



The future of electric machine development

Emerging trends in the design of automotive traction machines

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Our Home: The Institute of Sustainable Mobile Powertrains

- 3 principal engineers, 10 permanent staff, 21 PhD students
- 13 test cells dedicated to powertrain testing at up to 700 kW
- All energy carriers (fuel, electricity, H₂) available for research
- Workshops for machining, electronics and chemicals

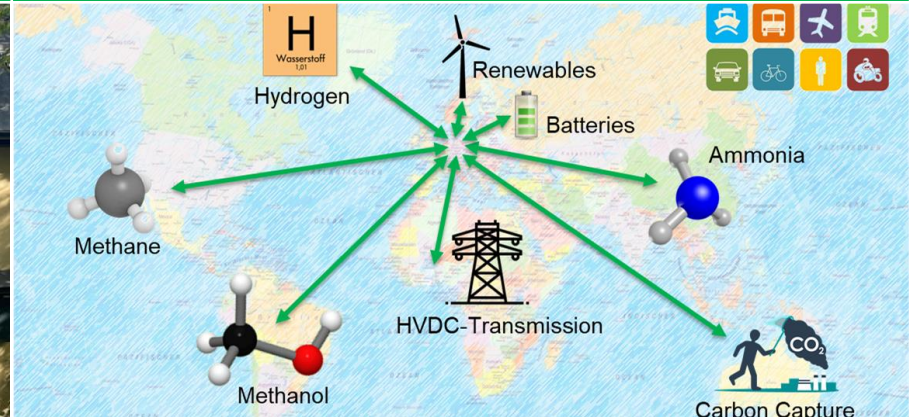
Our History: 87 Years of Research in Powertrains

- 1936 – 1945: Research Institute for Aircraft and Vehicle Engines
- 1945 – 2004: Institute for Combustion Engines and Vehicles
- 2004 – 2021: Chair of Internal Combustion Engines
- 2021 – **today**: [Chair of Sustainable Mobile Powertrains](#)

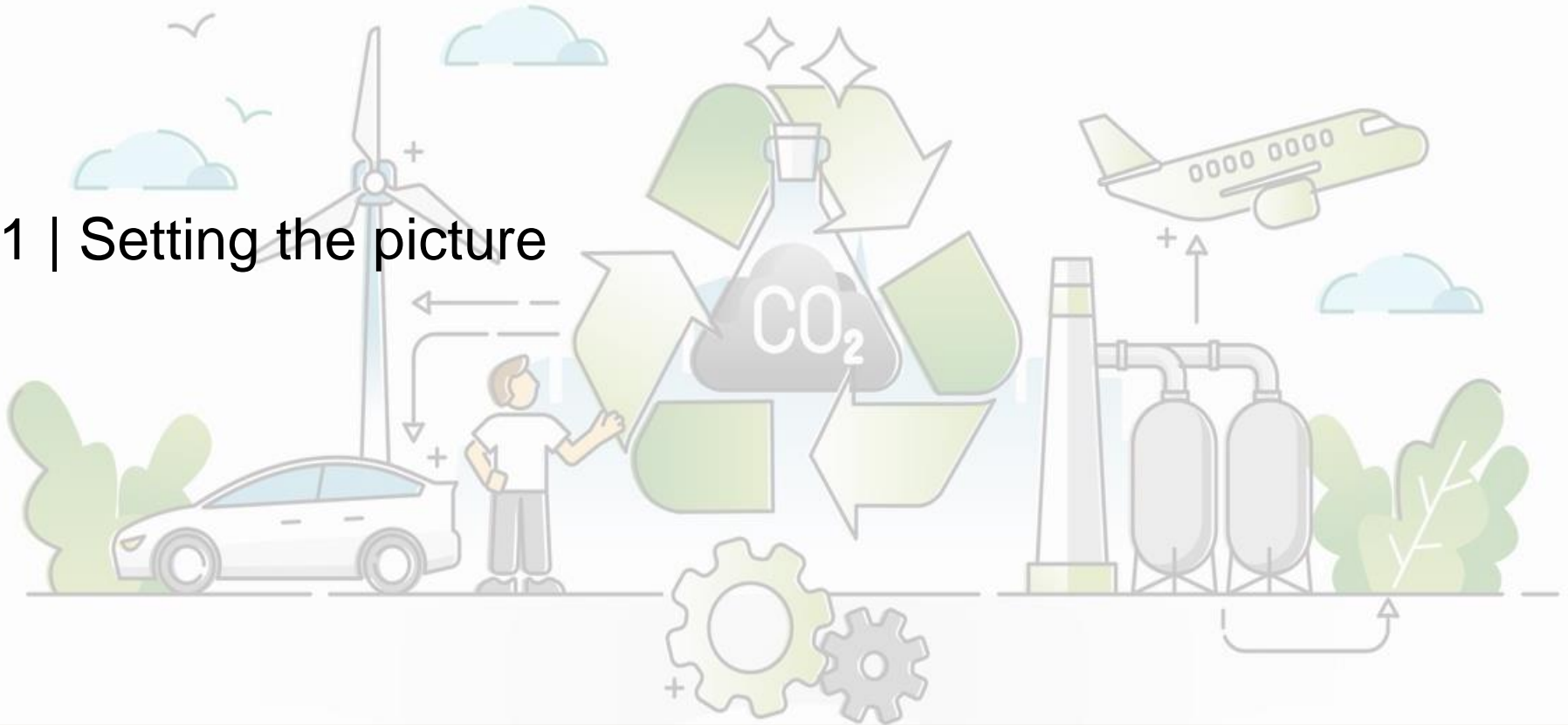
Our Location: Schragenhofstr. 31, Munich, Germany



