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Axial Flux Machines – Back to the Future

www.evo-electric.com

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Why Axial Flux? History

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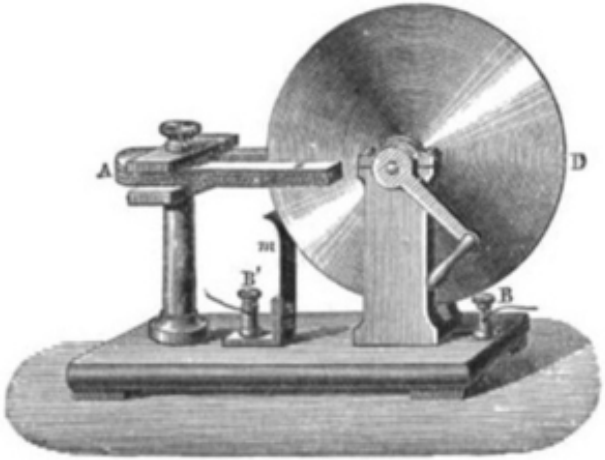
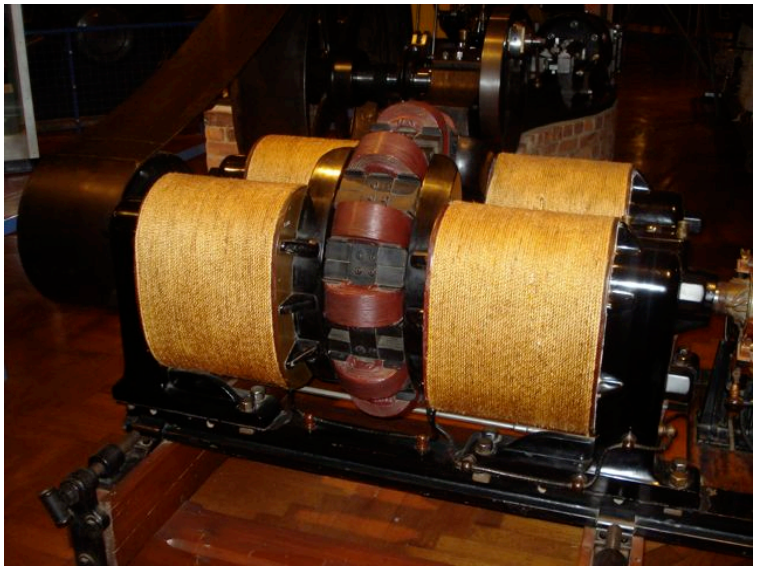
- Understood to offer:
  - High Torque
  - Good Packaging
  - High Efficiency
- Very first electric machine was axial flux
- Long track-record of machines in market but to date nobody has managed to get the technology to scale





Benefits of Axial Flux Technology

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- Higher Torque Density
  - The Axial Flux topology allows for more magnetic material to be used for a given machine length
  - This offers the potential for direct drive
- Better Cooling
  - More cooling area
- Higher Efficiency
  - For the same power and speed rating the axial flux machine can be made more efficient than the conventional type due to lower cooling efforts

What is axial flux?

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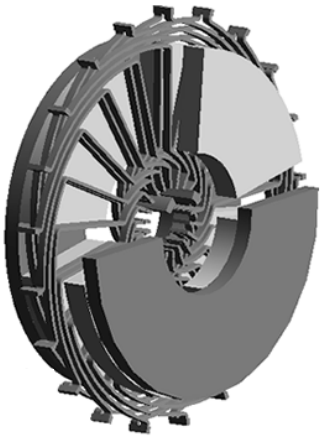

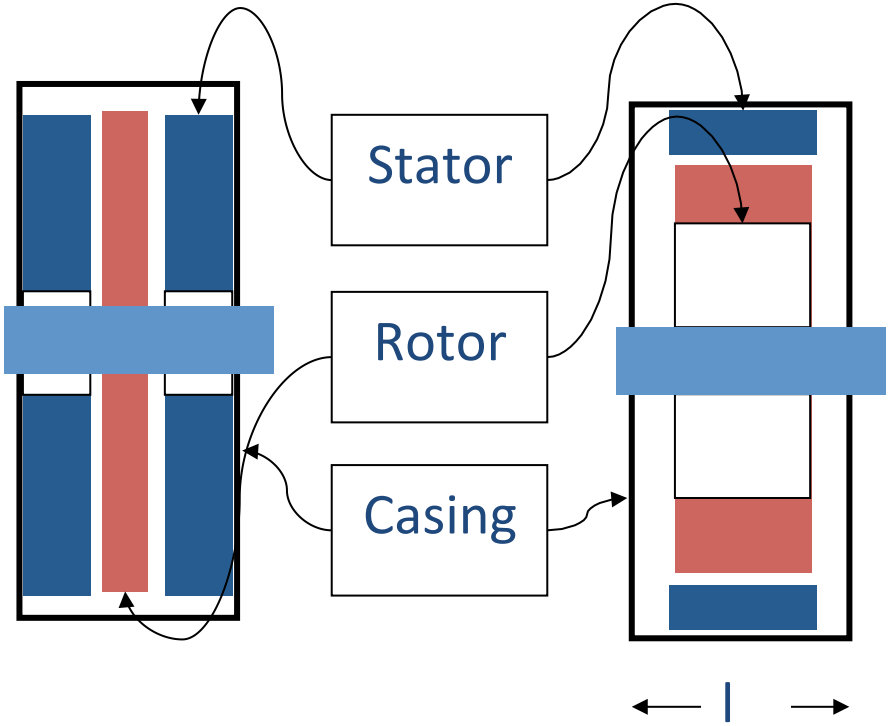

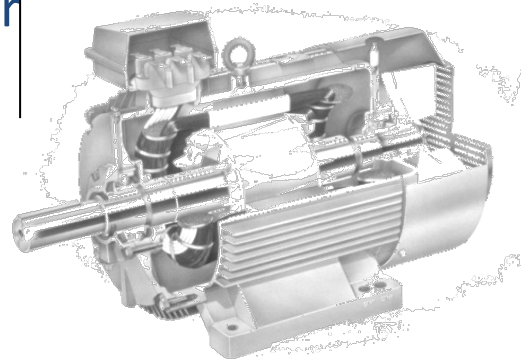

$$T_{axial} \propto \underbrace{r^2\pi}_{stator/rotorarea} \quad r \propto r^3$$

$$T_{radial} \propto \underbrace{2\pi rl}_{stator/rotor\_area} \quad r \propto r^2$$

Axial Flux Components:

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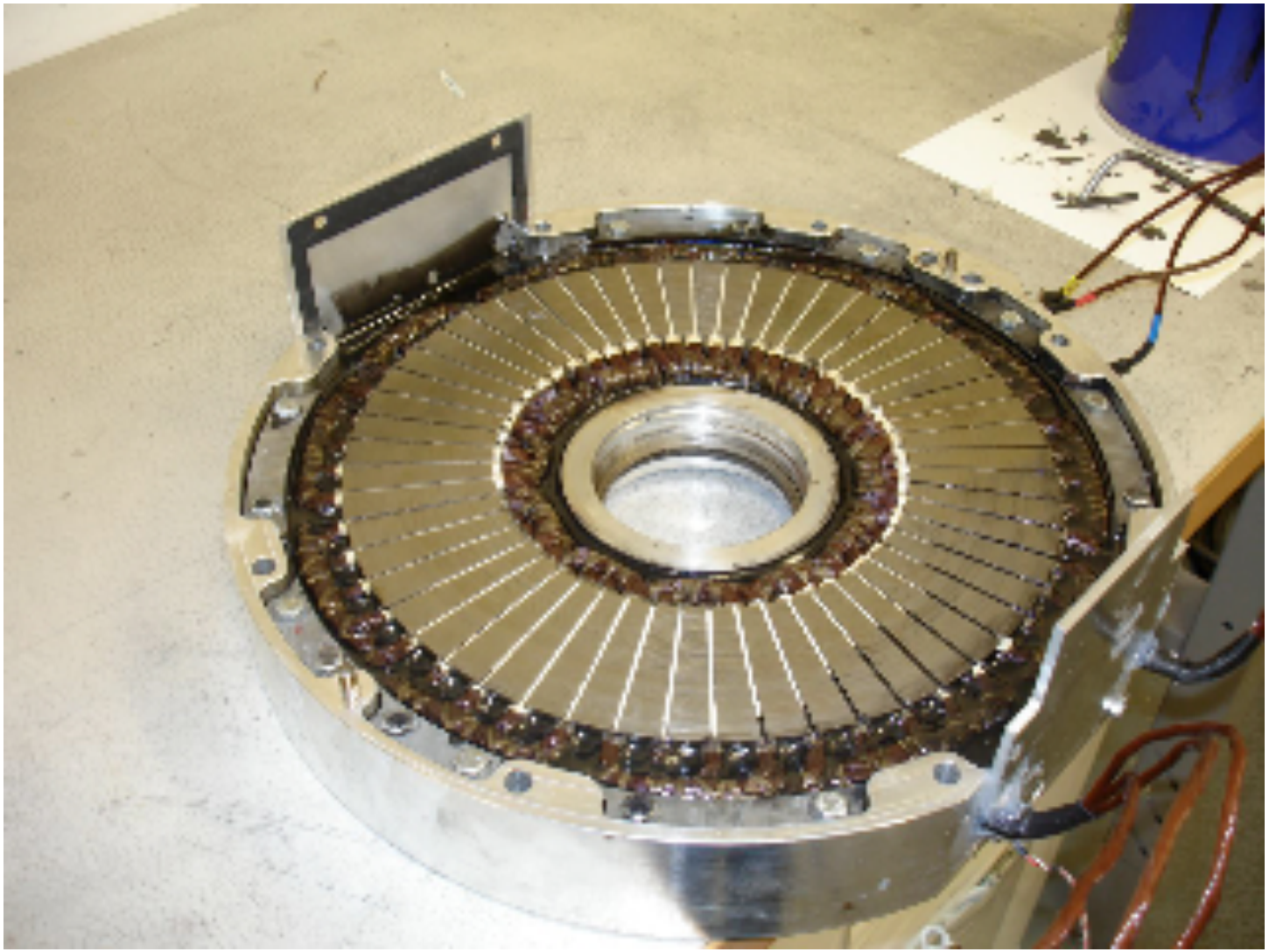

Shape

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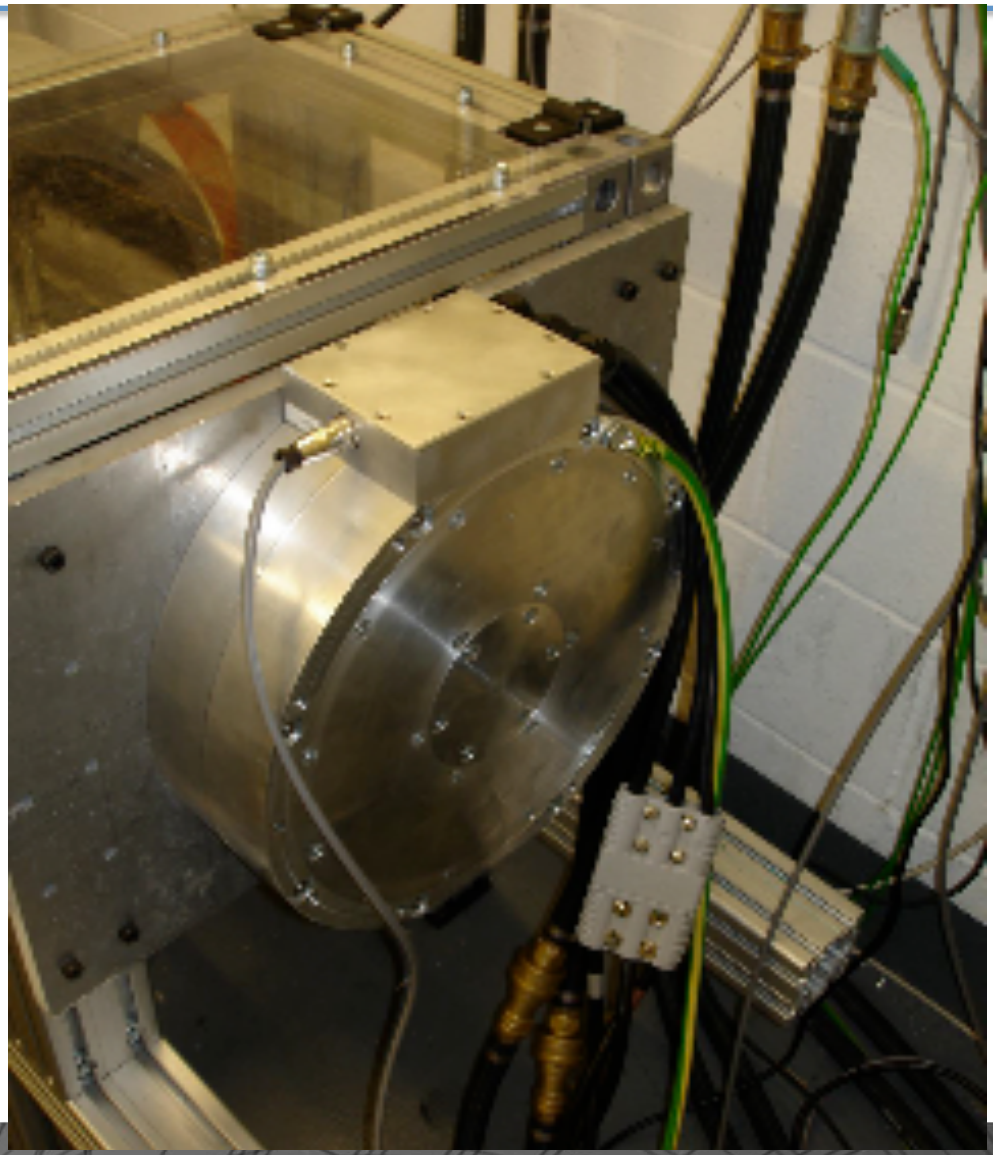

Effect of Radius on Torque

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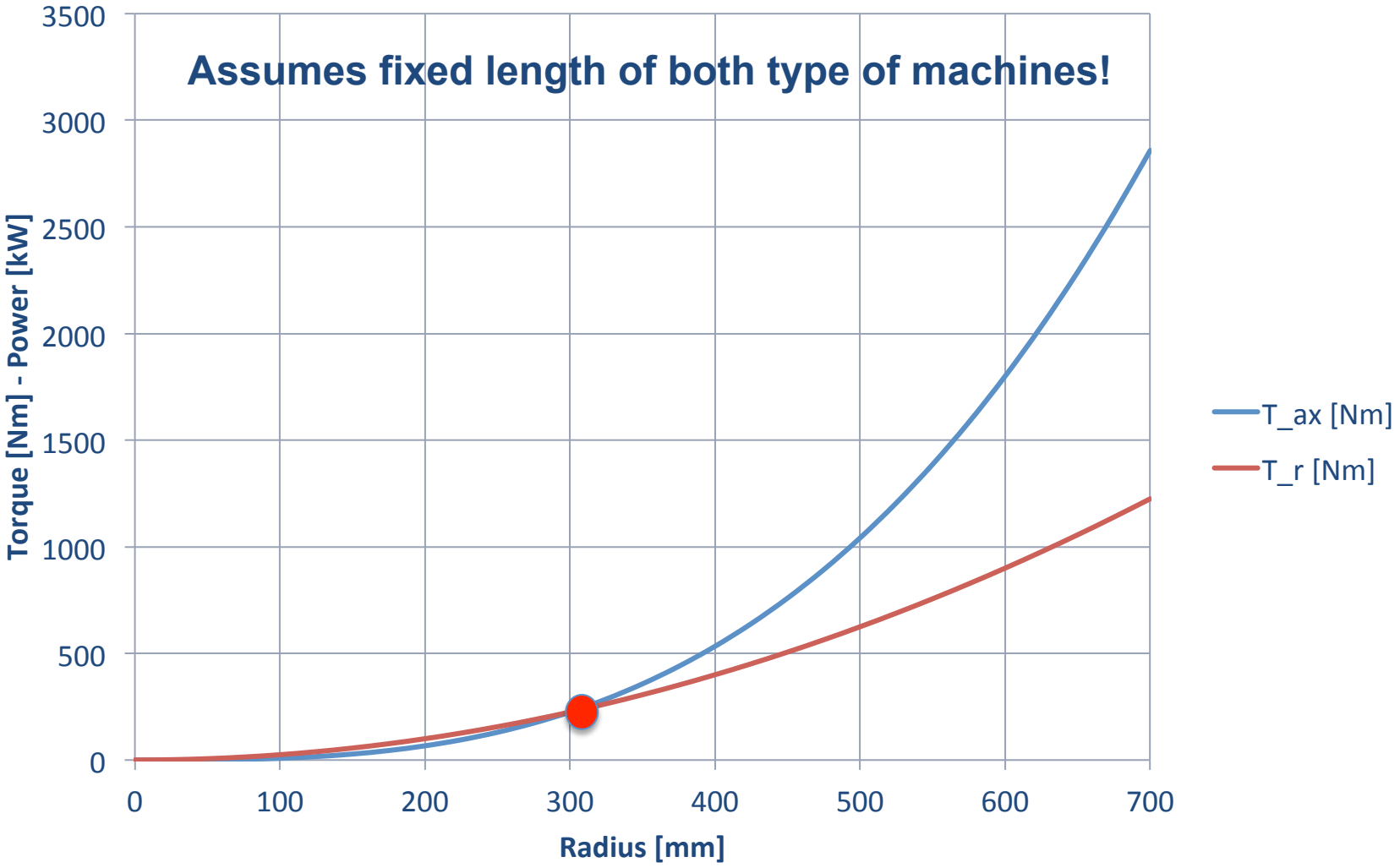

