Waste Heat Recovery for Hybrid trucks

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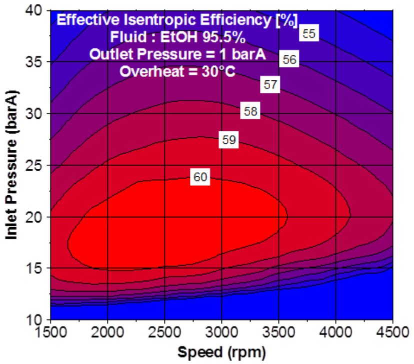
Exoès at a glance

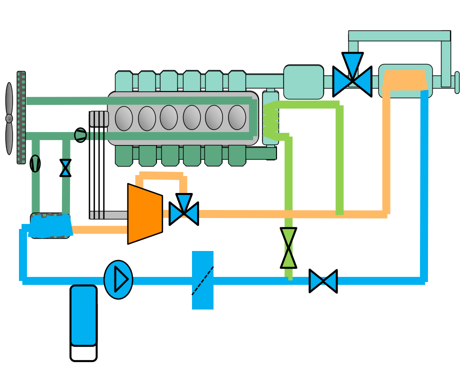
Our skills

EXOES is an engineering company providing its customers with:

Prototypes



Calibrated Simulation



System design

Test rigs

Vehicle integration

Prototype technologies:

Swashplate

Scroll

Pump

Fast charging batteries

Fuel cells

Experienced in demo-vehicles

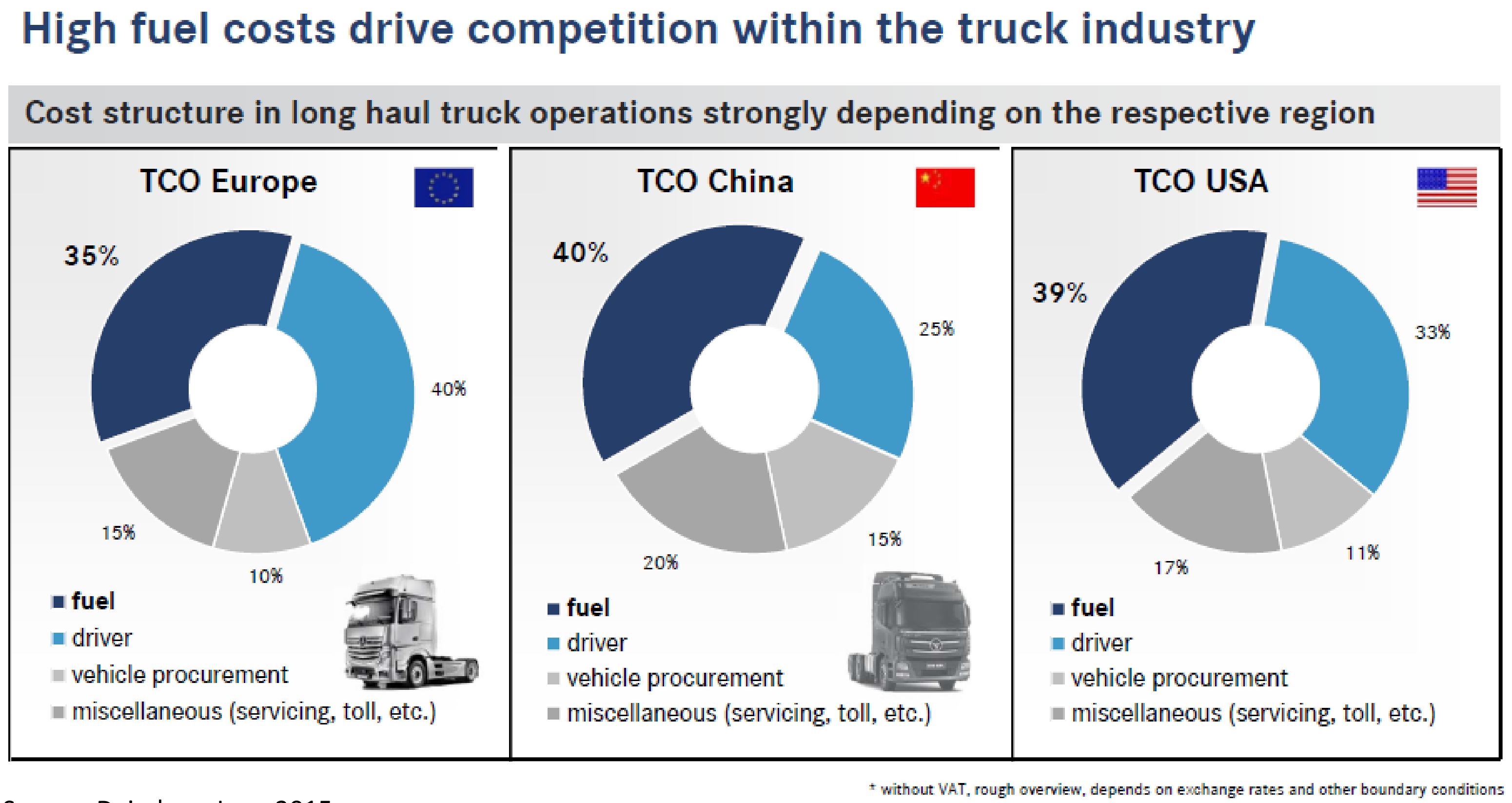
References:

Demotruck:

- EXOES, Renault-Trucks and Faurecia
- a 2-year program
- Waste heat recovery
- Integration of an EXOES expander
- Real life driving and roller test bench

Saving fuel
on long haul trucks ?

