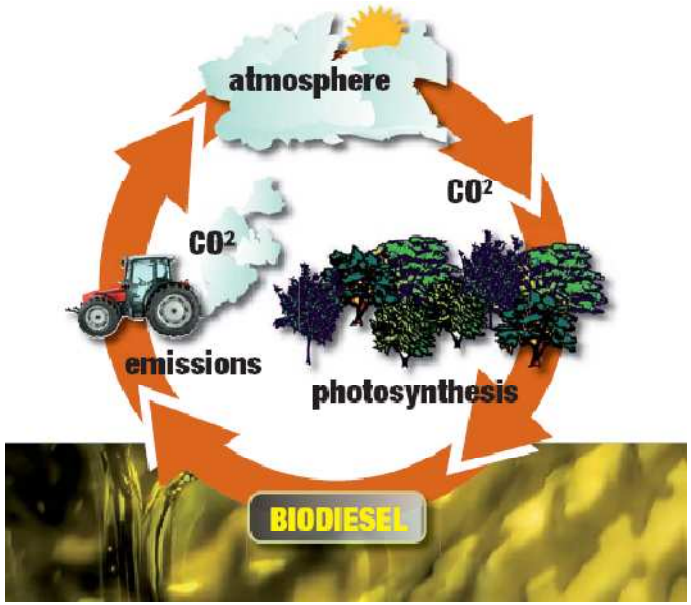
~ 20/30% of the agricultural land allocated only to the cereals cultivation (ITALY)!(**)

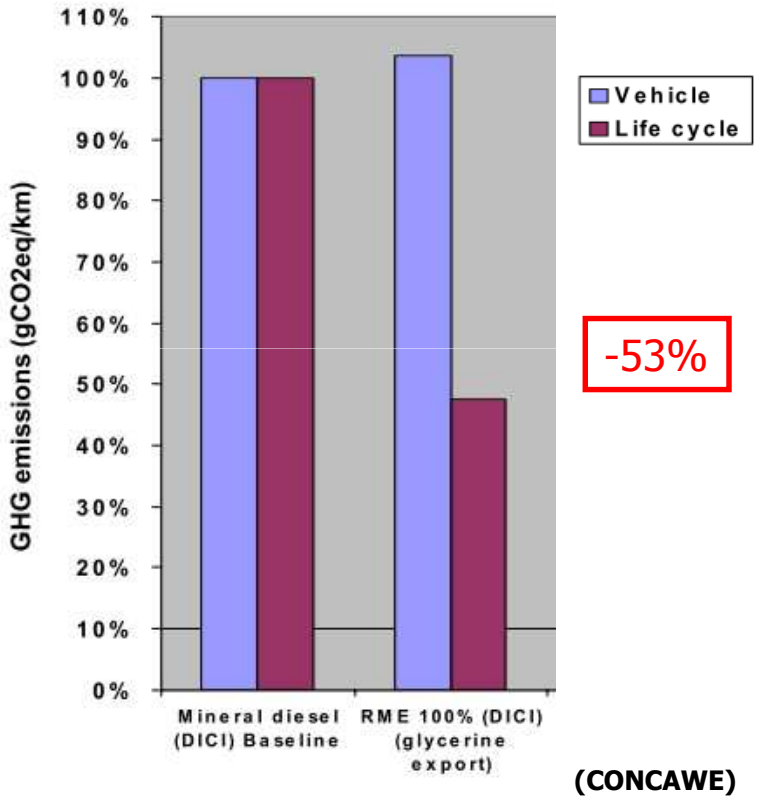
(*) Extimations based on 2003 not complete data. (ENAMA)
(**) Extimations based on 2003-2010 data. (ISTAT)

INTRODUCTION - *Biodiesel*

1st GENERATION BIODIESEL: CO_2 balance

- Biodiesel reduces the dipendence on traditional fuel & is a clean and ecological fuel.
- Life cycle from 'Cradle to Grave'.