Speed limitations !

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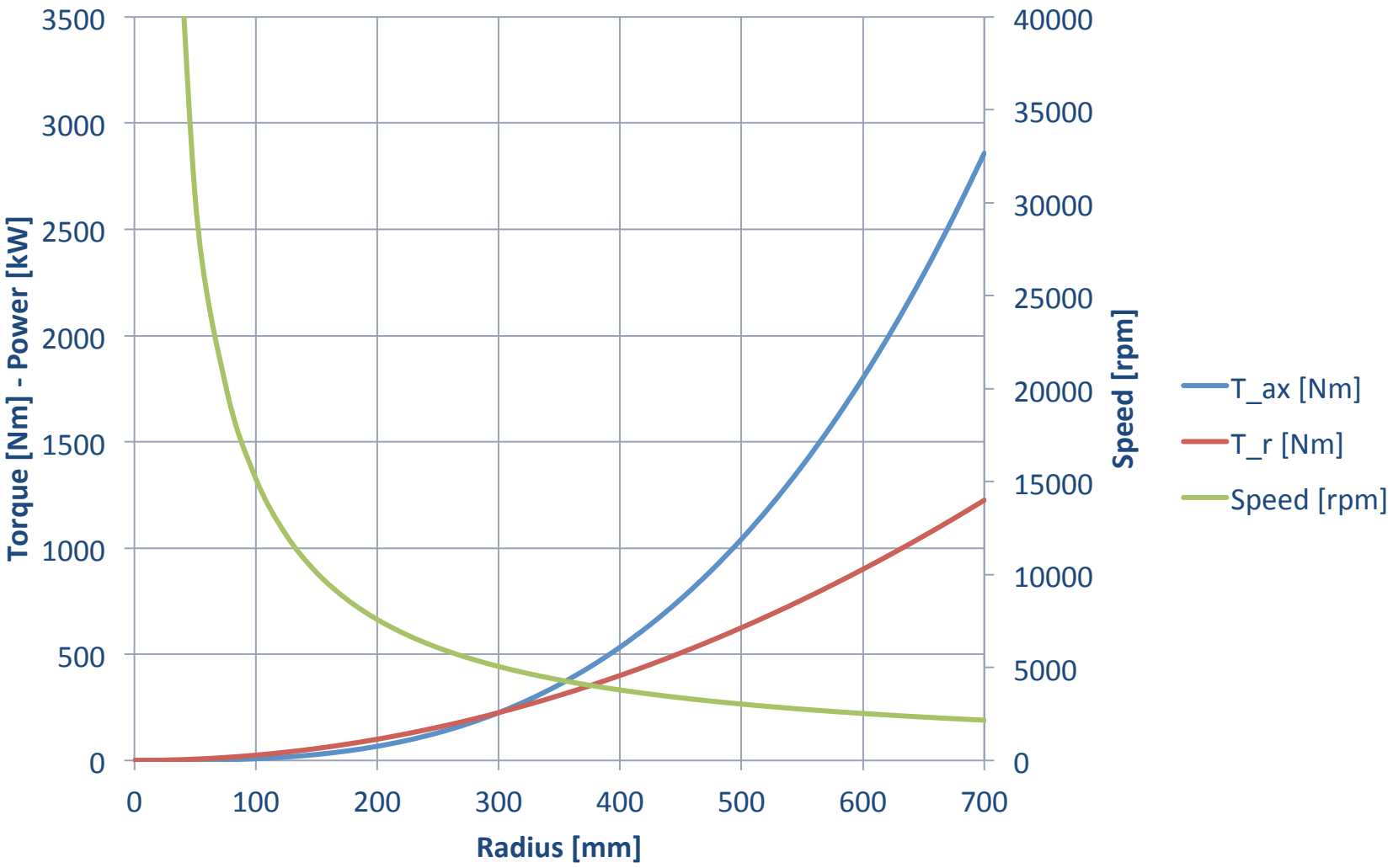

Power!

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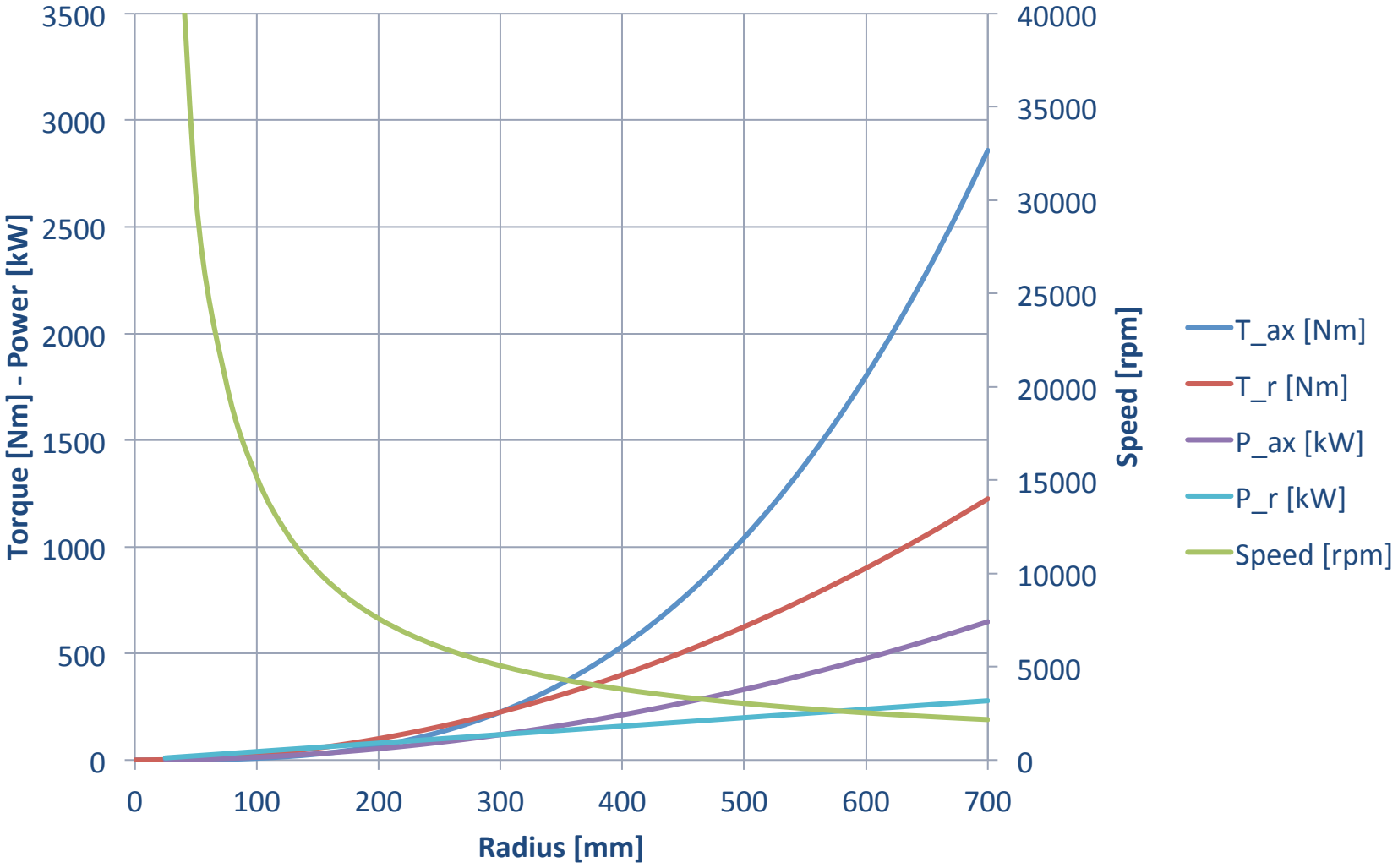

