XII MEET THE MARKET INTERNATIONAL CONFERENCE SOUTH AMERICA

Lubes em Foco - ICIS

Ultra Low Viscosity e-Fluids For A Sustainable Future

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Rio de Janeiro, July 7th, 2022

Performance you can rely on.

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Towards a Sustainable Future
Global Issues – A Warming World

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SUSTAINABLE DEVELOPMENT GOALS

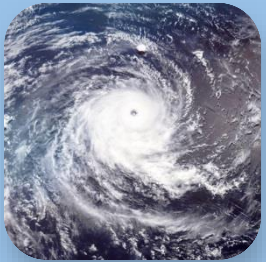
13 CLIMATE ACTION

Take urgent action to combat climate change and its impacts

Infineum supports the Sustainable Development Goals

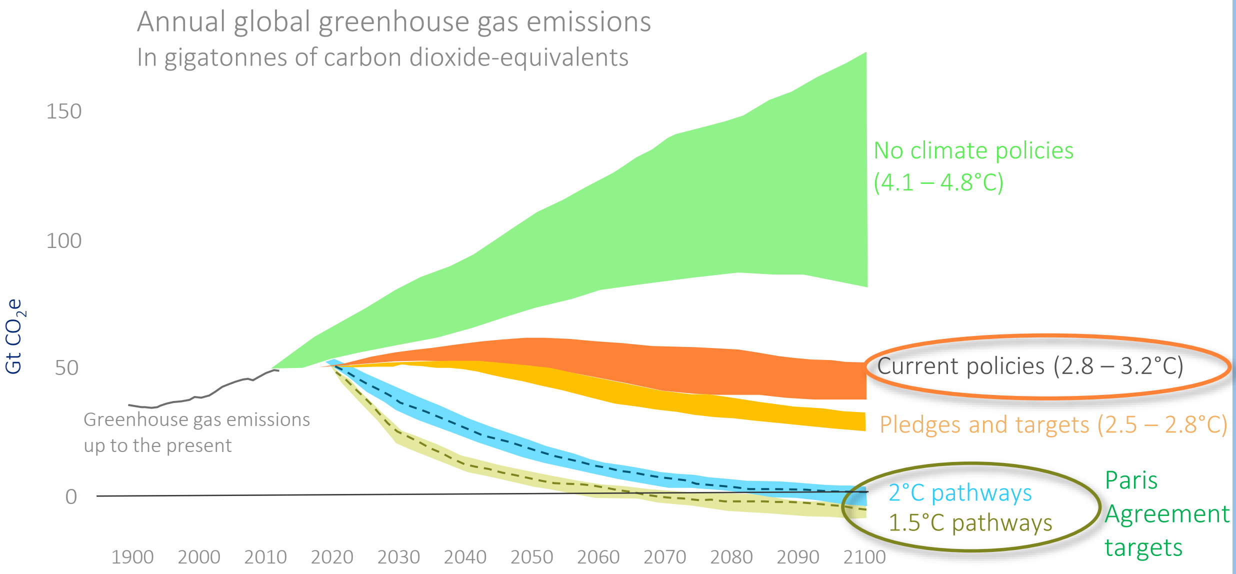
>10,000 species thought to go extinct every year

Greenland - rate of ice loss up **254bn t/y** this decade

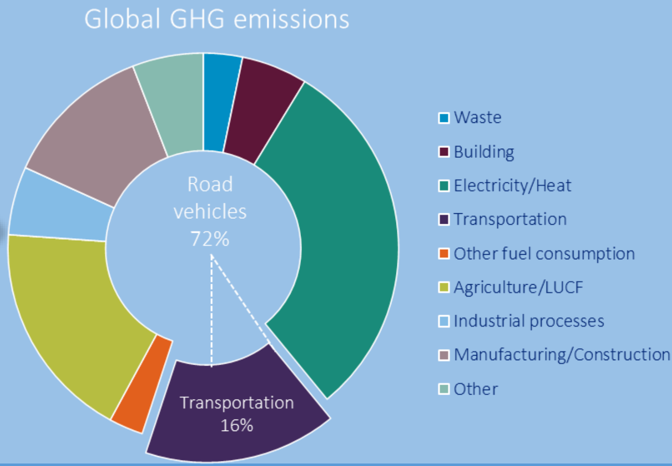


Extreme weather events up - 16 in 2011 to **64** in 2018

Towards a Sustainable Future
Reducing Greenhouse Gas Emissions



72% of transport emissions come from road vehicles



> "Despite a record drop in global emissions this year, the world is far from doing enough to put them into decisive decline."