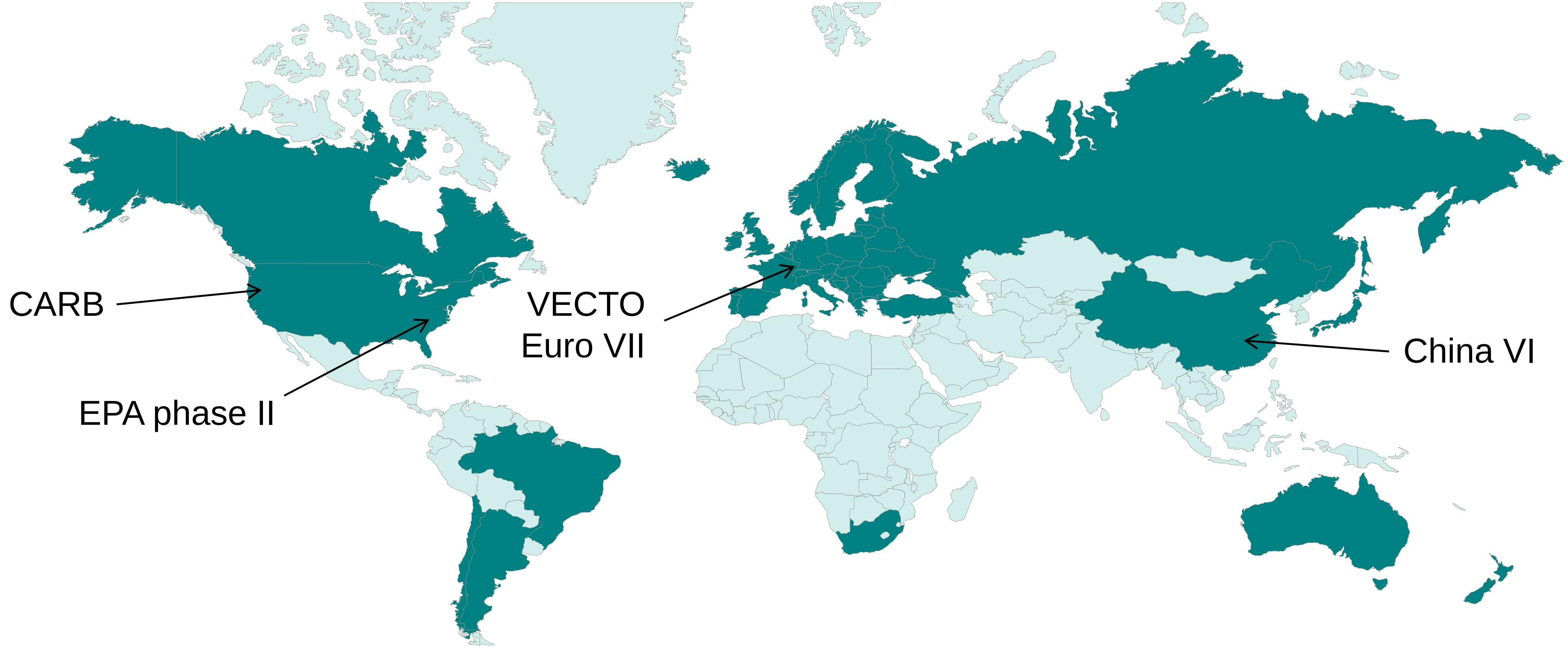
Drivers for fuel efficiency in HCVs: TCO



Source: Daimler – June 2015

Everywhere in the world, fuel efficiency for HCVs
is key factor for the end customer

Drivers for fuel efficiency in HCVs: CO_2 regulations



Source: Roland Berger

Countries where CO_2 emission targets for HCVs are expected to be voted by 2020

Tackle to the waste heat

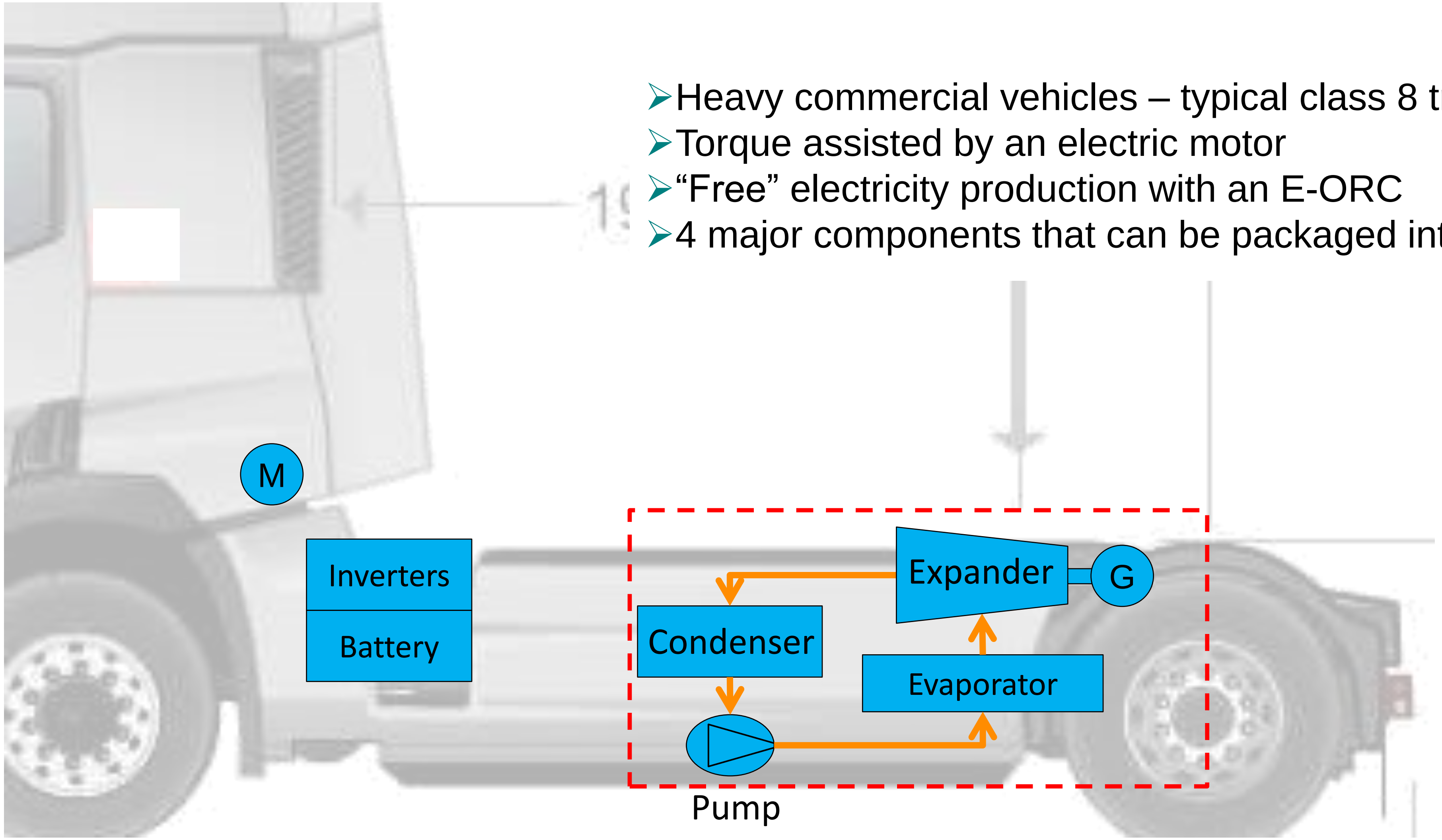
A third of fuel
is lost as heat
in the exhaust…

…we do believe that
Waste Heat Recovery
Systems will become a
standard as soon as
2024+