Axial does not always win!

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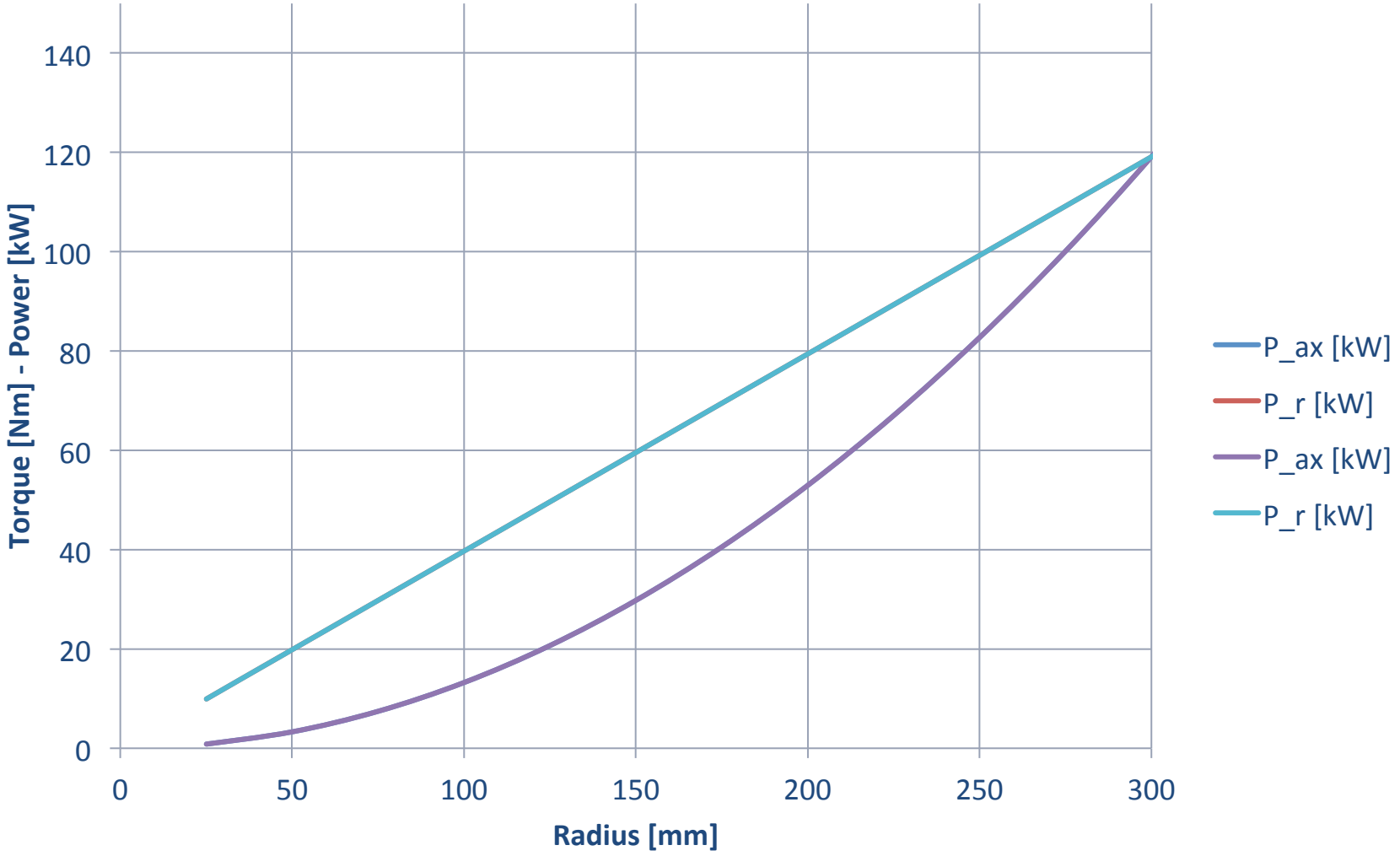