Our Research Focus: Energy and Mobility of the Future

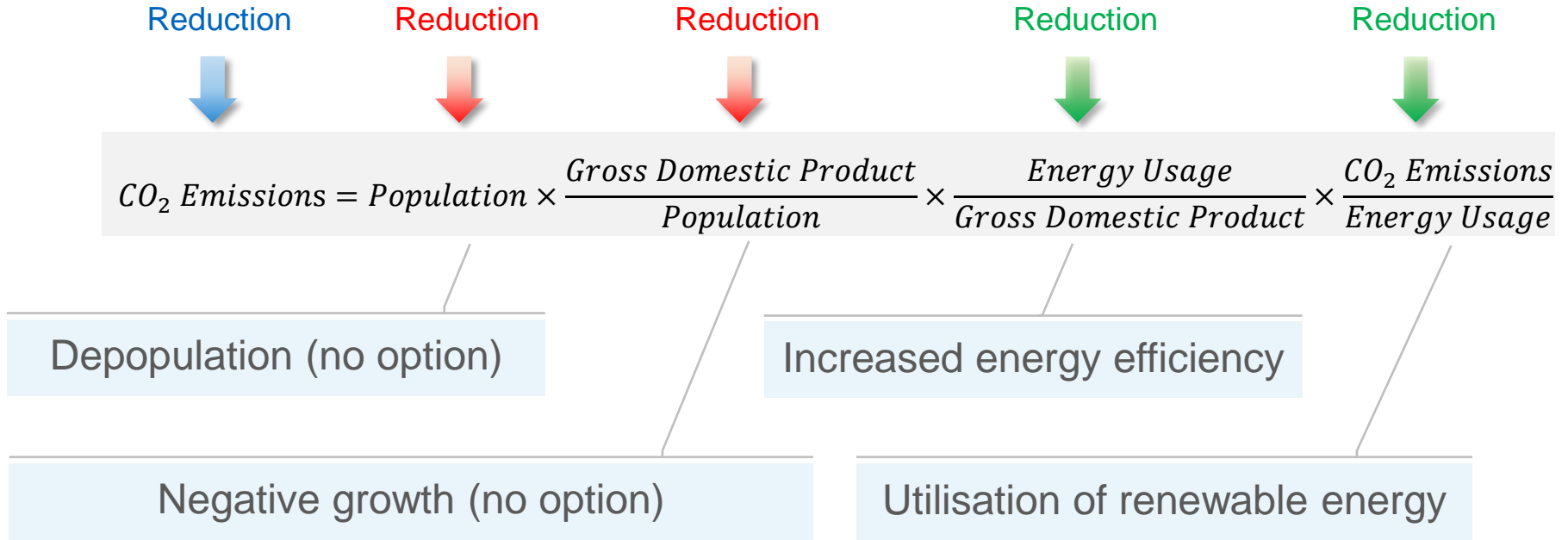


1 | Setting the picture