We engineer robust and versatile ORC technologies

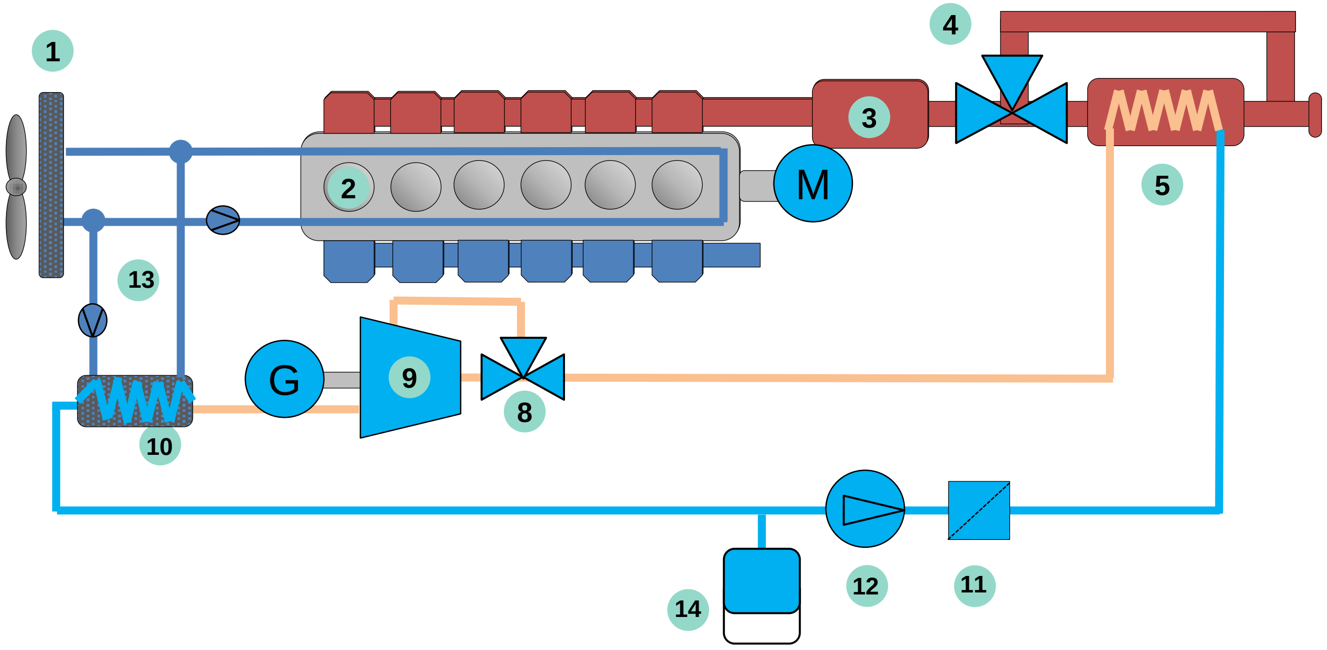
E-ORC system general architecture

- Heavy commercial vehicles – typical class 8 truck
- Torque assisted by an electric motor
- “Free” electricity production with an E-ORC
- 4 major components that can be packaged into 1 box



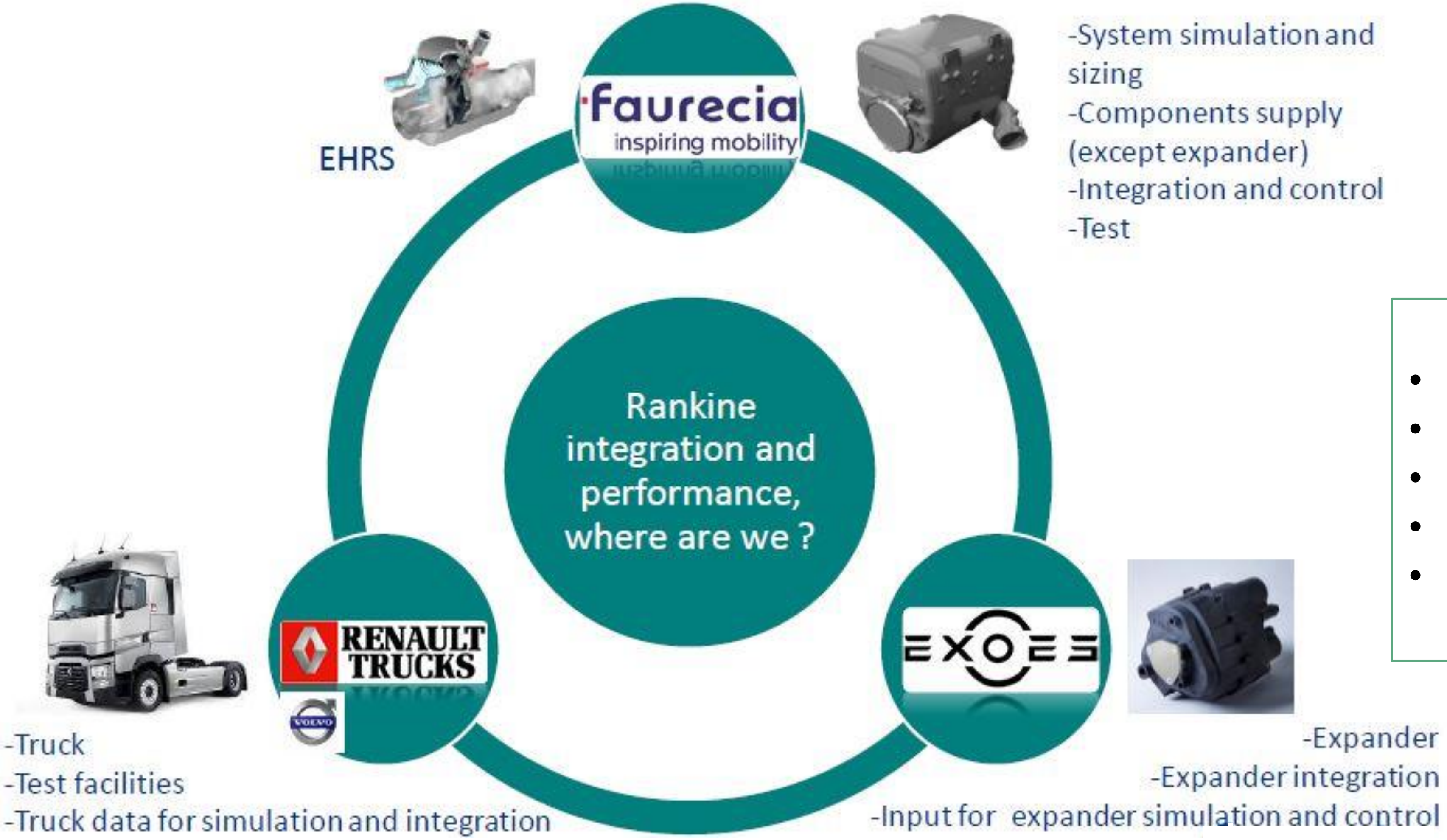
Detailed ORC layout

- Focus on exhaust heat recovery only
- 2.5 to 5% fuel cuts are expected on real trucks