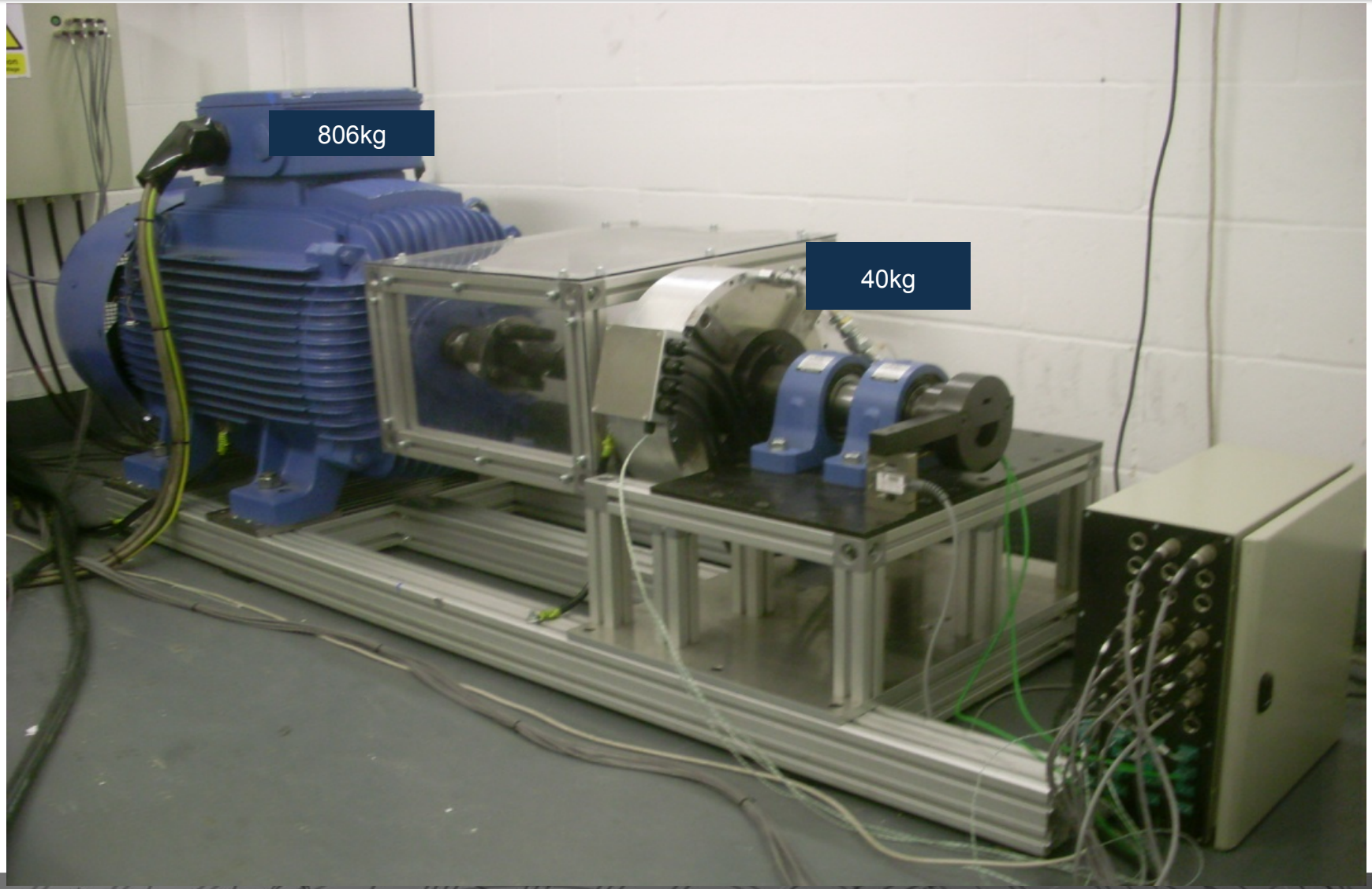

Product Family

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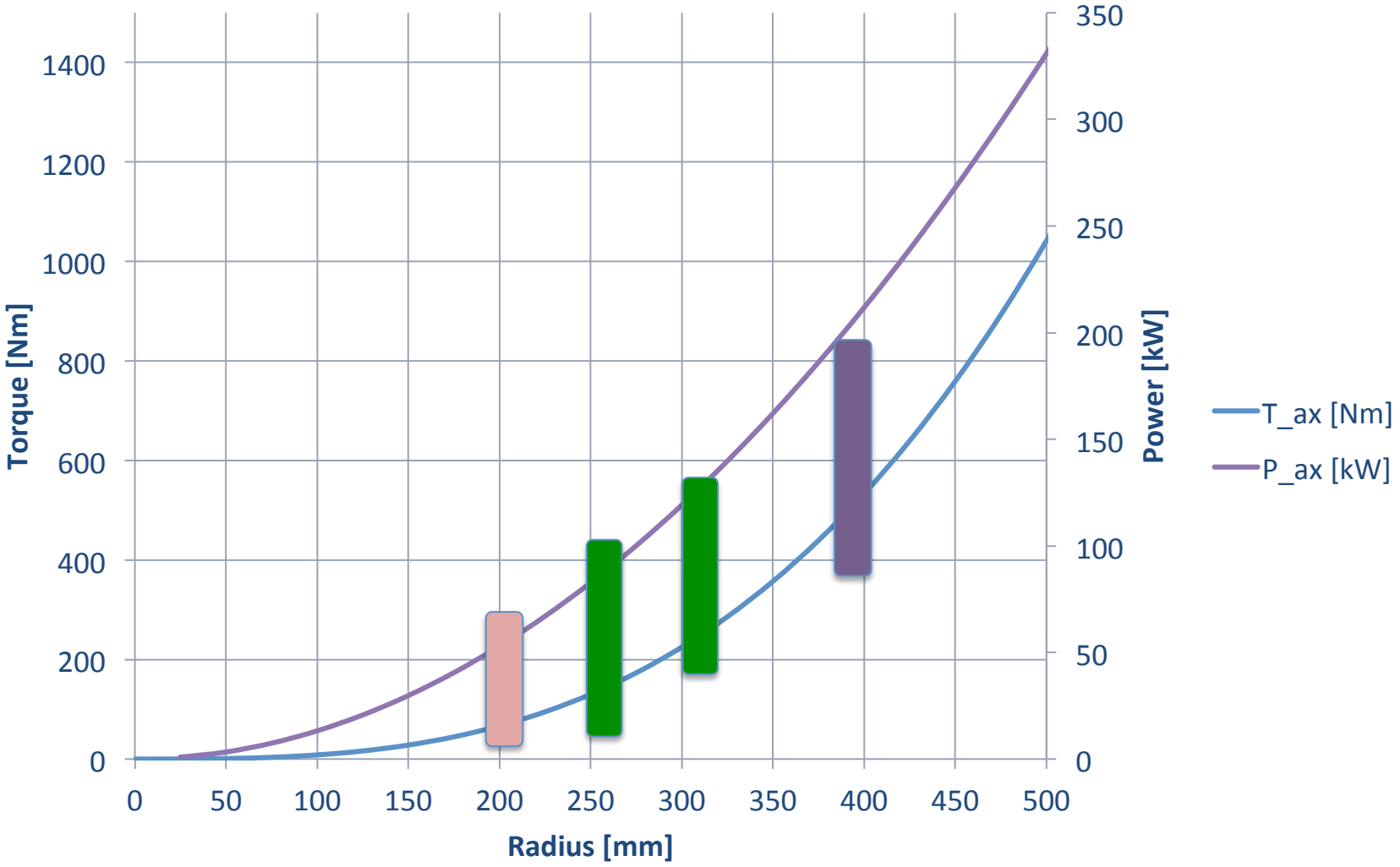

AF140

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EVO Electric offers permanent magnet motors based on proprietary axial flux technology that can be used in conjunction with custom built or standard industrial inverters. AFM type electric motors combine high performance with low weight and size, ideal for electric and hybrid electric vehicles and a wide range of demanding industrial applications.

The AFM-140 motor range has the following key features:

- Very high torque and power density
- Low cogging torque
- Compact design with flat front and back faces for mounting
- Integrated resolver for rotor position feedback
- Vibration tested to military standard
- Liquid cooling for enhanced performance
- Through shaft and customised versions available

Diameter:	**380mm**
Length:	**115mm**
Weight:	**40 kg**

AF240

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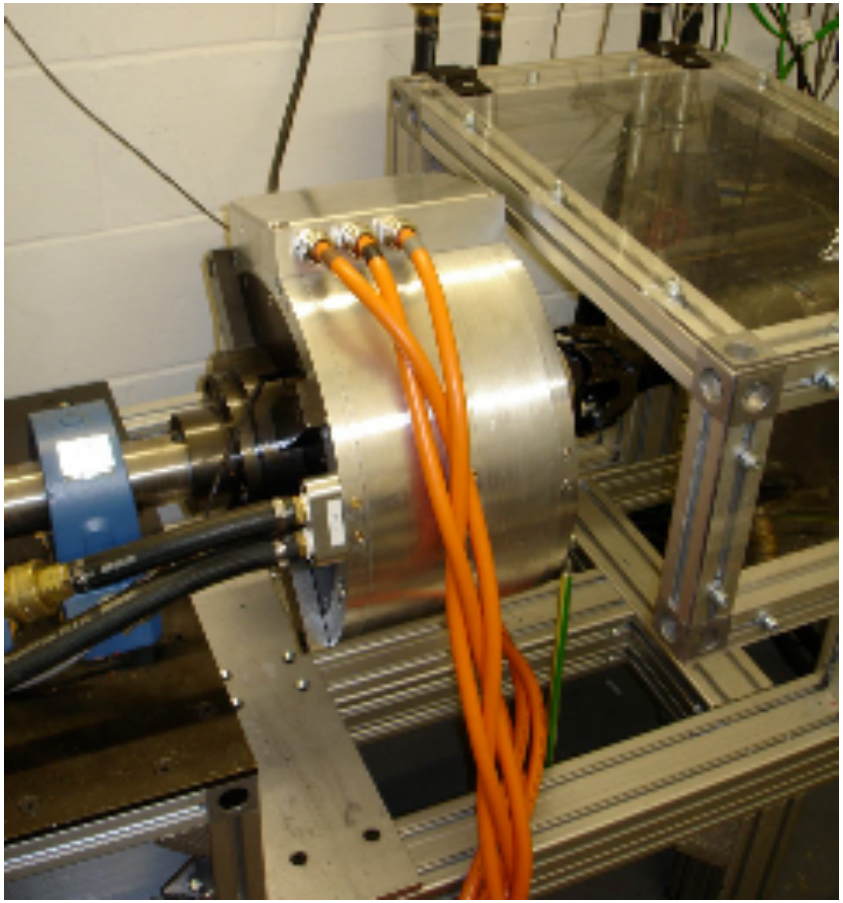