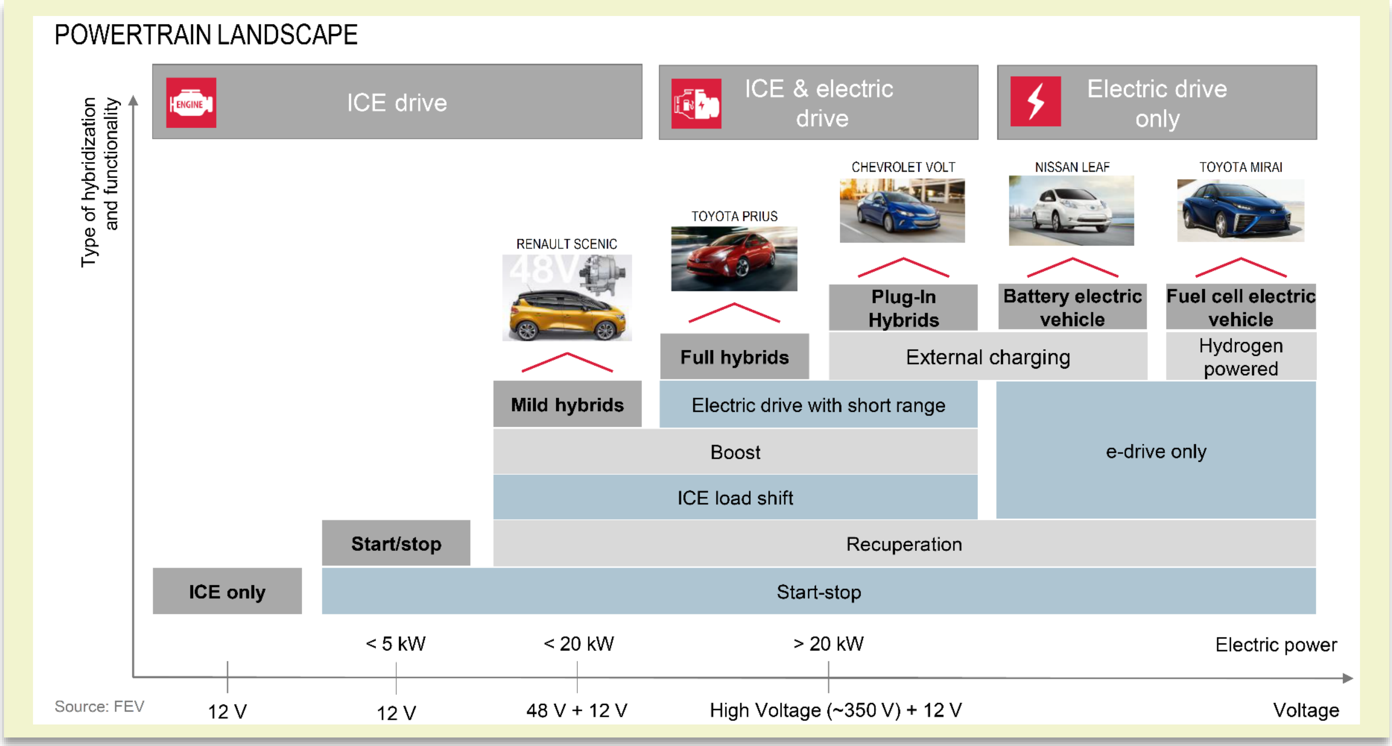
IEA Executive Director

Based on data from the Climate Action Tracker (CAT). The data visualization is available at OurWorldInData.org. There you find research and more visualizations on this topic. Licenced under CC-BY by the authors Hannah Ritchie and Max Roser.

Data source Climate Watch. 2018. Washington, DC: World Resources Institute.
www.climatewatchdata.org