1: Front radiator
2: ICE + E-Motor
3: EATS
4: Exhaust bypass valve
5: Exhaust evaporator
8: Bypass valve
9: Expander + Generator
10: Condenser
11: Filter
12: Charge pump
13: Cooling pump
14: Expansion vessel

Demonstration truck



Source: Faurecia, Heavy-Duty, On- and Off-Highway Engines 2017

- EXOES, Renault-Trucks and Faurecia
- a 2-year program
- Waste heat recovery
- Integration of an EXOES expander
- Real life driving and roller test bench

Challenges for the ORC

- Ethanol bottoming Rankine cycles are facing the following challenges to enter OEM development programs:

  - **Safety case**
    - Flammable working fluid
    - Extensive risk analysis already done by TÜV SÜD / FPT for IVECO
    - System supplier or OEM responsibility

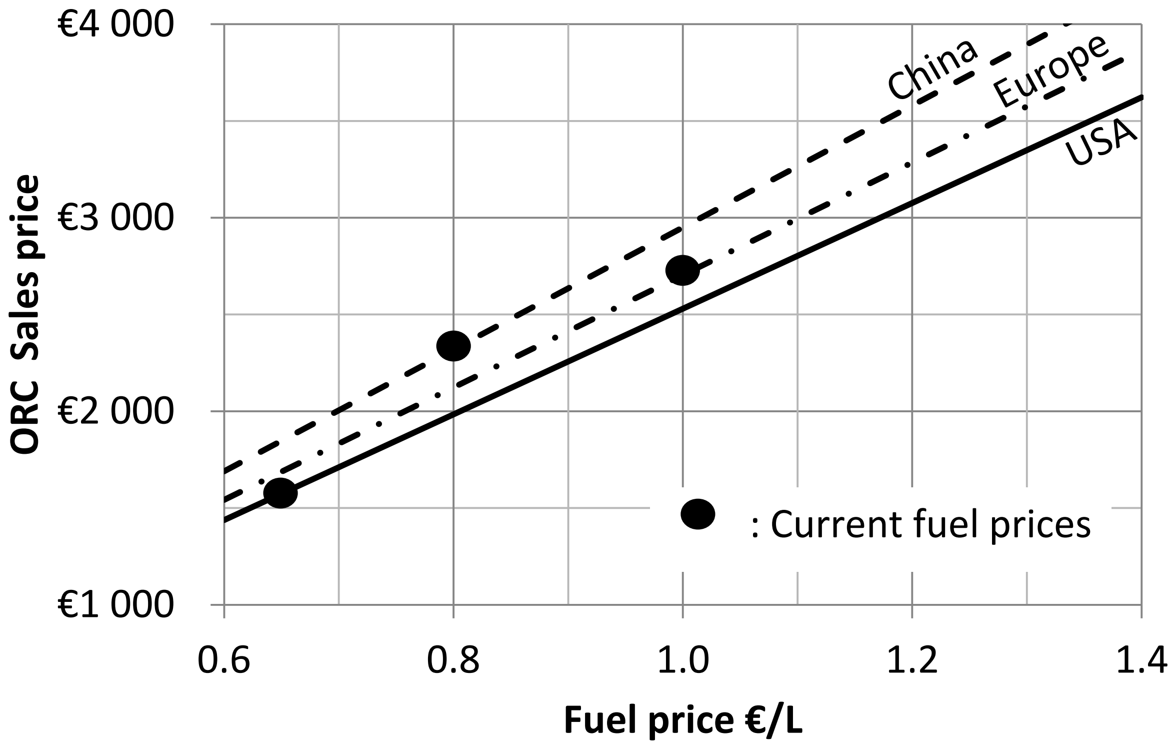
  - **Business case**
    - Ratio cost / benefit
    - Prove the fuel savings
    - Reduce the components and integration costs

  - **Durability case**
    - Prove the components reliability
    - Alcoholate corrosion
    - Fluid ageing: lubricant and ethanol breakdown

Target cost of the system

➢Link between payback time, fuel saving and system cost

Sales price of the ORC system for a 2-year payback assuming 3% fuel saving



➢Assumptions:

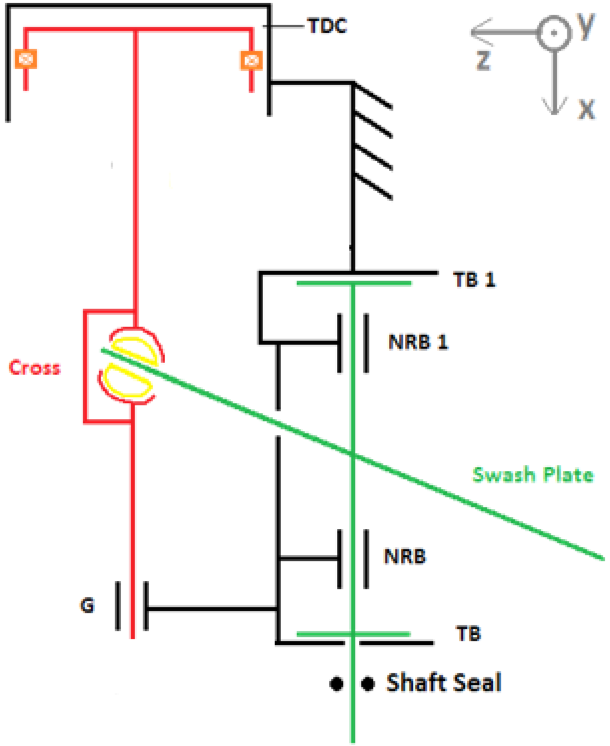
	Europe	USA	China	Unit
Mileage	130,000	110,000	150,000	km/y
Fuel	1	0.65	0.8	€/L
Consumption	35	44	35*	L/100km
ORC Maintenance	100	100	100	€/y