AF130

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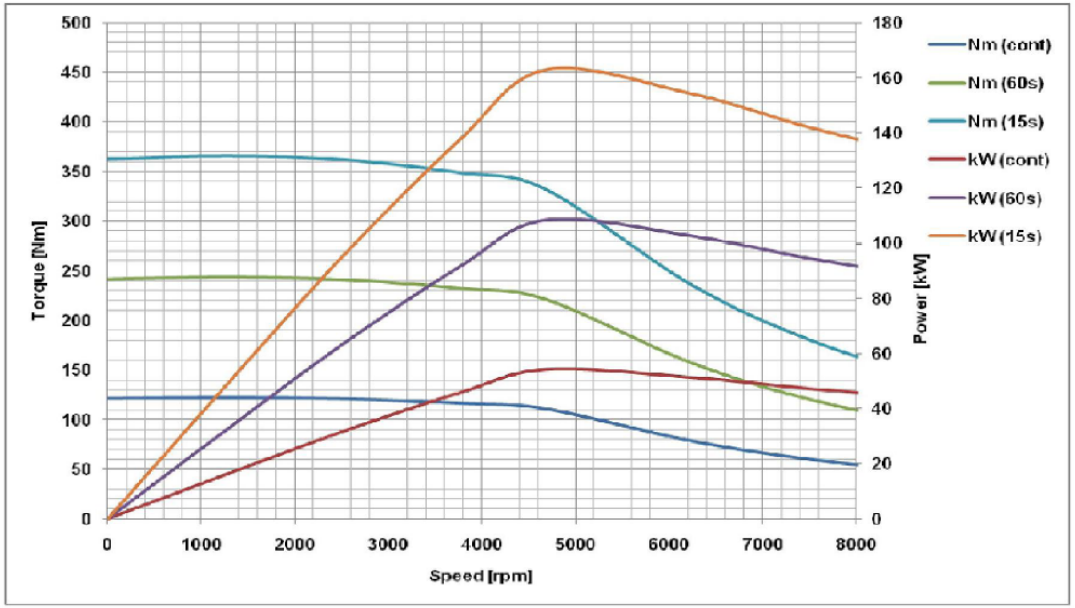

Diameter: **300mm**
Length: **115mm**
Weight: **28 kg**

Direct Drive Solution -

racing green ENDURANCE
Newsletter Issue 01 – Jan 2010

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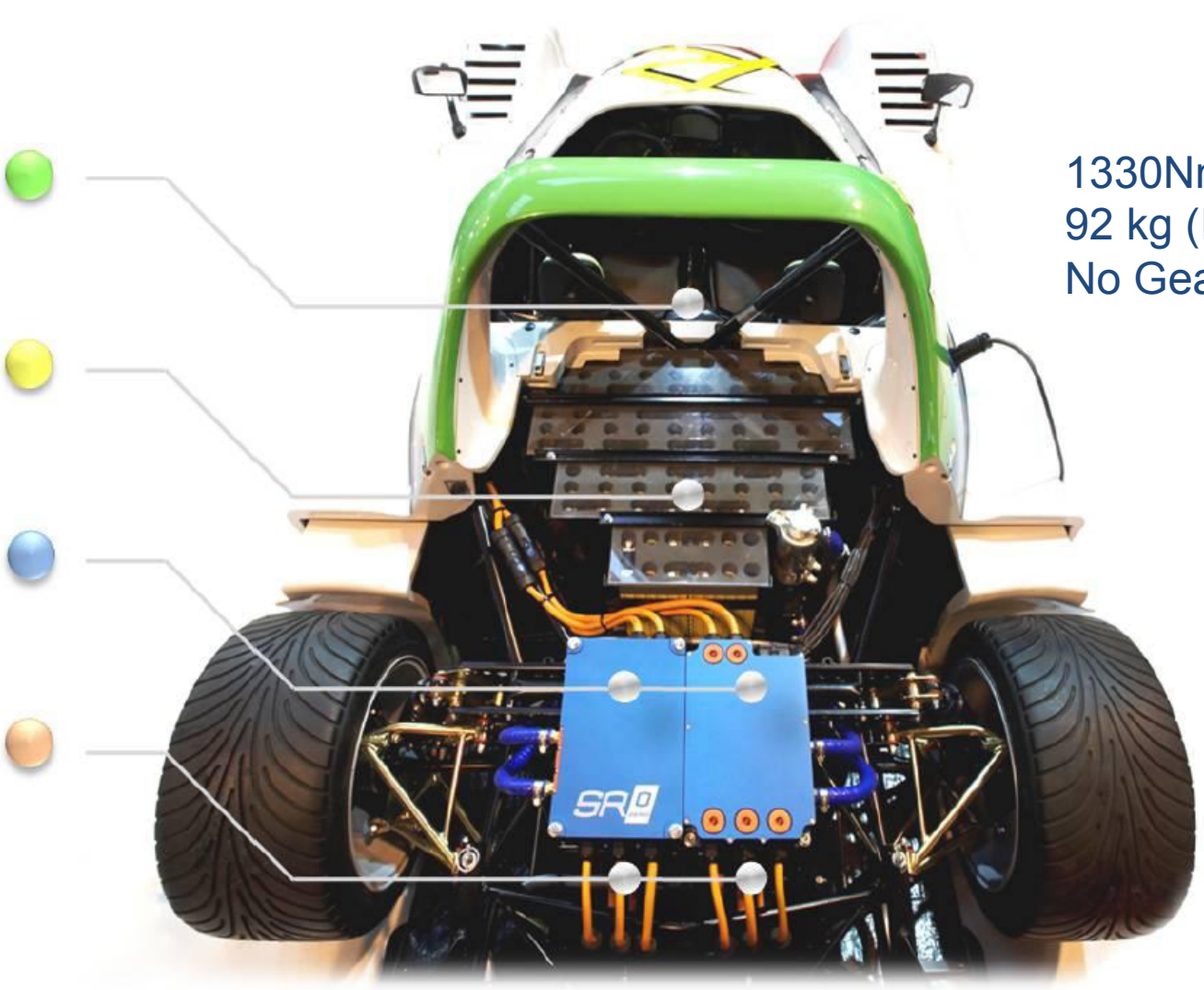

1330Nm Peak Torque
92 kg (Inverters and Motors)
No Gears!

and in real live …

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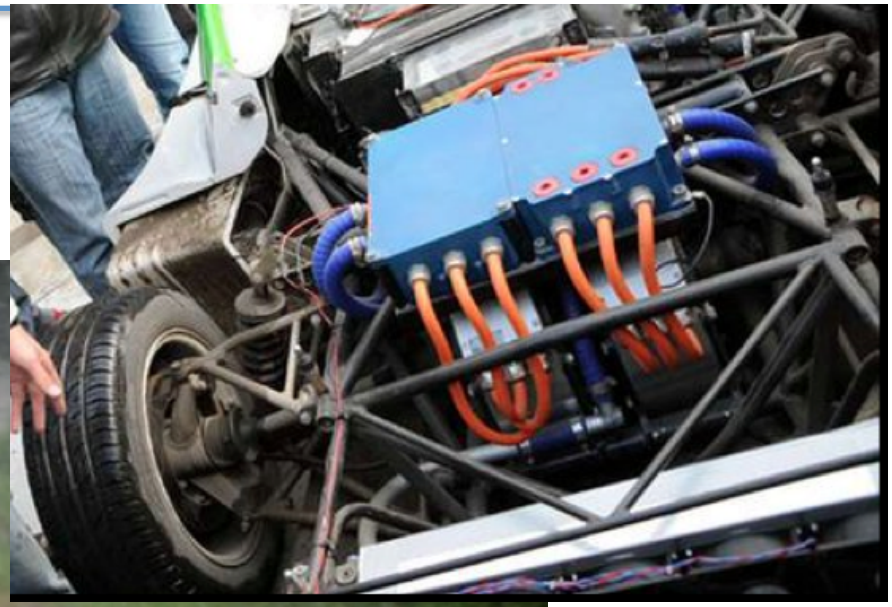