(CONCAWE)

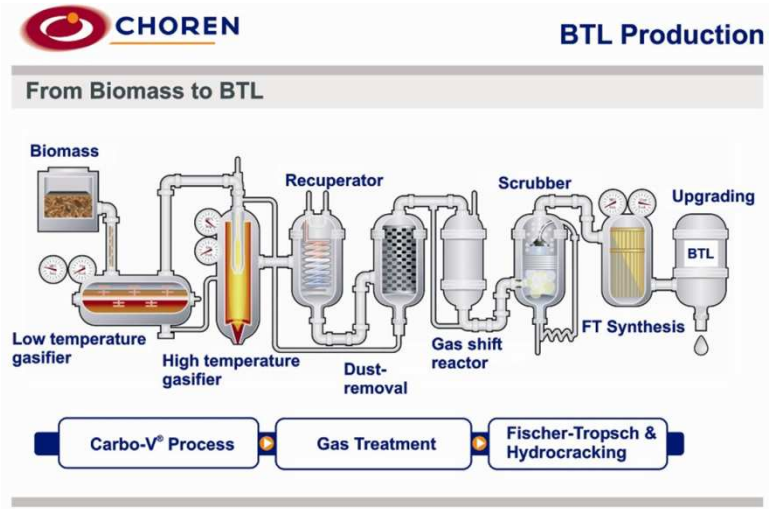
INTRODUCTION - *Biodiesel*

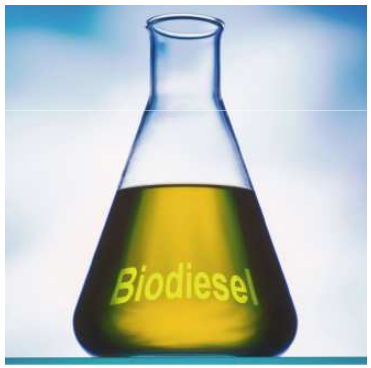
2nd GENERATION BIODIESEL:

- Biodiesel that is produced from biomass agricultural or forest residues → no interference on food chain.