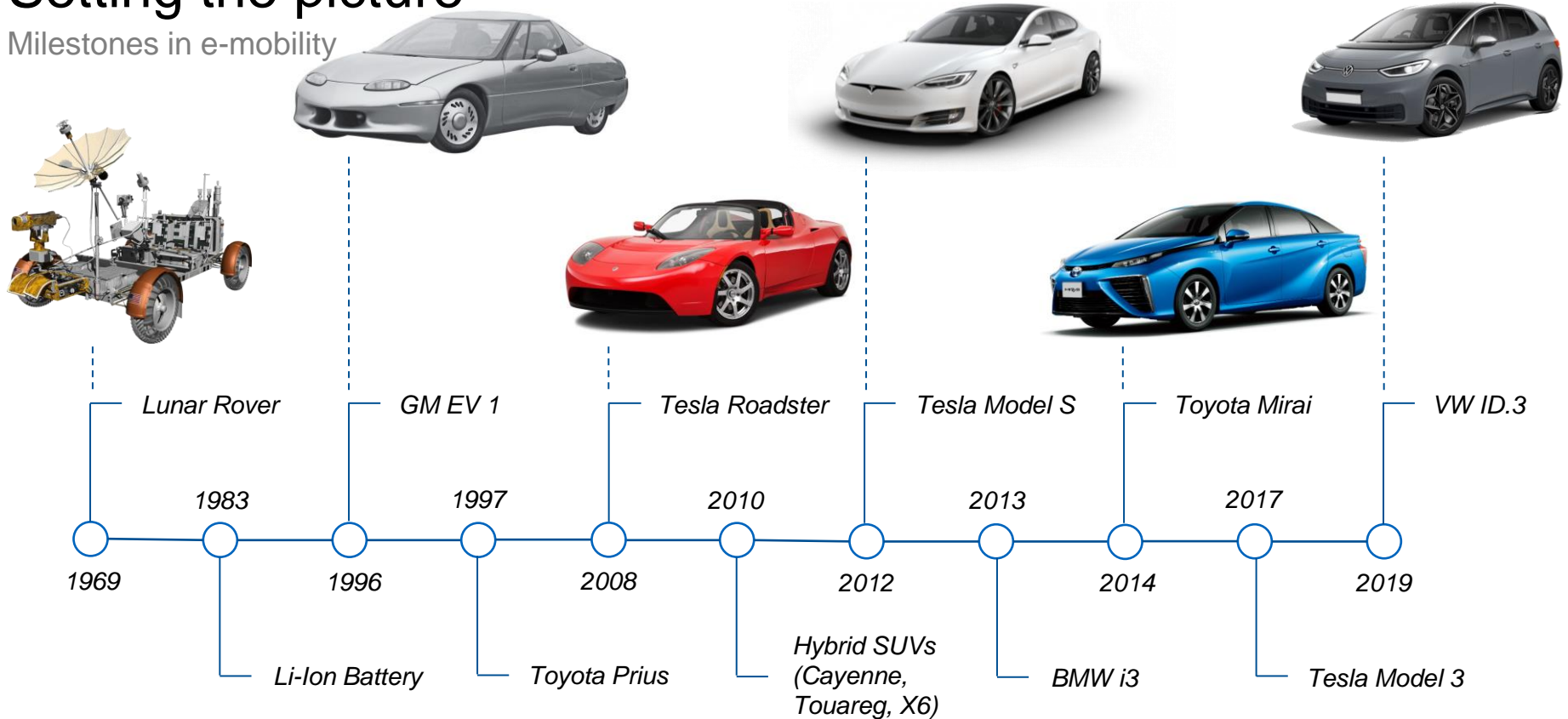
Setting the picture

Electric mobility as a means of CO₂ reduction (Source: The Economist, Yoichi Kaya)