Direct Drive Solution

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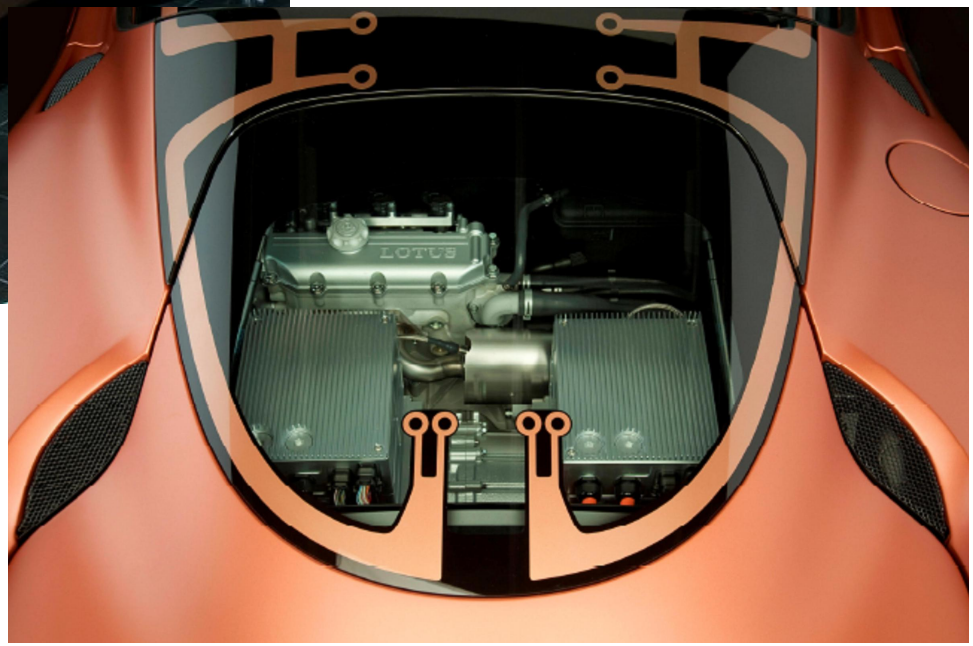

Van Direct Drive

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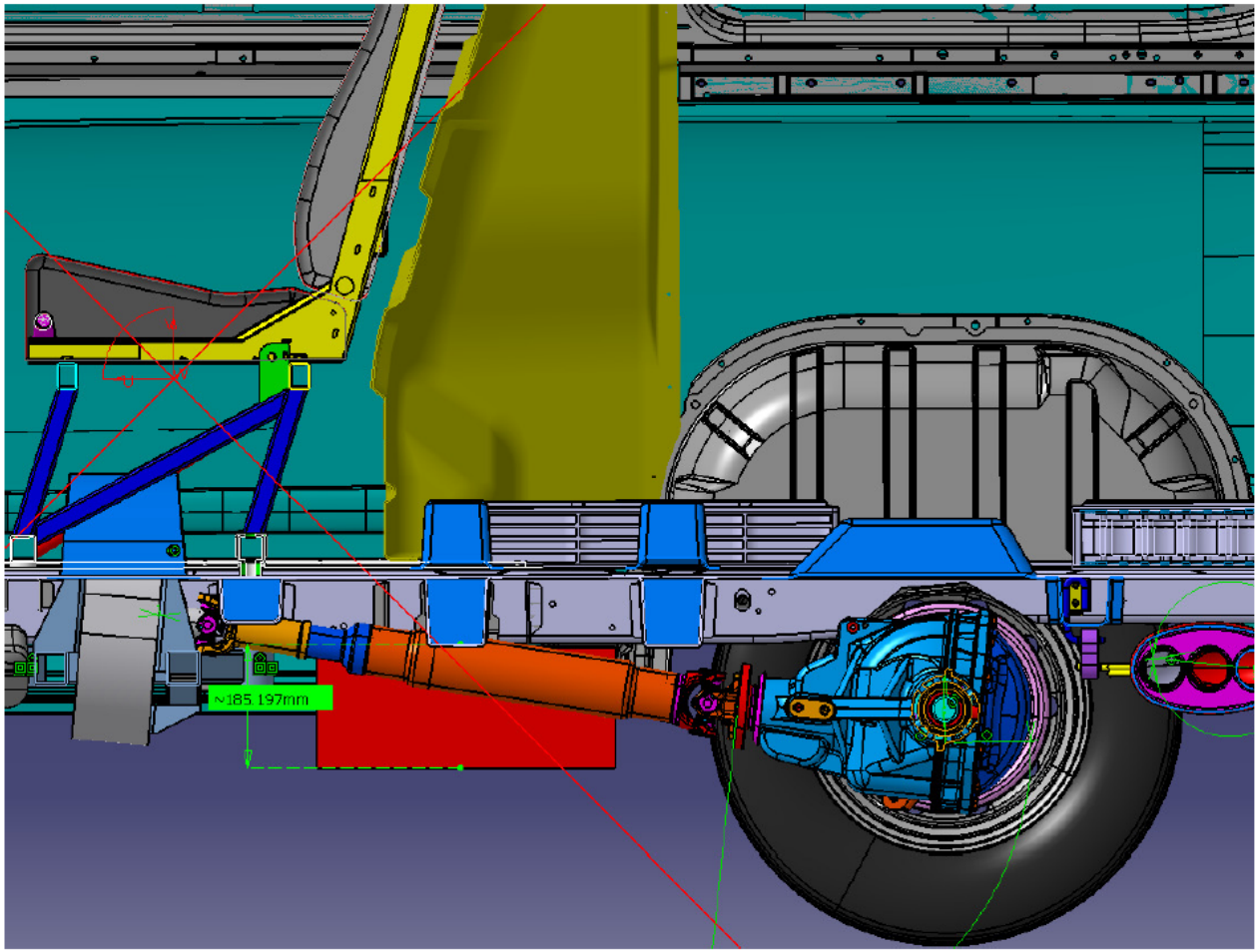

EVO Hybrid DuoDrive

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Dual Mode without the gears

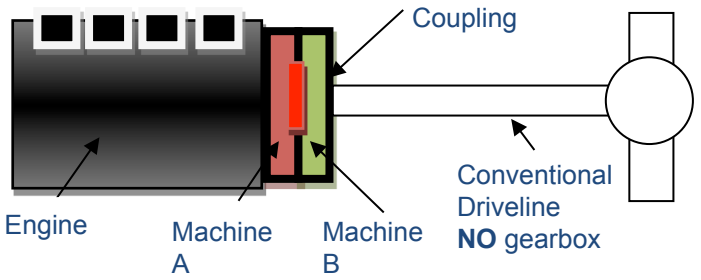
= A two stage machine with added internal clutch

Only possible with the short length of EVO's machines

Several possible modes of operation:

- **Series hybrid mode**
- **Parallel mode**
- **All electric mode**

An **optimal hybrid** system for various applications
Including:
delivery vehicles, taxis, buses, &heavy duty trucks



Approx dimensions for a 3.5t vehicle: Diameter 450mm, Length 330mm, Weight ~140kg

DuoDrive – Installation

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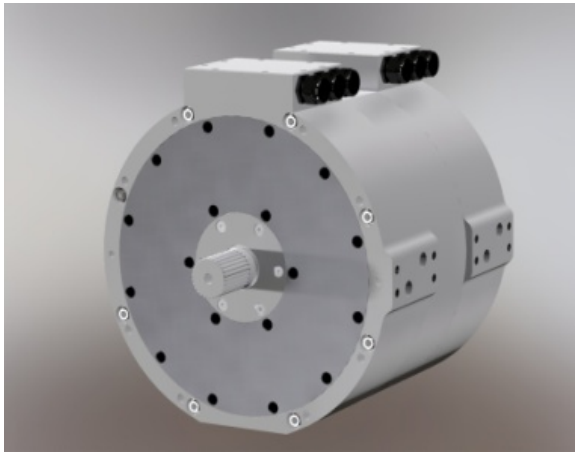
Duo Drive motor drive / generator unit



AF140 Motor	200Nm
Peak Torque Output	400 Nm
AF140 Generator	72kW
Peak Power Output	145kW