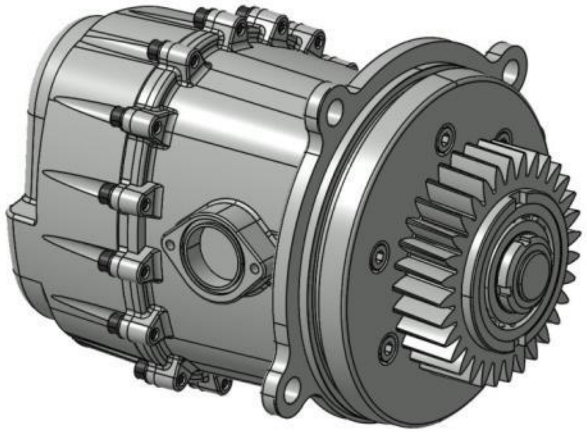
*: projected in 2025 with new regulation implementation

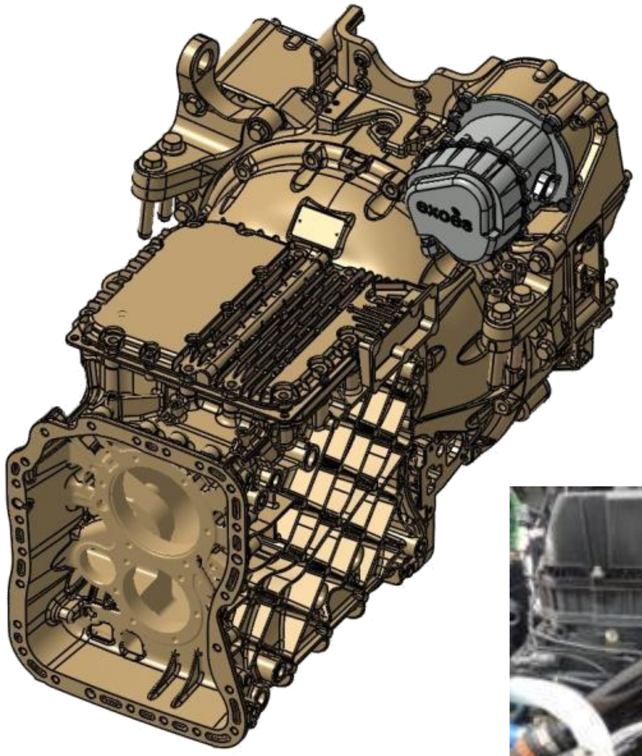
Expander design

Exoès piston expander technology

- ➢EVE-T2: Single acting swashplate technology – 3 pistons
- ➢Inlet poppet valves, and exhaust ports and valves