Setting the picture

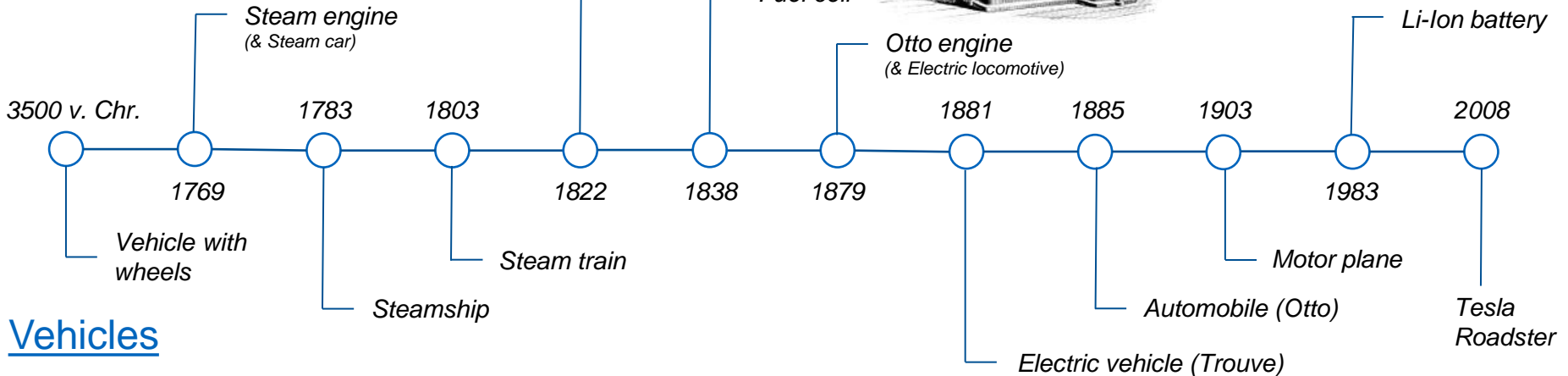
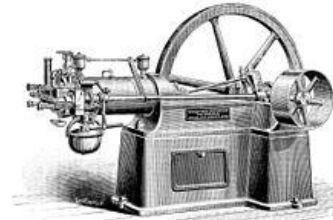
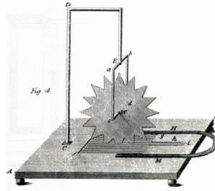
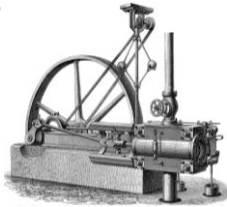
Milestones in e-mobility