Towards a Sustainable Future

e-Mobility – A Path to Sustainability



+ Increased efficiency
+ Reduced green house gas emissions

Towards a Sustainable Future
e-Mobility – Vehicle Integration

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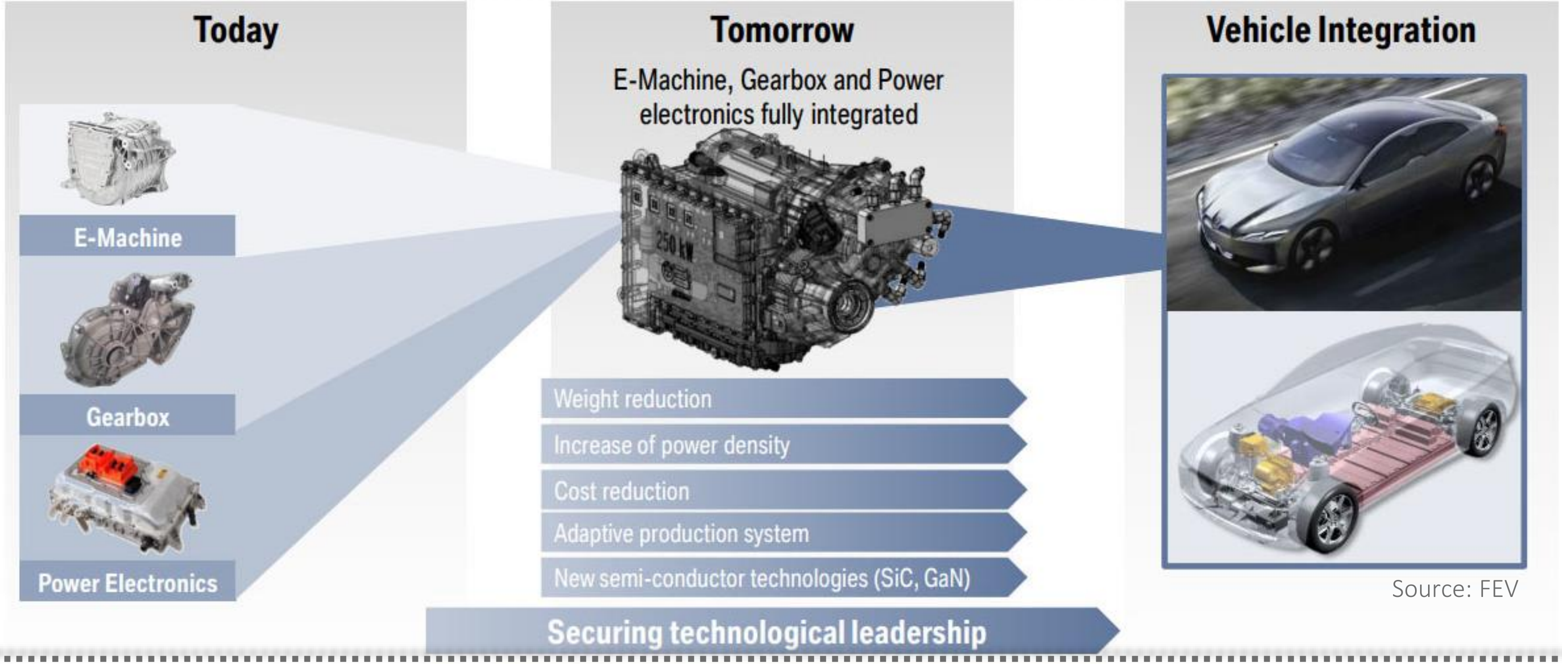
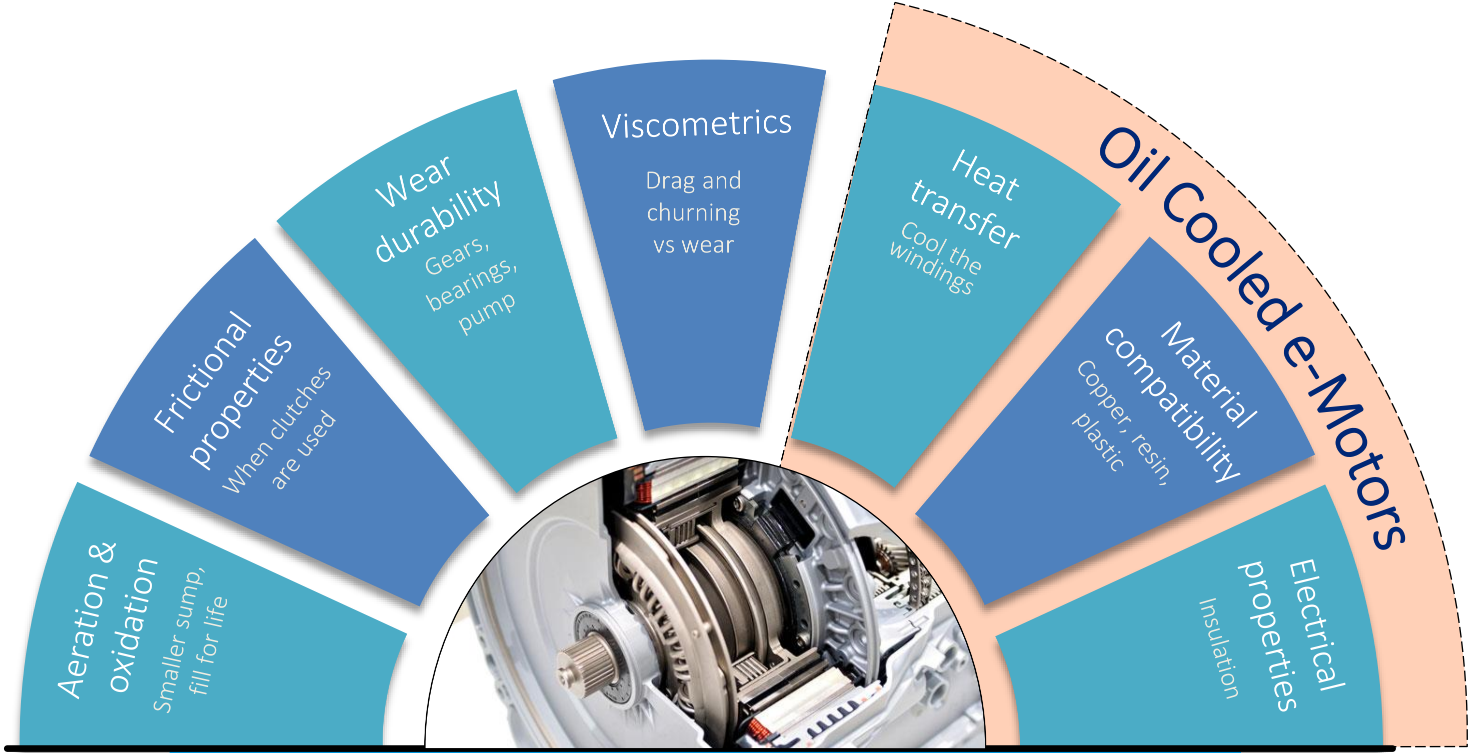
Reduced package size and increased power density - vehicle integration

- ✔ Allows for reducing material cost and integrated cooling
- ! Increased design complexity and higher working temperatures



Source: FEV

Towards a Sustainable Future
e-Fluid Requirements



Oil cooling brings additional requirements including heat transfer, material and electrical compatibility

Towards a Sustainable Future
Ultra Low Viscosity (ULV) e-Fluids

Increase Fuel Economy and Cooling

Ultra Low Viscosity [ULV] Fluid

- KV100°C ~ 3.0 cSt

ULV advantages:

Improved fuel efficiency

- Increased driving range for BEVs

Improved heat transfer

- cool electronics and battery

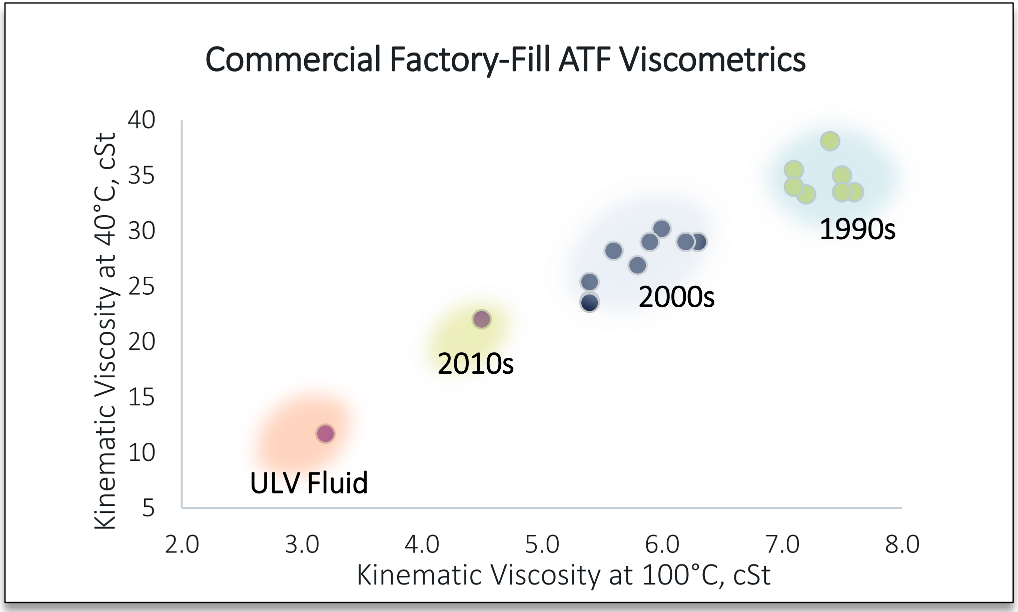
ULV challenges:

Gear and bearing durability

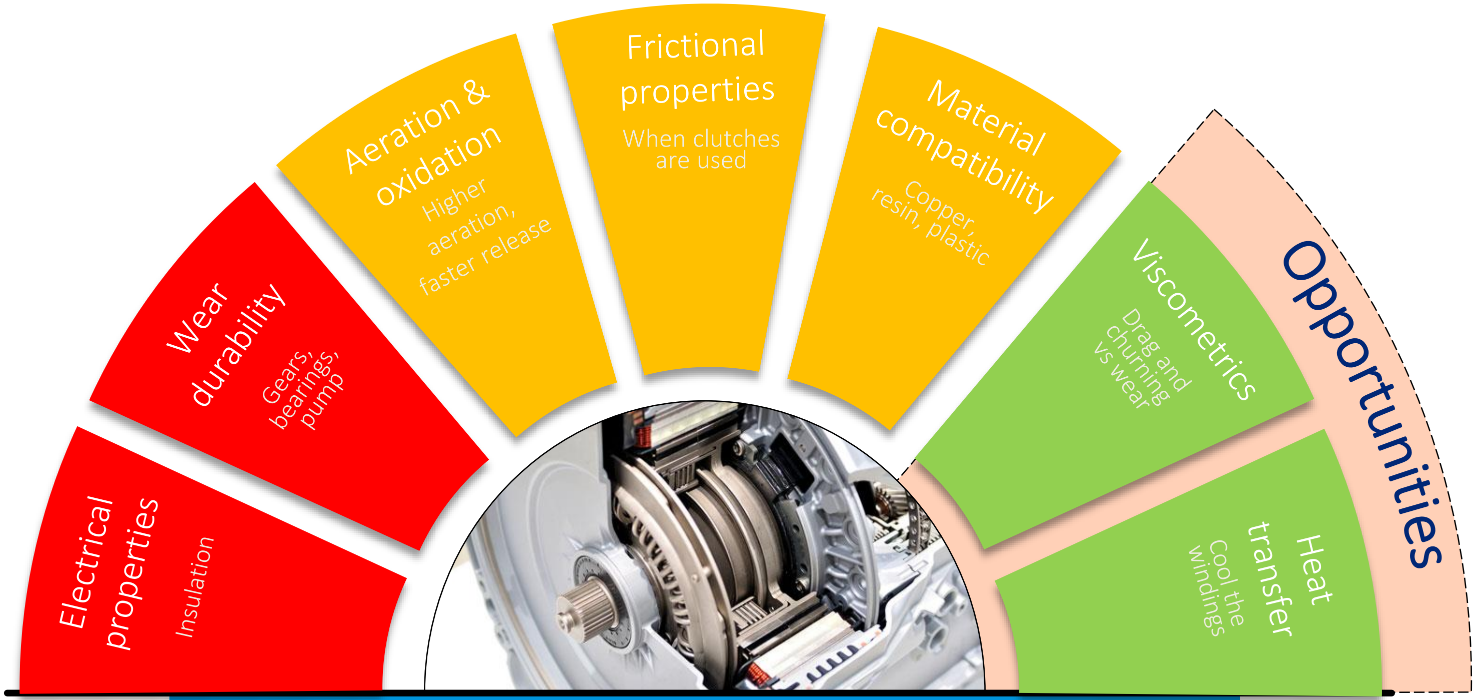
- Next generation anti-wear components

Reduced electrical properties

- Step out resistivity formulation



Ultra Low Viscosity e-Fluids
Challenges and Opportunities

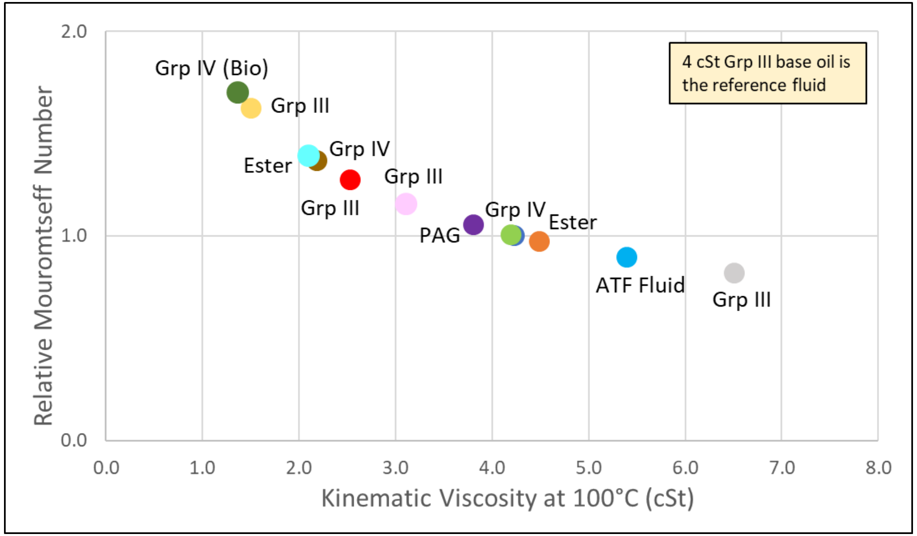


Careful balance is necessary in a lower viscosity environment

Ultra Low Viscosity e-Fluids
Impact on Heat Transfer Coefficient

The *Mouromtseff* number [M_0] is used to compare the heat transfer capability of turbulent fluids

e-Fluids are subject to turbulent flow



Mouromtseff Number for turbulent fluids

$$M_0 = \frac{\rho^{0.8} k^{0.67} c_p^{0.33}}{\mu^{0.47}}$$

Fluid properties:
- ρ = Density [kg/m^3]
- k = Thermal conductivity [W/(m·K)]
- C_p = Specific heat capacity [kJ/(kg·K)]
- μ = Dynamic viscosity [cP]

Provides formulation guidance, largely on base oil selection

↑ Increase fluid thermal conductivity –
Function of base oil purity [Grp IV > Grp III]– small effect on M_0

↓ Reduce fluid dynamic viscosity -
Lower viscosity oil – major effect on M_0 [balance vs. wear]

Ultra Low Viscosity e-Fluids
Electric Motor Cooling: YASA P400S

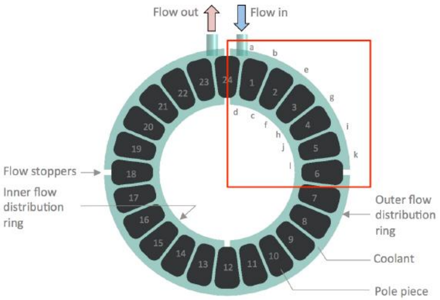
Test fluids scoped to evaluate heat transfer by probing the efficiency map of the e-motor

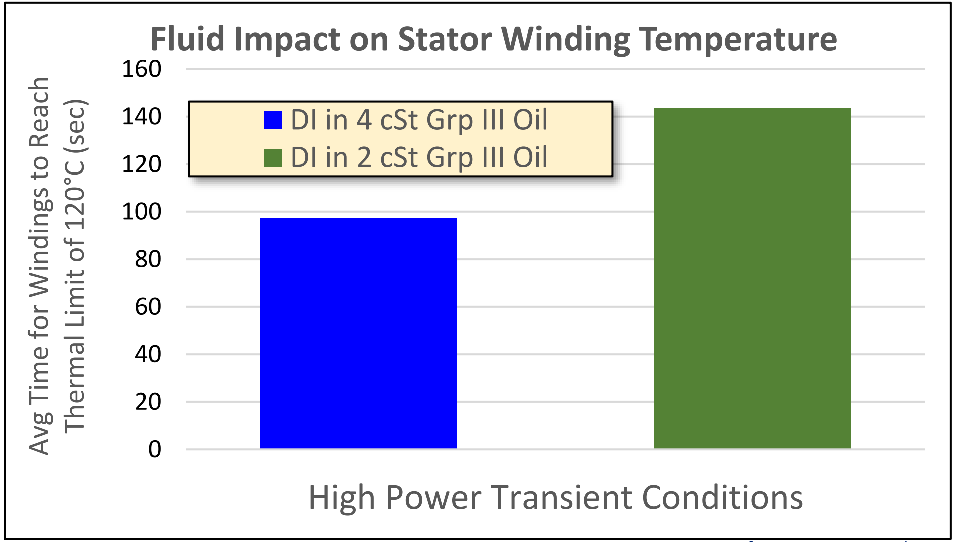
- Steady state operating conditions (long)
  - Observed motor temperatures allowed to stabilize over time
- High power (transient) operating conditions (short)
  - Observed motor temperatures increased sharply until thermal limits of individual components were reached