High amount of residues worldwide

Fischer-Tropsch synthesis

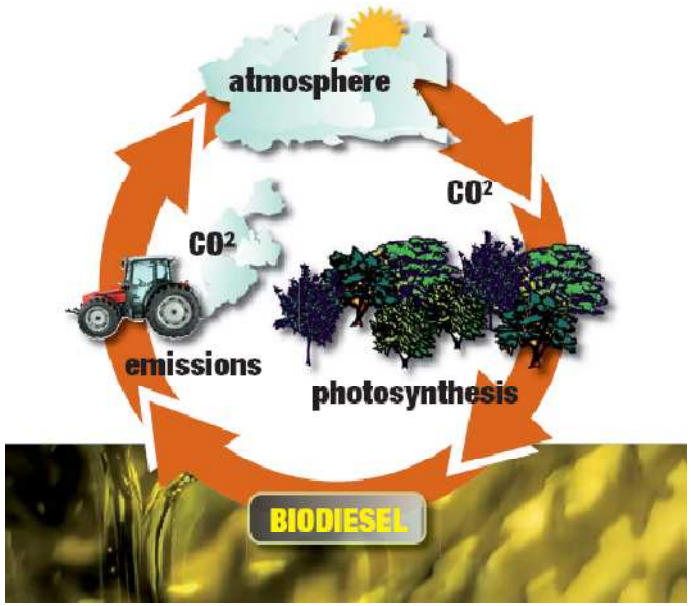


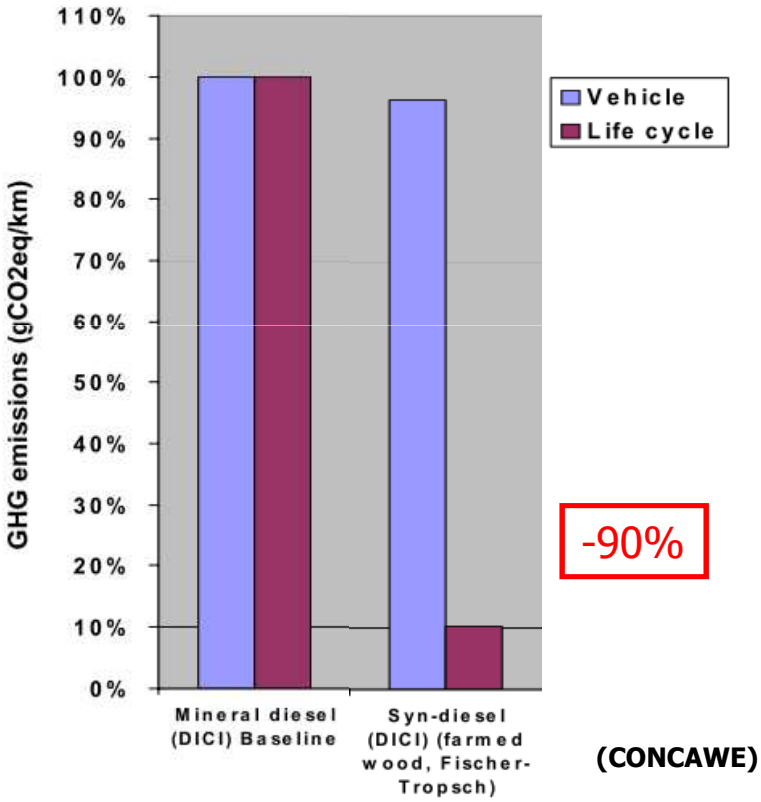


INTRODUCTION - *Biodiesel*

2nd GENERATION BIODIESEL: CO_2 balance

- 2nd generation biodiesel has 90% likely reduction on GHG emission (Life cycle from 'Cradle to Grave').





(CONCAWE)

INTRODUCTION - *Biodiesel*

PHYSICAL – CHEMICAL PROPERTIES

		DIESEL	RME	CRUDE OIL (RSO)
Density	kg/m^3	820 - 845	860 - 890	900 - 930
Viscosity (@40°C)	mm^2/s	2 - 4,5	3,5 - 5	34 - 36
Lower calorific value	kJ/kg	42860	37200	37500
Cetane n°		51 - 55	54 - 58	40 - 42
Carbon content	$\%_{weight}$	0,01	0,05	0,15 - 0,4
Boiling temperature	°C	180	220 - 300	250 - 300

STANDARDS

- RME according with EN14214.
- RSO according with DIN V51605.

Considerations on RSO properties (as fuel)

- Lack of evaporability.
- Very high viscosity: poor air/fuel mixture formation.
- Poor ignition quality due to a low cetane n°.
- Potential RSO deterioration during storage (oxidation).

GLOSSARY

- FAME: **F**atty **A**cid **M**ethyl **E**ster.
- RME: **R**apeseed **M**ethyl **E**ster.
- RSO: **R**ape**S**eed **O**il (Crude oil).
- BTL: **B**iomass **T**o **L**iquid.

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RME *B100 project (above 90kW)*

RME *B100 project (above 90Kw)*

Tractor features :

- **All engines from Deutz-AG Stage 3a released for RME (B100) in according with EN 14214.**
- **All SDF tractors above 90 kW (from 2008) are in RME-resisting materials (engine and fuel circuit).**
- **More than 10 tractors were tested for more than 1000 hours.**

RME advantages:

- **Useable in all normal ambient conditions due to characteristics close to standard fuels.**
- **Lower emissions (HC, CO, PM, CO_2 ['Life cycle'])**