Setting the picture

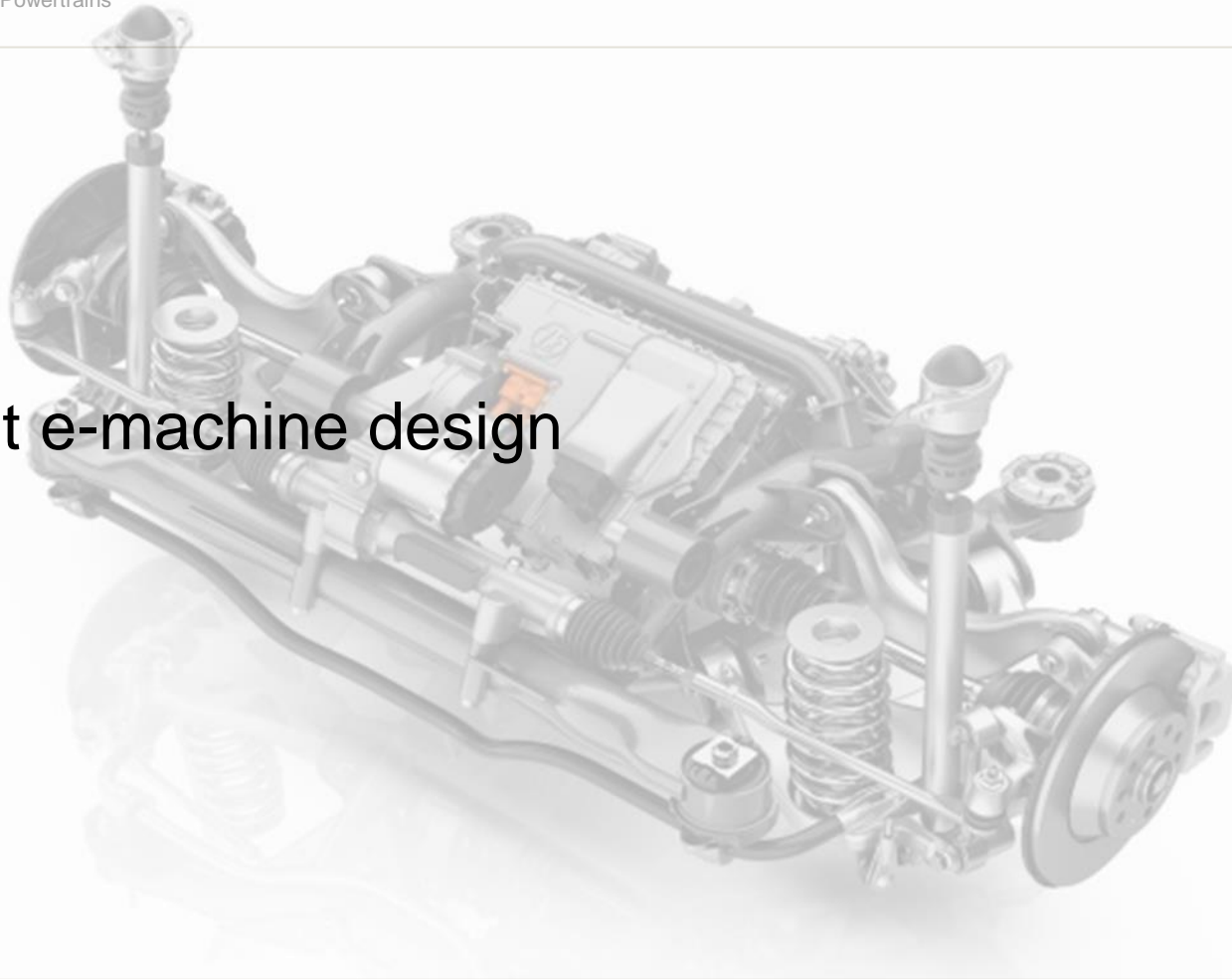
Milestones in powertrains and corresponding vehicles

Powertrains



Vehicles

2 | Current e-machine design



Current e-machine design

The last 15 years has seen a flurry of innovation in electric machines (Image sources: Mitsubishi, Lucid Motors)

- At the beginning of the 21st century, the electric motor seemed mature, with little potential for improvement
- The advent of e-mobility brought with it a hitherto unprecedented focus on efficiency, performance and cost
- Billions of dollars in automotive R&D fundamentally changed the e-motor and the way it is developed

Mitsubishi i – MiEV e – Motor (2011)



Peak Power	47 kW
Speed	10,400 rpm
Weight	30 kg
DC Voltage	330 V

Lucid Air e – Motor (2021)



Peak Power	410 kW
Speed	20,000 rpm
Weight	34 kg
DC Voltage	900 V

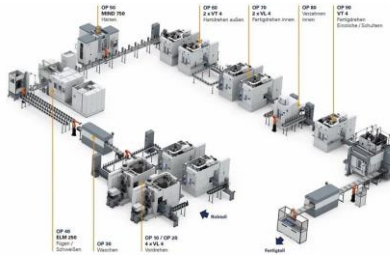


Current e-machine design

Electric motor development trends



Speed increase



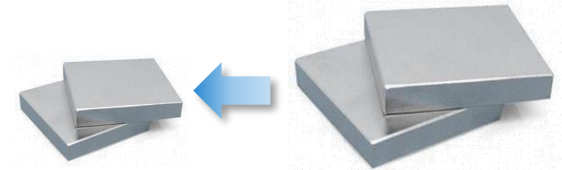
Fully automated production
(Source: Automobil-produktion.de)