Performance benefits found using low viscosity fluid

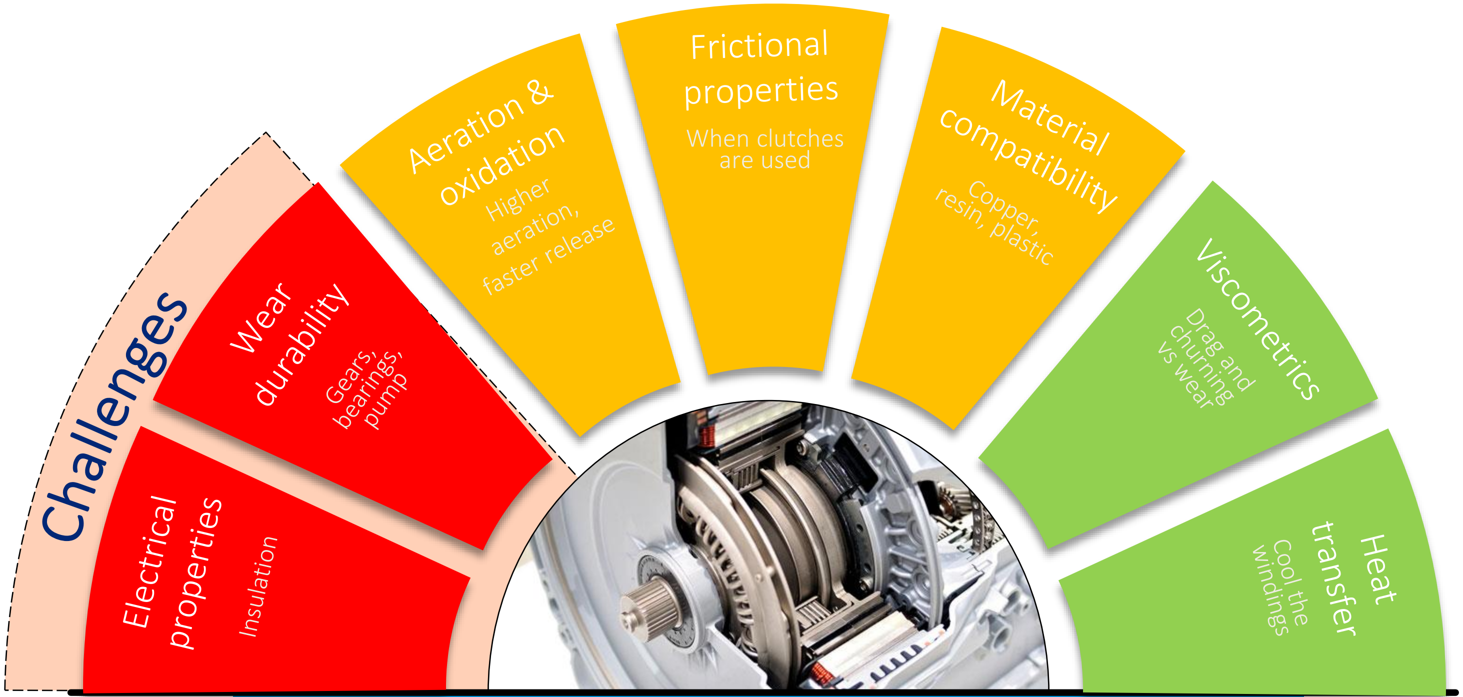
- Delayed derating of stator windings
- Magnitude of effect dependent on motor conditions

YASA P400 axial flux machine





Ultra Low Viscosity e-Fluids
Challenges and Opportunities



Careful balance is necessary in a lower viscosity environment

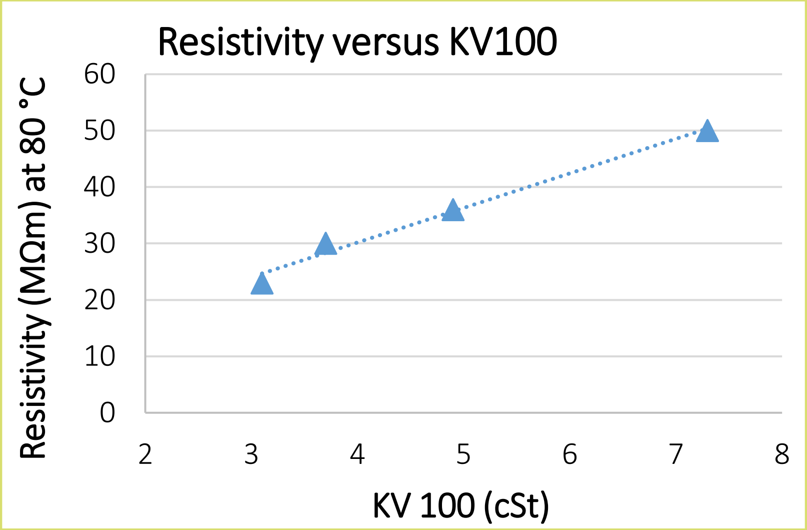
Ultra Low Viscosity e-Fluids
Reduced Electrical Properties

Motors rely on insulating material to isolate high voltage components

When oil cooled, the e-Fluid's resistance to current flow must be considered

Volume Resistivity [VR]

+ Fundamental property of a material that measures its resistance to electric current.
+ Inverse of conductivity



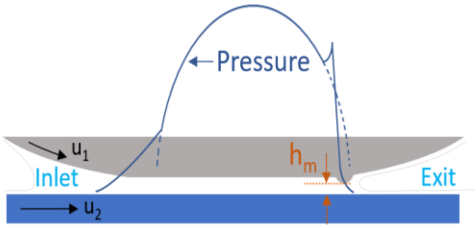
Charges in the fluid can be more easily carried when the viscosity decreases

→ lower VR at lower viscosity.