RME *B100 project (above 90Kw)*

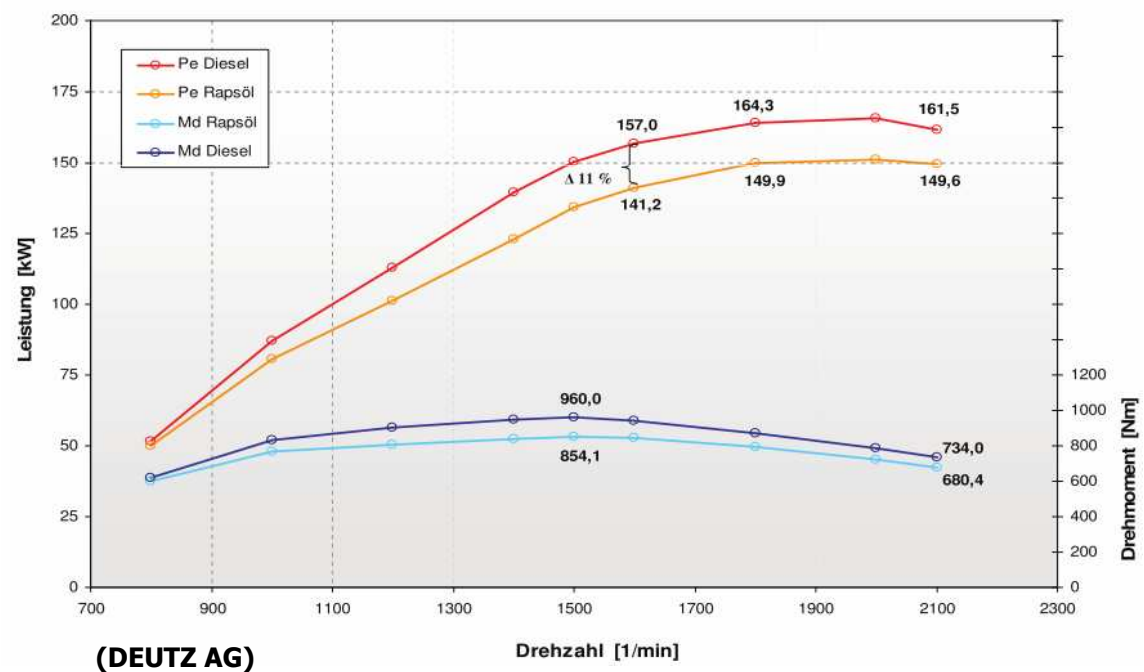
Emission level Standard Diesel Fuel (EN 590) vs RME (EN 14214)

BIODIESEL vs MINERAL DIESEL	
NO_x	+15%
HC	-80%
CO	-40%
PM	-40%
SO_2	-99%
Smoke	-70%

RME *B100 project (above 90Kw)*

Disadvantages:

- Higher consumption (~5%).
- Lower max. available Power (~10%).
- Aggressivity against other components (expecially against painting).
- Reduced service-levels (from 500Bh reduction to 250Bh).



(DEUTZ AG)

Engine performances

Damaged standard injector

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RSO *- 100 tractors program*

'100 tractors program' - University of Rostock

Generals:

- OEM's weren't official partners of this program.
- '100 tractors program' started in April 2001 and ended in October 2005.
- Tractors of different brands were part of this program (→ 42 Deutz-Fahr).
- Tractors used in this program have had emission-stage 2.
- Different fuel circuit layouts were used:
  - **1-tank-system**: only crude-oil was used in all ambient-conditions (major part of fleet).
  - **2-tank-system**: crude-oil was used only in warm-conditions, in cold-conditions diesel-oil was used.

    Simple control-logics of the systems (i.e: temperature-based ON/OFF system on 2-tank-system).

'100 tractors program' - University of Rostock

Advantages:

- Very low costs of Rape-oil-fuel (no taxes of government).
- Very low costs of investment to modify tractor (especially with 1-tank-system).
- Very low CO_2 emmission.
- Very good behaviour in terms of enviromental pollution :
  - PM: -40%
  - No_x: +5%
  - HC: -60%
  - SO_2: -99%

Notes:

- 100% practical test-conditions at real customers.
- Monitoring done by University of Rostock.
- In this period the use of Rape-oil was a sort of mainstream.

'100 tractors program' - University of Rostock

Disadvantages:

- **Variable quality of fuel (no norming was present).**

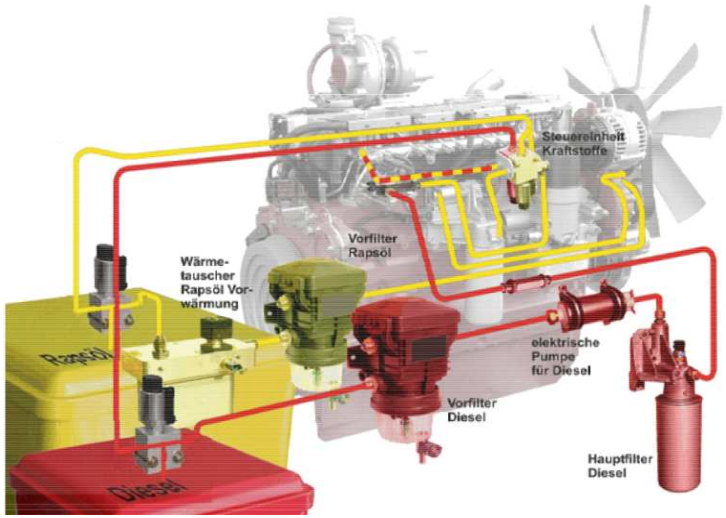
- **1-tank-system: at cold ambient temperatures it was necessary to drive a mixture of diesel/rape-oil and heat up the rape-oil with heating device in the tank.**
- **2-tank-system: at cold ambient temperatures it was hard to reach switching-temperatures for rape-oil-use and therefore very limited working-hours because of small diesel-quantity.**

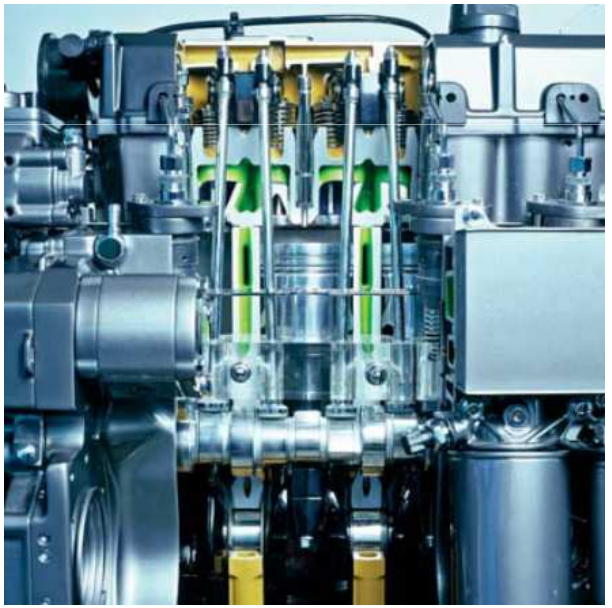
- **Partially high contamination of lubrication-oil with rape-oil. Result was in some cases fatal engine-damage because of no lubrication.Reduce service oil intervals is needed.**
- **Risk of engine-damages was much higher than with diesel-fuel (especially for injection-systems) due to RSO higher viscosity and T_{boil} .**

‘100 tractors program’ - University of Rostock

Results for further developments:

- 1-tank-system not reliable system due to high oil contamination
- 2-tank-system better option
- 4-valve-engines with higher reliability because of central injection





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RSO - *Natural power Deutz-Fahr project*

SDF-Tractor Natural Power (130kW – 180HP)

Production of 10 tractors (from 2008).

RSO *Natural power Deutz-Fahr*

Main features:

- Based on engine TCD 2012 6.0L of Deutz-AG with 4-Valve-technology and Emmission-Stage 3a.
- 2-tank-system.
- Shifting-logic of Deutz AG based on temperatures and engine-load:
  - Temperature of Rape-oil is between 62-75°C.
  - Engine-Load higher than ~30%.

Notes:

- Development together with Deutz-AG.
- After SOP of tractors, costs of rape-oil increased remarkable (new taxes on Rape-oil-fuel).

SDF-Tractor Natural Power – How does it work?

'ENGINE LOGIC' management

START – UP:

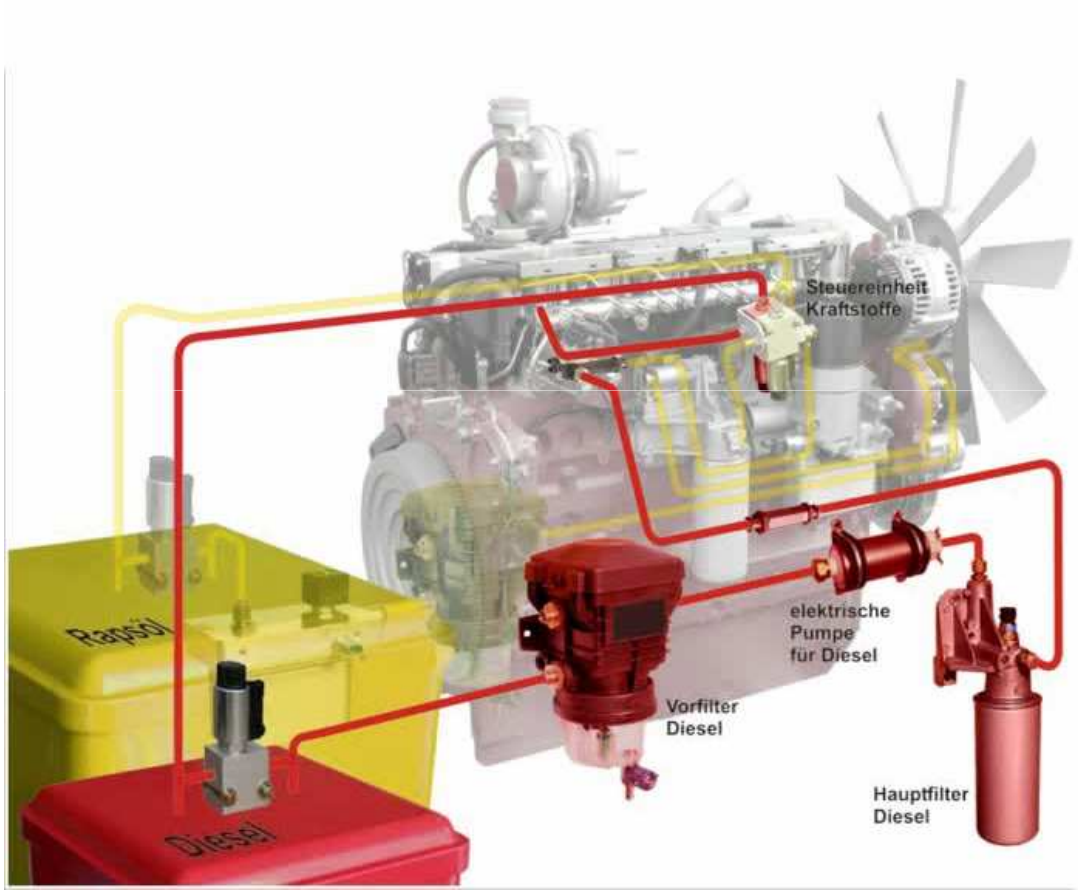
Always using mineral diesel.

IF:
engine load is ~ 30%
&
temperature of pre-heated RSO is > 62°C

Automatic switching to RSO (100%).

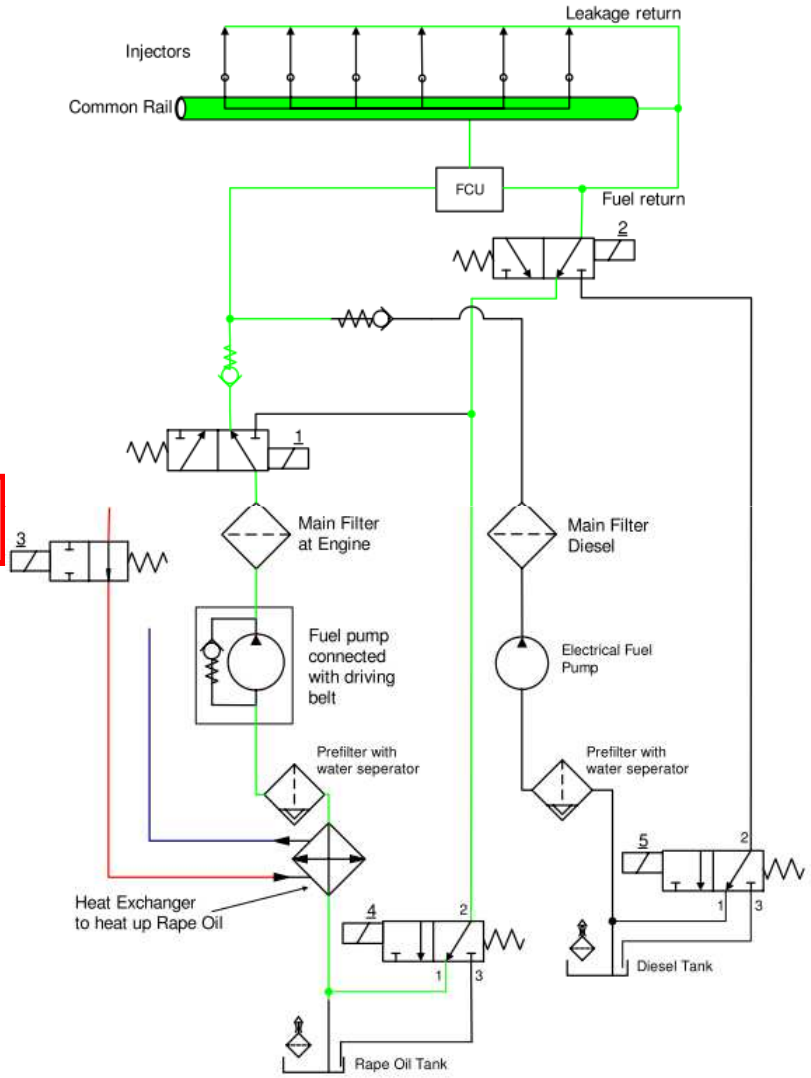
SHUT – DOWN:

Automatic switching from RSO to mineral diesel. (*)



(*) In order to clean injector and engine from RSO residual.

2-tank-system (Technical layout)



SDF-Tractor Natural Power

Advantages:

- **Fully integrated system.**
- **Low contamination of lubrication-oil.**
- **Low contamination of diesel-fuel with rape-oil.**
- **Very quick heat-up of rape-oil-tank with medium / high load and therefore a possible switching of fuel.**
- **Automatisation of switching prevents cases of misoperations.**
- **In emergency-cases an override of switching was possible.**

SDF-Tractor Natural Power

Disadvantages:

- **High development costs.**
- **High production costs.**
- **Reduction of max. available engine-power in rape-oil-condition (~5%).**
- **Higher fuel-consumption in rape-oil-condition (~10%).**
- **Reduced engine-dynamic in rape-oil-condition.**
- **Complex system with many components.**
- **Complex Control-Strategy → increased failure-rate in field.**
- **2-tank-system: at cold ambient temperatures and low engine-load it was hard to reach switching-condition for rape-oil-use.**

SDF-Tractor Natural Power

Conclusions:

- 20 tractors tested.
- More than 500 hours tested/tractor (heavy/light duty, transport) .
- During development many problems happened:
  - Fuel injection system.
  - Injectors
  - Damages in combustion zone
- Lower CO_2 emissions.
- Lower emissions (not for NO_x) proven:
  - NO_x: +5%
  - PM: -40%
  - HC: -60%
  - CO: -80%
  - SO_2: -99%

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CONCLUSIONS

CONCLUSIONS

Technical issues

- Same Deutz-Fahr Group over this last 10 years collected many experiences on vegetable fuels with encouraging results:
  - RME (100%): fully approved on present production.
  - RSO: more than 20 tractor tests and 10.000 hours collected.
- Preliminary technical feasibility for using RSO is proven.
- Further engine and tractor developments are needed in view of reliability and reduce product cost with RSO.
- It is an open issue the possibility to use BIODIESEL on Stage 3B /Stage 4 engines due to EAT.
- RSO quality could be an issue for engine reliability.

Environment and impact on food chain

- Considering 1st generation of vegetable fuels used , big amount of agricultural area is needed for a significant replacement of petroleum source It's means also a strong impact on food chain.
- Lower CO_2 life cycle emissions proven but far from 100% reduction(from " cradle to grave").
- Lower emissions proven in view of HC, CO, PM and SO_2, but higher NO_x emissions detected.

CONCLUSIONS

Costs

- Product cost, commodities cost and taxes could be an issue in view of the economic competitiveness.

Fuels

- Permanent, large availability with the right infrastructure investments; quality and standardization of the bio fuels are key points for addressing the huge technical investments of the future engines for complying with Stage 3B on and improving the fuel consumption.

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THANK YOU for your attention!