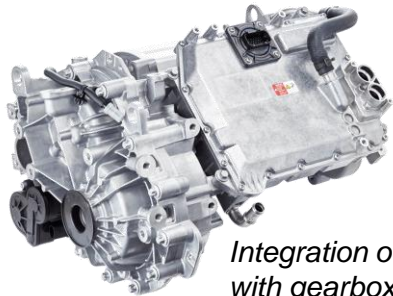
Hairpin windings
(Source: Additive Drives)



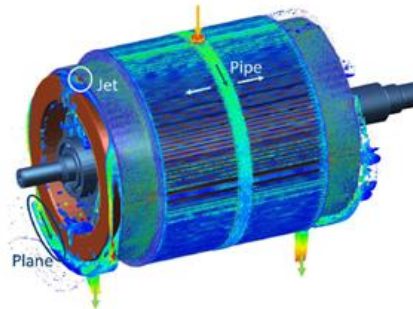
Increase of DC bus voltage



Reduction of magnet material
(Source: Porsche Engineering)



*Integration of electric machine
with gearbox and inverter*
(Source: Vitesco)

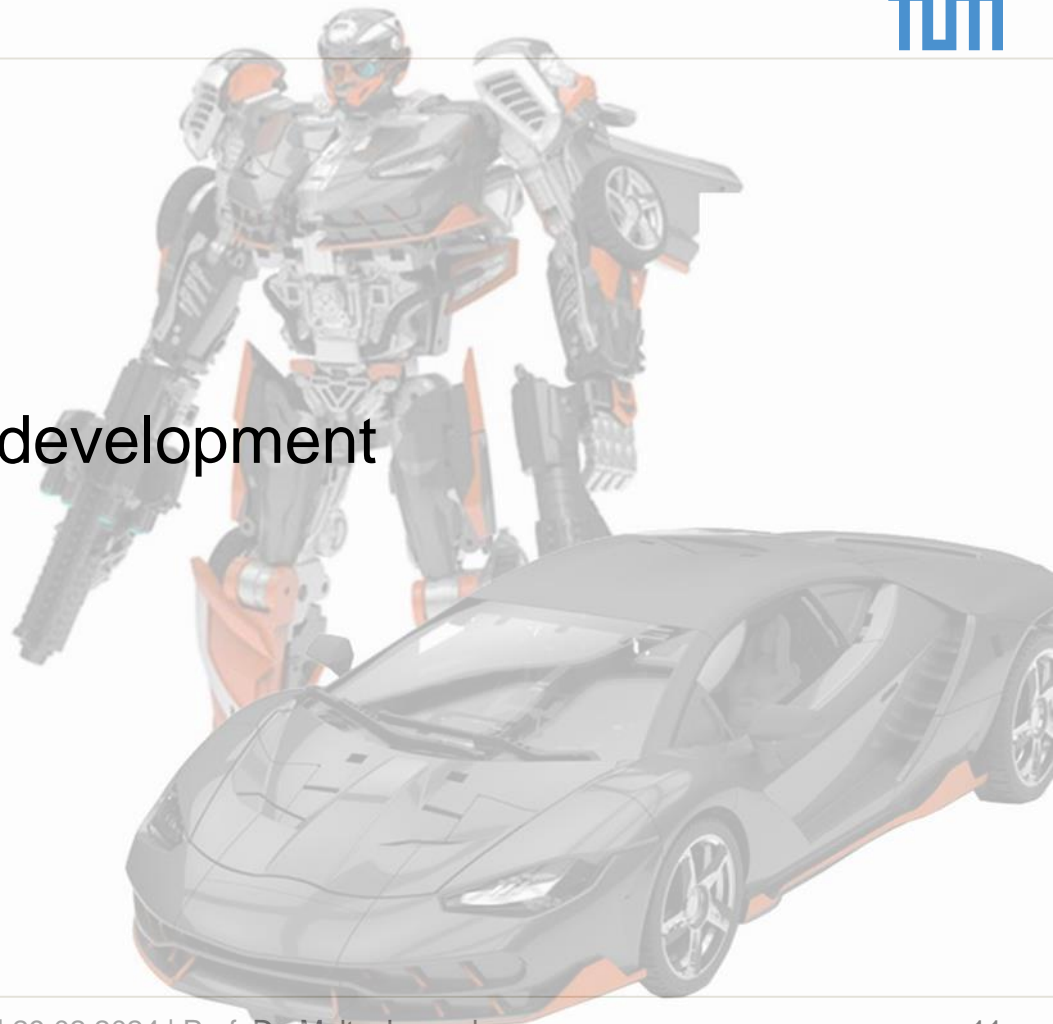