Mahle Dynamometer

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Mahle Dynamometer Results

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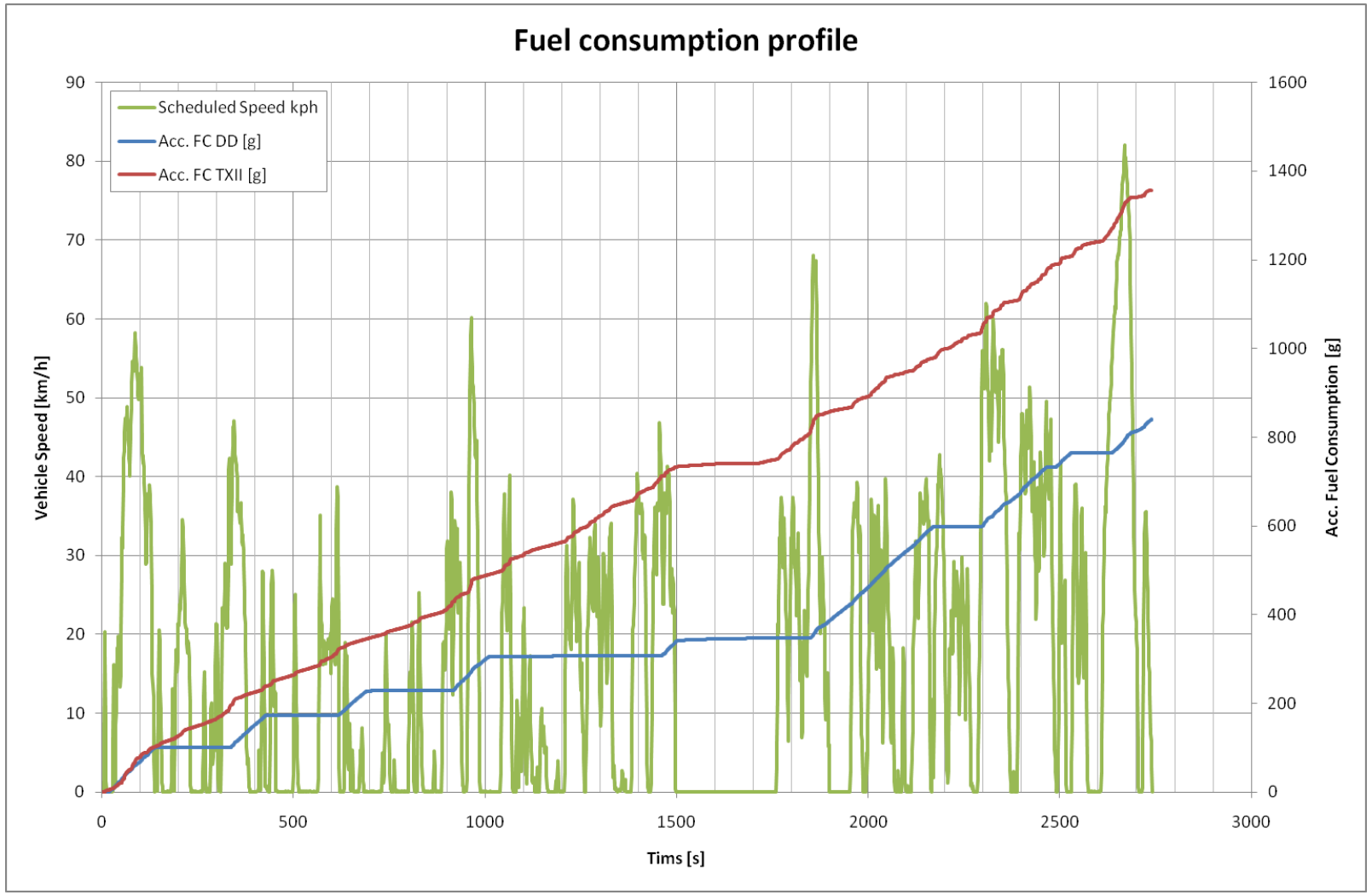

Fuel Used on Cenex Cycle

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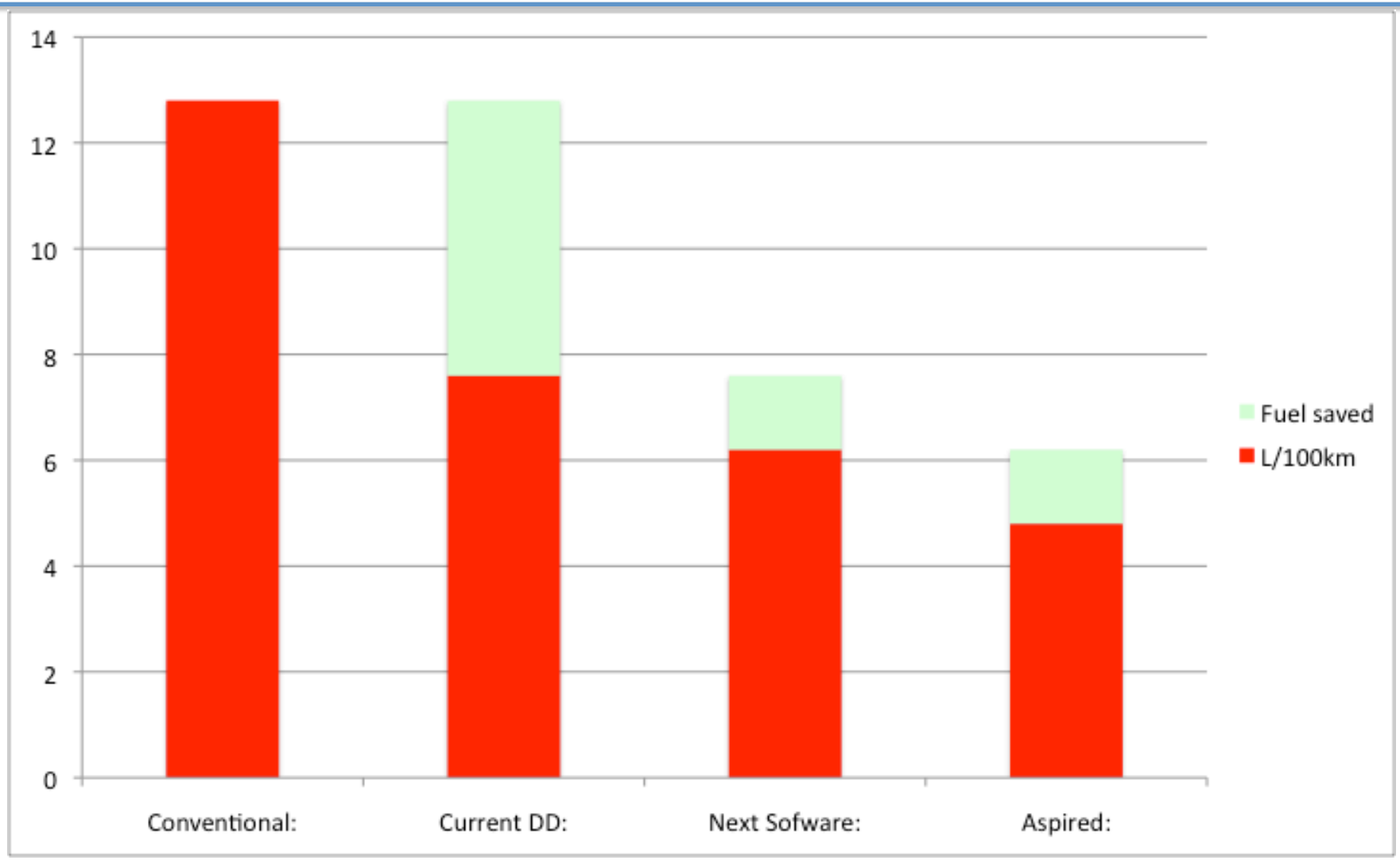

Summary

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- Series/Parallel Hybrids are not new - but usually complex
- By using high torque motor gearboxes can be omitted and the system simplified
- Axial Flux machines allow for very short power train structure helping with vehicle integration.

Teams make it happen!

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