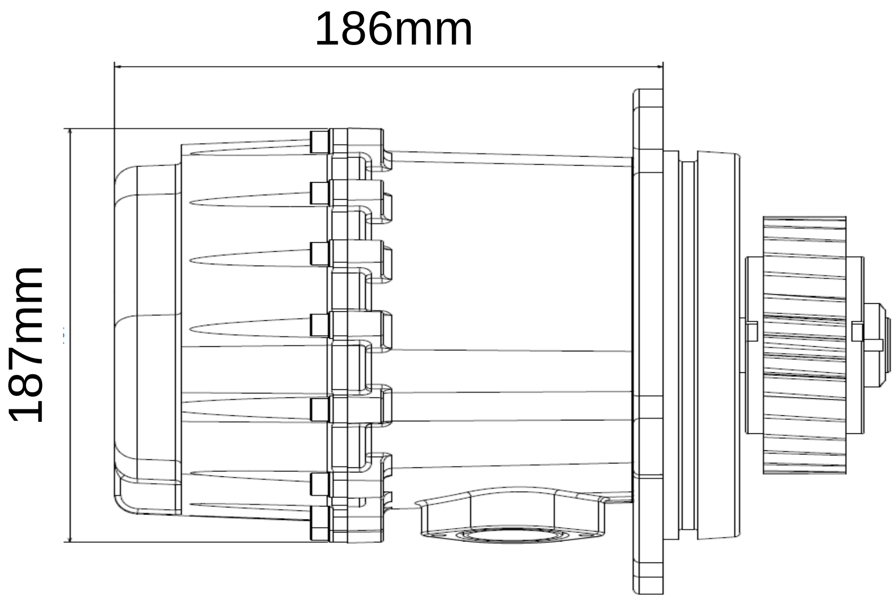




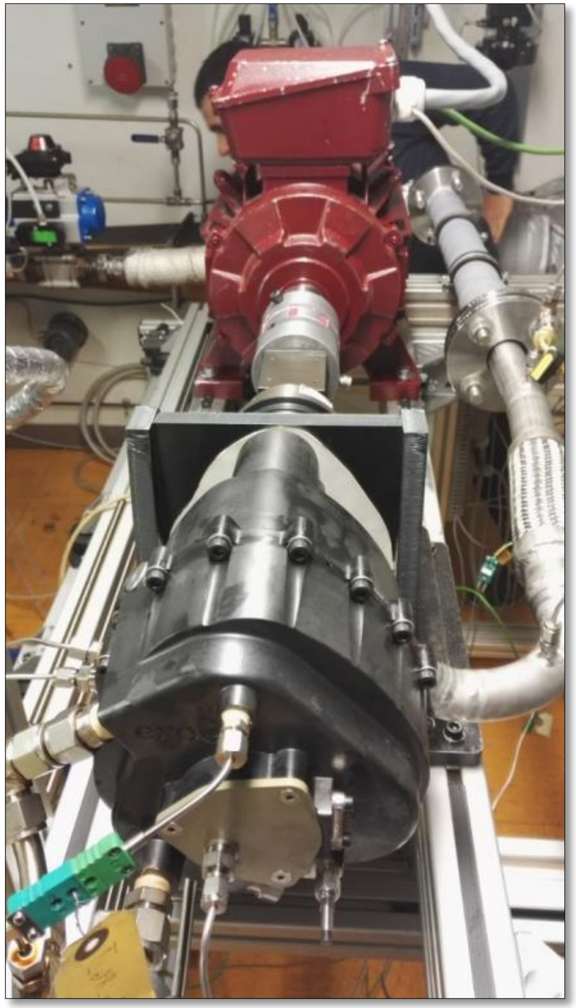


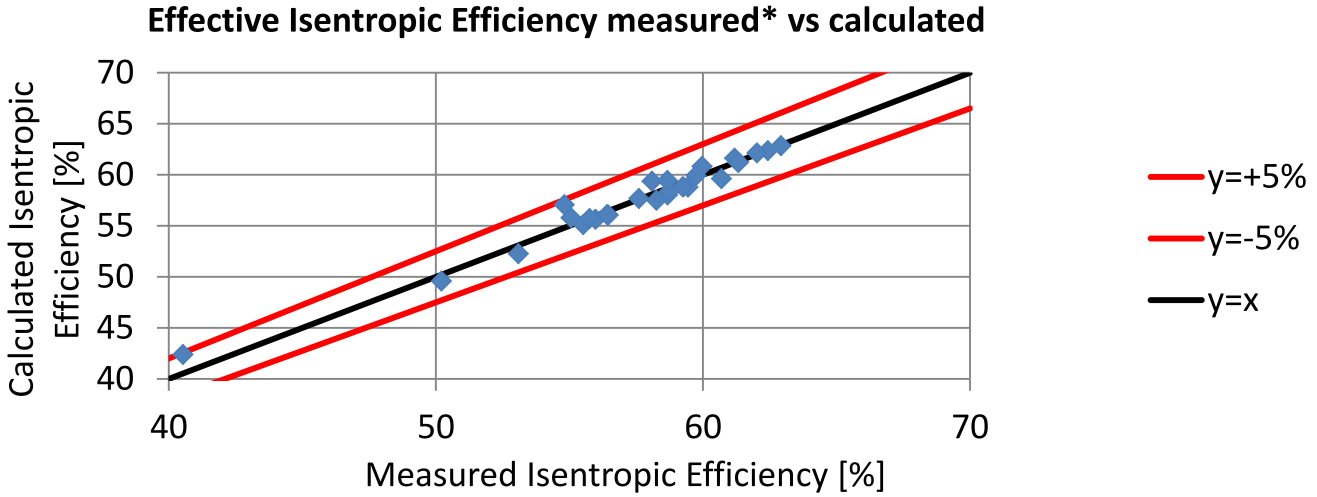
Expander Datasheet

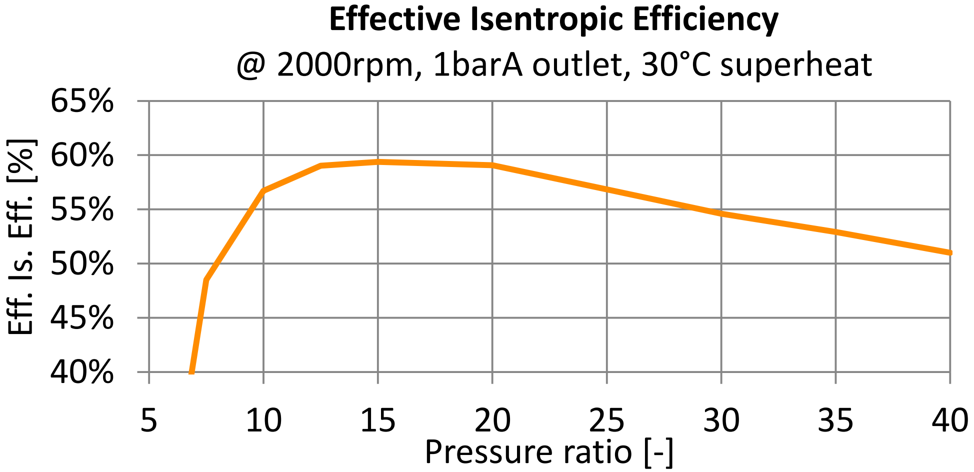
	EVE-T2
Speed range	1,000 - 4,530 RPM
Shaft power range	<12 kW
Eff. Is. efficiency range	Typ. 55 - 65%
Size	< D200xL200mm
Weight without coupling	15kg
Oil circulation rate	Typ. 10%
Outlet pressures	1 - 4barA
Inlet pressures	<40 barA
Nominal pressure ratio	15 – 20 for ethanol
Nominal gear ratio	1.5 – 2.5 for trucks
Transmission	Freewheel
Bypass valve	Integrated



Expander tests and model calibration







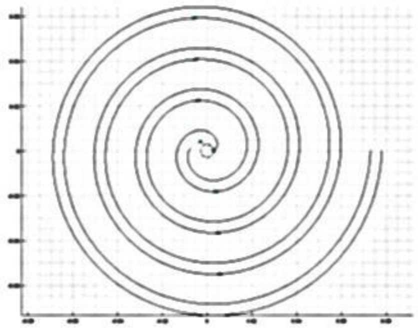
Effective isentropic efficiency:

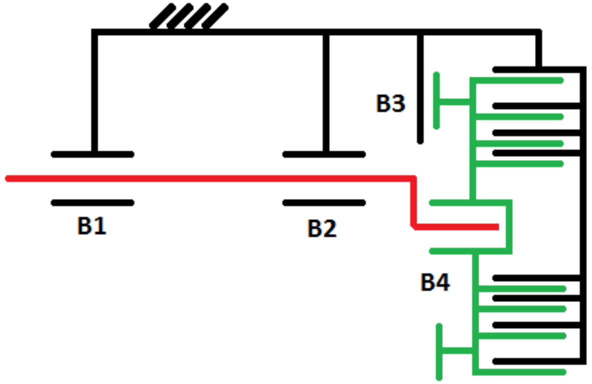
$$\eta_{eff,is} = \frac{\dot{W}_{shaft}}{\dot{M}(h_{in} - h_{out,is})}$$