Direct oil cooling
(Source: Enginsoft)



New motor topologies
(Source: Continental, Deep Drive)

3 | The future of e-machine development



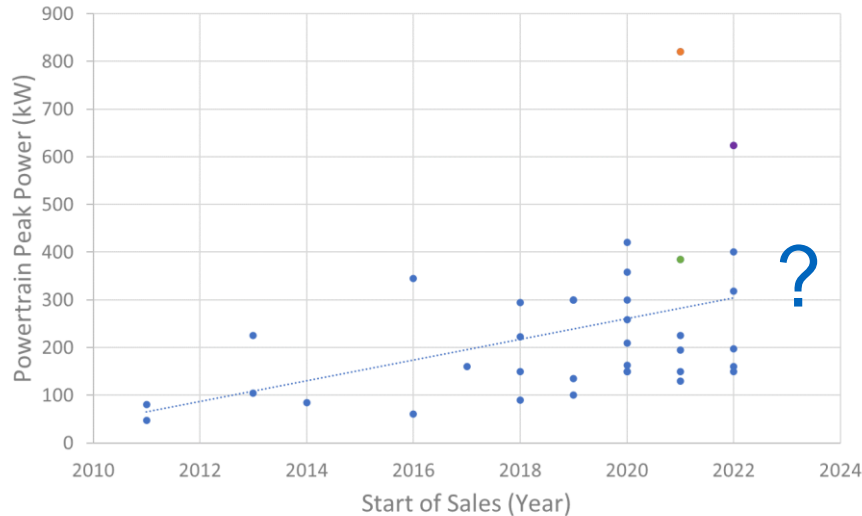
The future of e-machine development

More performance

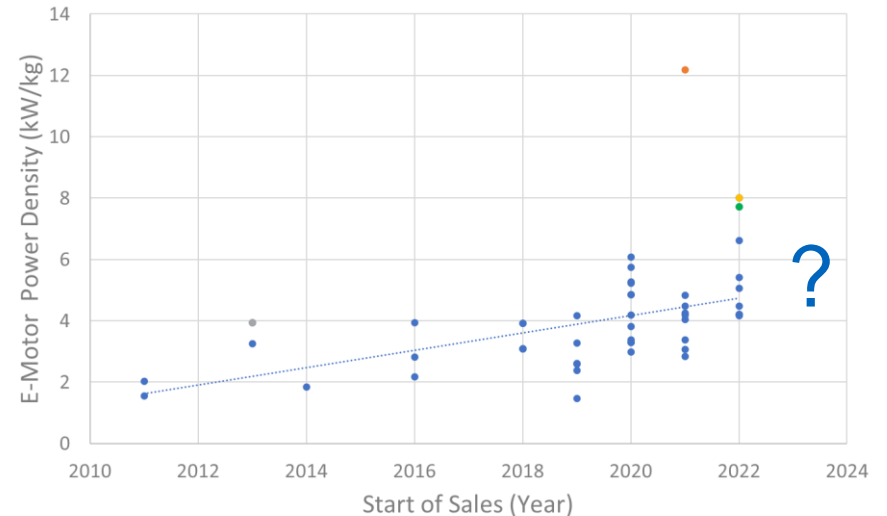
- Analyses based on A2MAC1 database, comprising more than 60 e-powertrains