Ultra Low Viscosity e-Fluids
Durability Challenges

The lubrication mechanism in gear and bearing contacts is elastohydrodynamic

- \+ Film thickness (h) depends most heavily on *entrainment speed (U_e)* and fluid *viscosity (μ_0)*
- \+ *kV100 from 5.5 cSt to 3.0 cSt ~ 30% reduction in EHD film thickness*



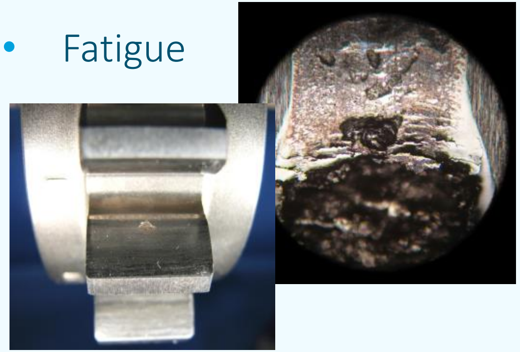
$$h_m = \frac{3.07\,(\mu_0 U_e)^{0.71}\,\alpha^{0.57} R^{0.40}}{E'^{0.03} w^{0.11}}$$

h_m = minimum film thickness
μ_0 = viscosity at atm pressure
U_e = entrainment velocity
α = pressure-viscosity coefficient
R = combined radius of curvature
E' = combined elastic modulus
w = applied load

- Scuffing

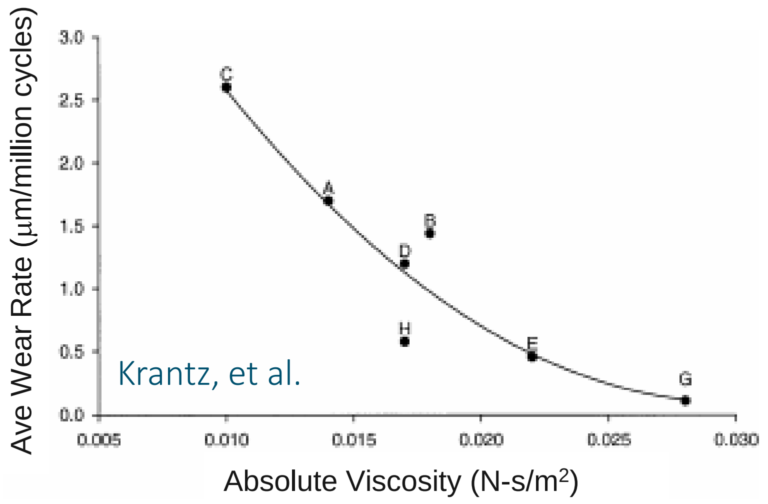
- Micropitting

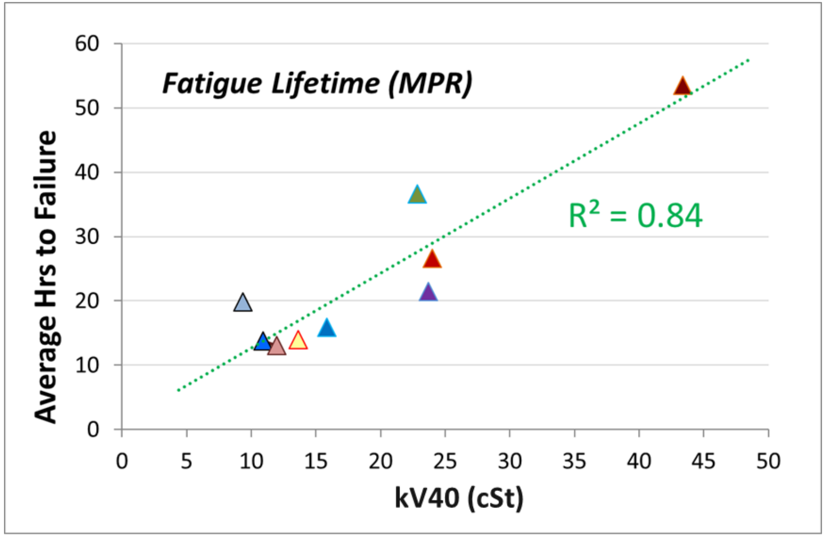
- Fatigue



Ultra Low Viscosity e-Fluids
Durability Challenges

Gear wear rate as a function of fluid viscosity – reduced viscosity results in significantly higher wear



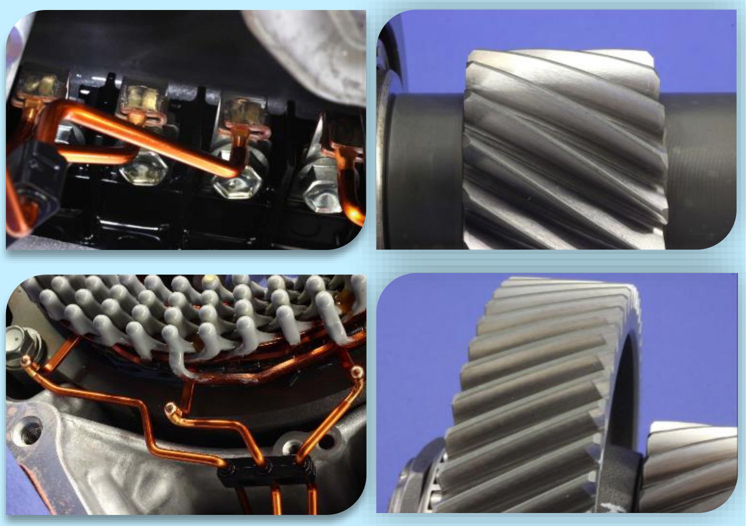


Fatigue lifetime measured in the micropitting rig, comparing oils with the same additive package in different viscosity base oils.