*Measured = calculated based on measured values

Exoès scroll expander technology

- Compliant Scroll – Volume ratio 4.6 – Capacity 139cm^3

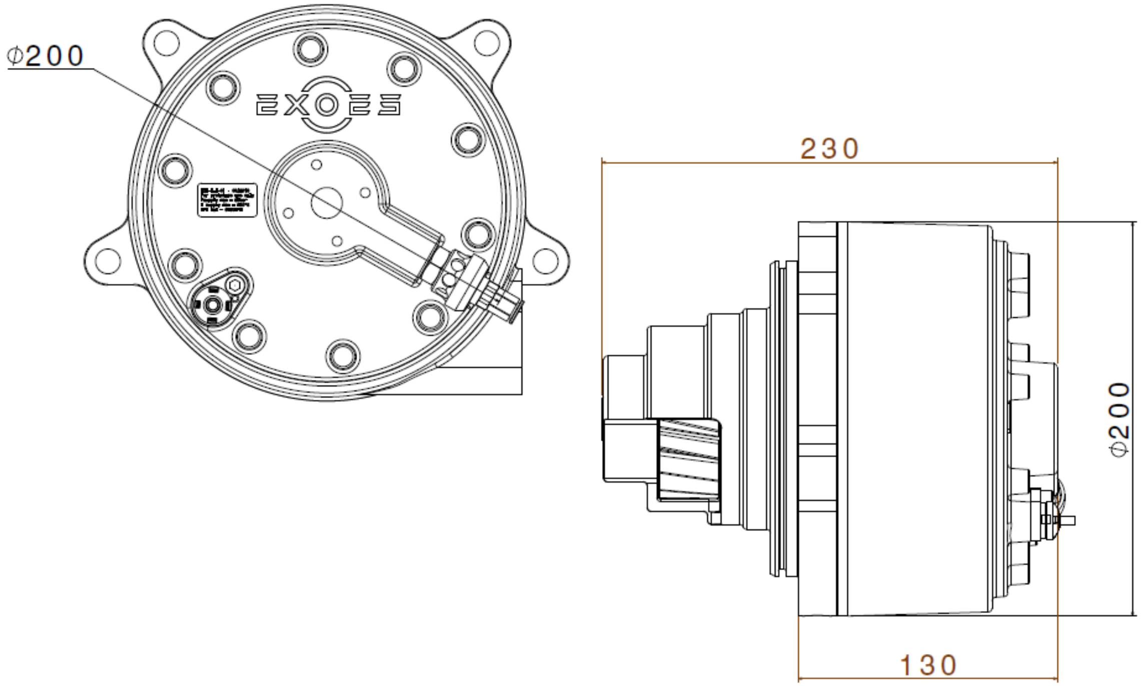




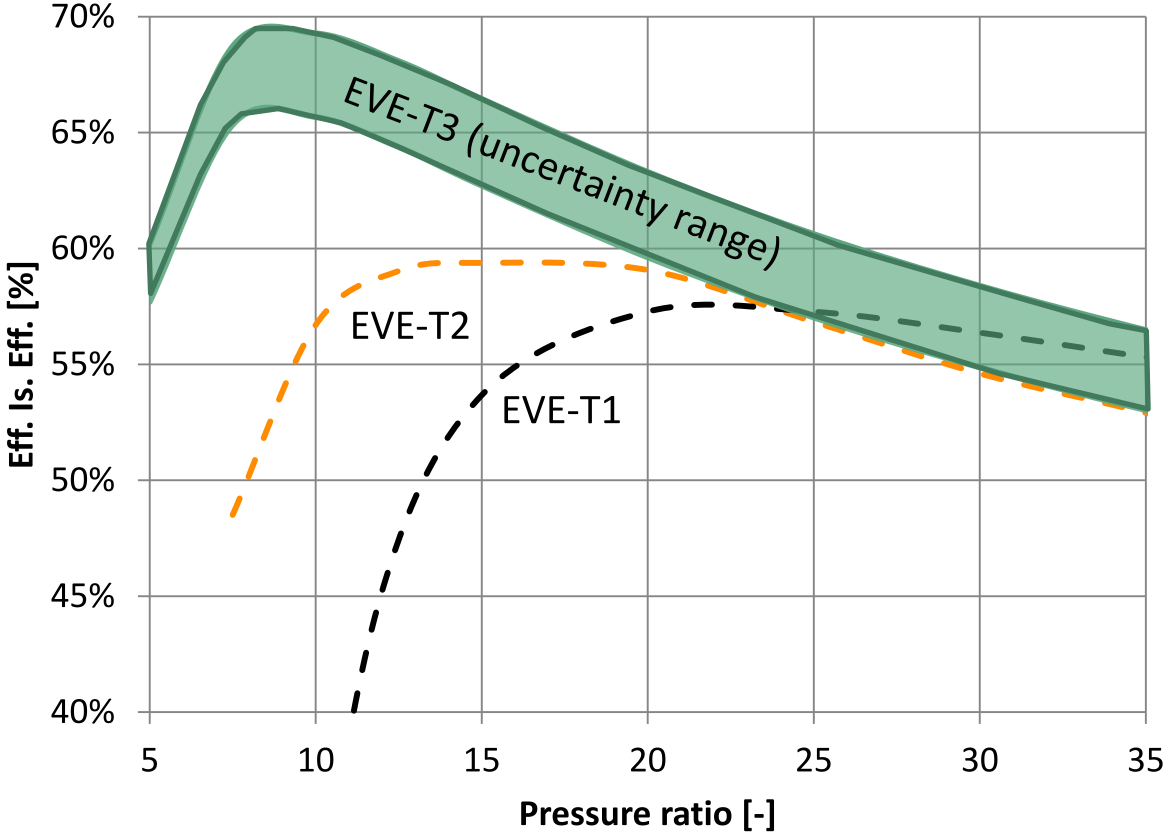
	EVE-T2 - piston	EVE-T3 - scroll
Speed range (RPM)	1,000 - 4,530	1,000 – 6,000
Shaft power range	<12 kW	<15 kW
Eff. Is. efficiency range	Typ. 55 - 65%	Typ. 60 - 75%
Size	< D200xL200mm	< D200xL130mm
Weight w/o coupling	15kg	16kg
Oil circulation rate	Typ. 10%	Typ. 5%

Efficiency forecast

➢ Higher efficiency expected



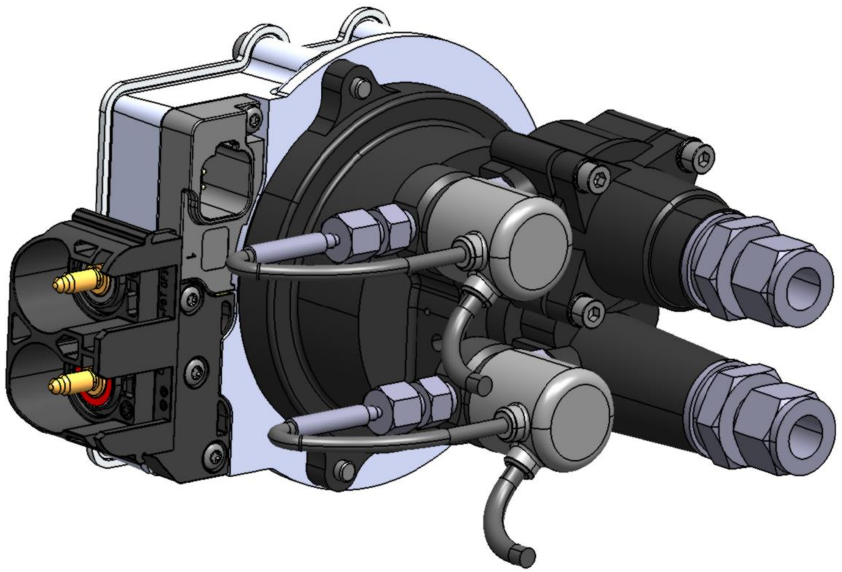
Efficiency comparison with Ethanol 95.5%mass
@ 2000rpm, 1bar outlet, 30°C superheat (EVE-T1 and T2)
@ 3600rpm, 1bar outlet, 20°C superheat (EVE-T3)



Pump design

Exoès gear pump technology

- A unique design for low flow, high pressure, with no lubricant
- A one-stop product for several required functions