Higher power
Higher speed
Higher voltage

Lower weight
Lower volume
Lower cost



Powertrain peak power vs. vehicle market entry (Source: NMA & A2MAC1)



E-Motor power density vs. vehicle market entry (Source: NMA & A2MAC1)

The future of e-machine development

More intelligence ... just not exclusively of the human kind

- Optimisation of development, production and testing through AI-supported modelling and simulation
- Continuing mechanical, thermal and electrical integration of all relevant powertrain components
- Sustainability as a core requirement affecting design and material choices in e-machine development



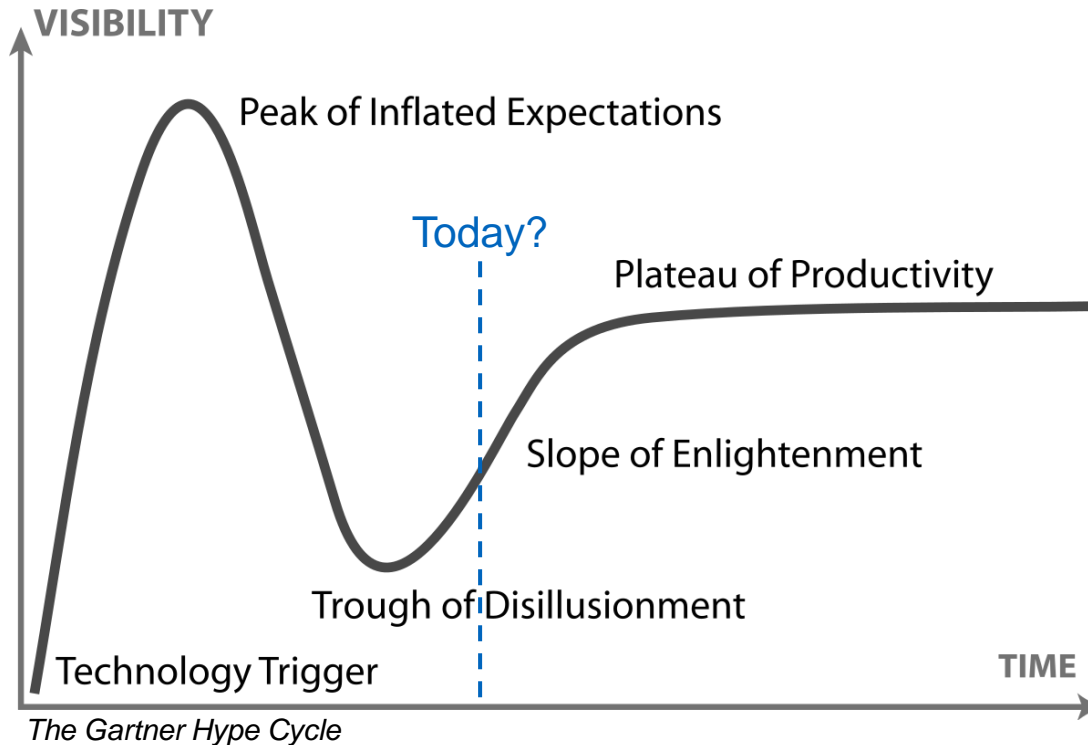
Highly integrated powertrain of the BMW iX (Source: BMW)



Impression of areas influenced by artificial intelligence (Source: IoT Times)

The future of e-machine development

Will autonomous vehicles turn electric powertrains into a commodity?



Possible implications of autonomous driving for electric powertrains

- Increased demand
- Increased cost pressure
- Increased standardisation
- Less customer attention
- Less performance
- Dominant design emerges

➔ **Commoditisation of the electric powertrain?**

The future of e-machine development

Will a „Dominant Design“ emerge and will this commoditise the electric traction motor ?



Tailor-made electric traction motor
(Source: Bosch)



Commoditised electric motors
(Sources: Amazon, Indiamart)

Thank you for your attention!