ULV fluids will require carefully balanced formulation chemistry to offset the durability loss

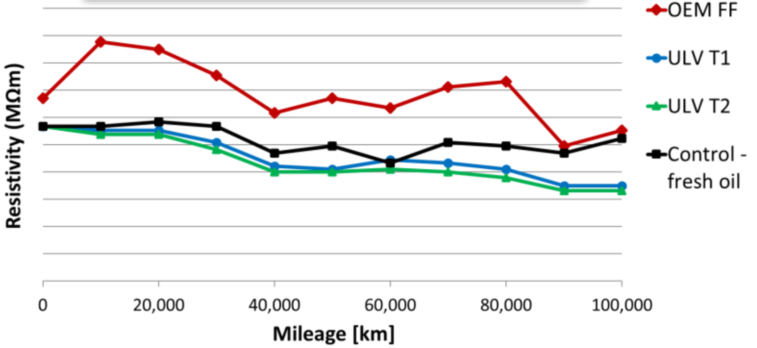
Ultra Low Viscosity e-Fluids
Field Trial Performance

Field Trial Distance	100,000 km
Test Cycle	Mixed: city/country/highway
Engine	1.8 L petrol / 4 Cylinders
Transmission Type	DHT
Vehicle Load	75% of max. load

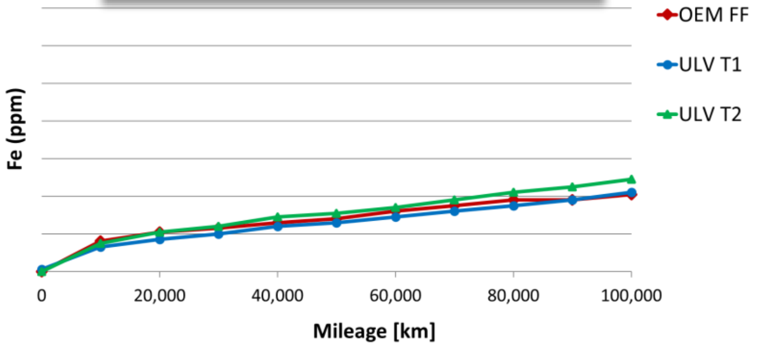


ULV e-fluid EOT Images

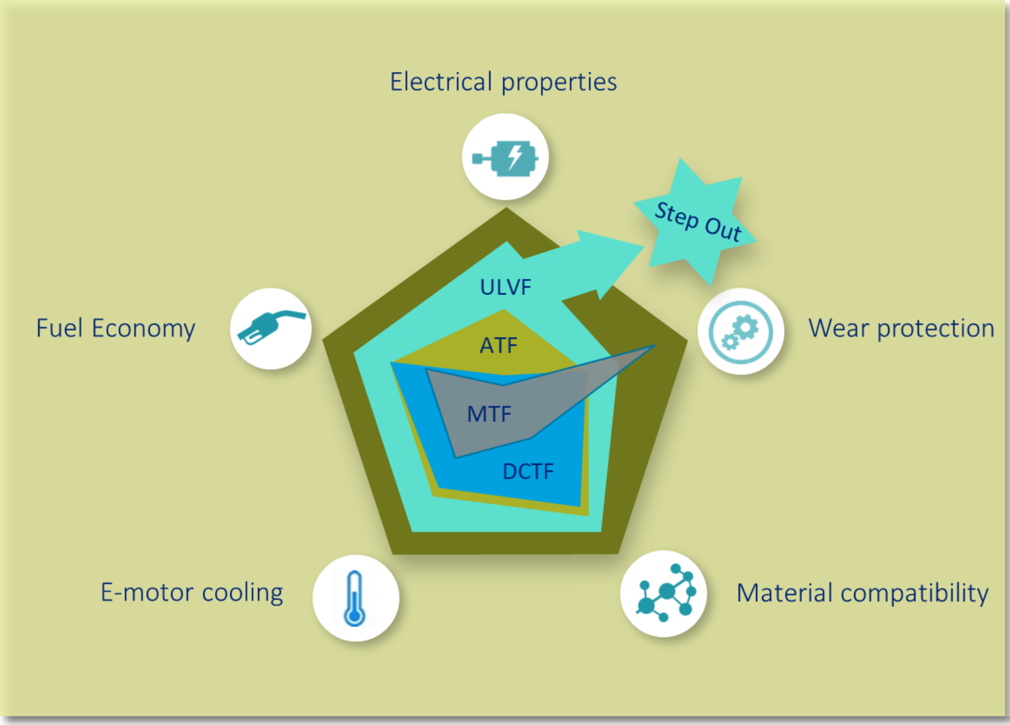
Resistivity



Fe ingress is comparable for all fluids



Ultra Low Viscosity e-Fluids
Towards A Sustainable Future



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