Flow	0.75 – 6 L/min
Elec. power range	<1.2 kW
Pump size	<D180xL210mm
Weight	<4kg
NPSHr	~300mbar
Inlet pressures	1 - 4barA
Outlet pressures	1 - 40 barA
Additional functions	100 µm inlet filter 10 µm outlet filter Relief valve 43 barG Expansion tank w/ pressure regulator
Sensors	In & Out pressures Temperature
Motor	24 Vdc – CAN bus

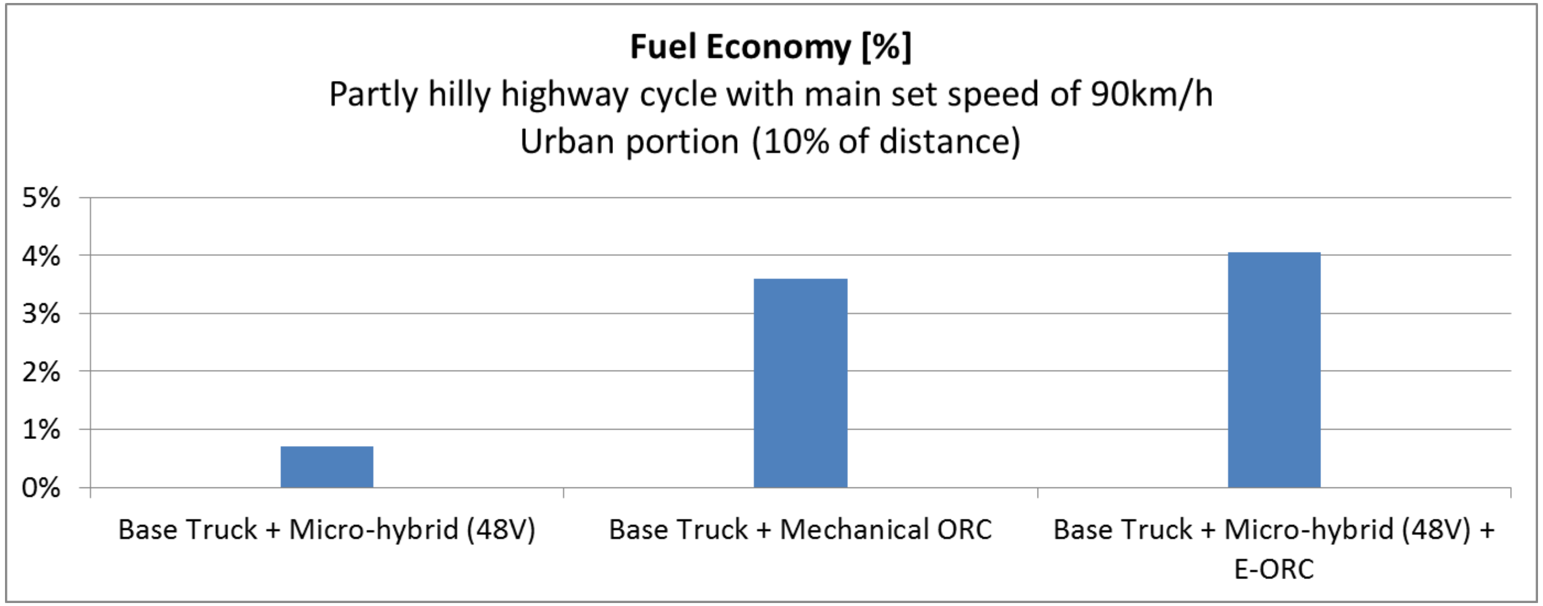
Electrical vs Mechanical

Micro-hybrid favors E-ORC

Electrical energy recovery vs Mechanical energy recovery

- Easier integration
- Better control
- Recovery when engine brakes

- Coupling efficiency
- Cost



Source: Volvo Trucks – November 2017 - EORCC

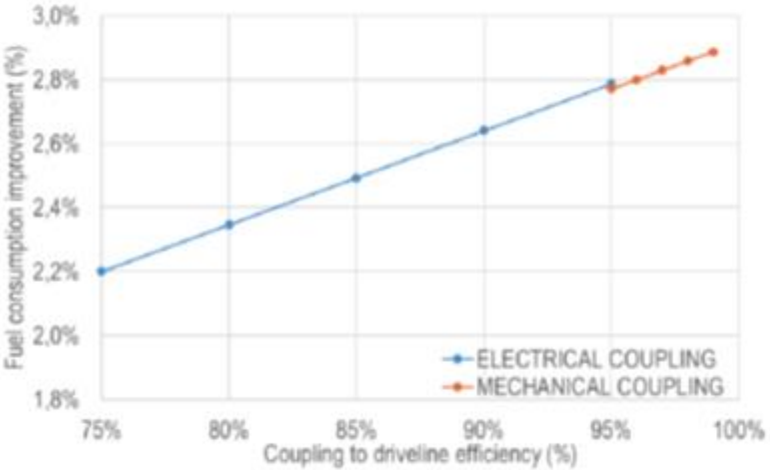
Dynamics favors E-ORC

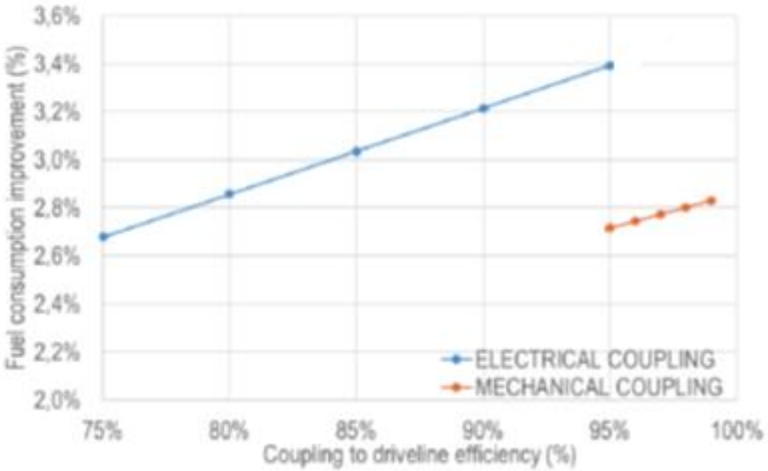
Steady state

- In steady state, the additional degree of freedom offered by the expansion machine speed control is not compensating the decrease in coupling efficiency.

Dynamic

- In dynamic, recovery is enabled during a longer period giving a relative advantage to the electrical coupling.





Source: from Tenneco – November 2017 - EORCC

Conclusion

Conclusions

- Electric waste heat recovery may reach the market in 2024+
- >4% fuel economy are expected
- 48V – 12kW Electric expander & 48V – 500W Electric pump are 2 key products of the system

Thank you for your attention