@FUTUREBEV
KEY CHALLENGES IN WBG ENABLED AUTOMOTIVE POWER ELECTRONICS

INPUTS TO HIGH EFFICIENCY DRIVETRAIN

EA-4-UK

@FUTUREBEV APC15

APC & Partner backed Project started 2020 running till 2024

Collaboration of UK talent to enable and accelerate BEV technologies

BMW Transfer of knowledge to UK based design team

Key goals:

Accelerate technologies for BEV powertrain

- Development of standardised power module
- Agnostic architecture for power module (power of choice)
- Flexible architecture for powertrain Inverter core component

Enable path to vehicle CO2 reduction

Shortening of powertrain development cycle

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Designing next generation powertrain in UK

- Team focused on delivery of SiC based 800V inverter solutions for BMW
- Development of highly integrated system
- Key goal for best in class efficiency, no compromise

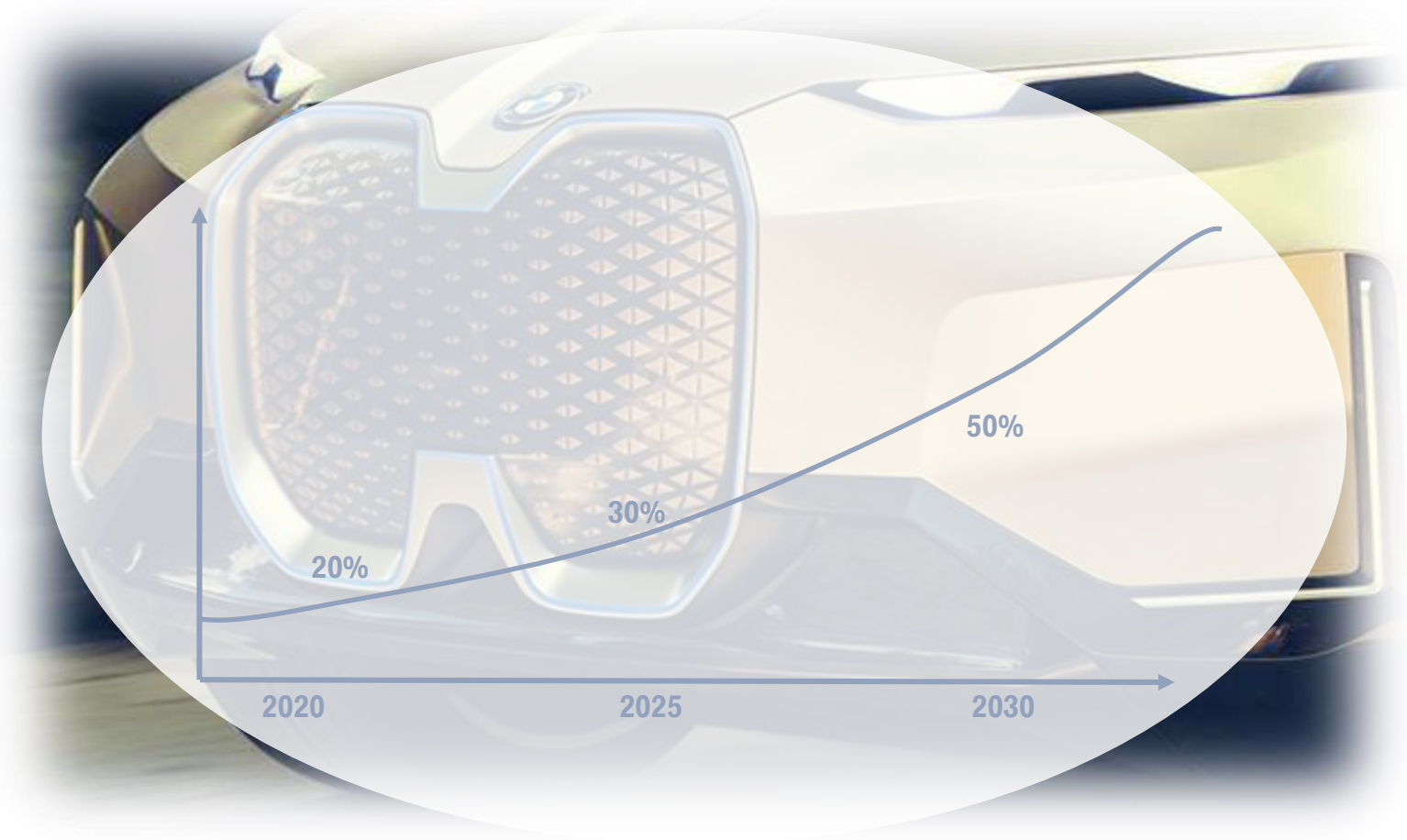
Development of strategy for standardised power module

- Cross discipline expert group from Academic to Design, Manufacture and vehicle
- Capture of Automotive specific requirements for FutureBEV
- Delivery of innovative design with target for high efficiency automotive powertrain

Partners:

- APC
- BMW
- CSAC
- University of Warwick
- Custom Interconnect Ltd
- Lyra

Why? Continuous increase of demand (BEV vs. ICE)



How to align development cycle to emerging technologies?

Future-proofing vehicle architecture?

Delivering best in class with protection for rapid changes in technologies?

Reduction of high development and qualification cost?

Customer acceptance, transparent technologies

BEV Enabling Technologies

Goals v Technologies

Effective range and WLTP
Efficiency Wh / km
Delivering range by efficiency or powertrain

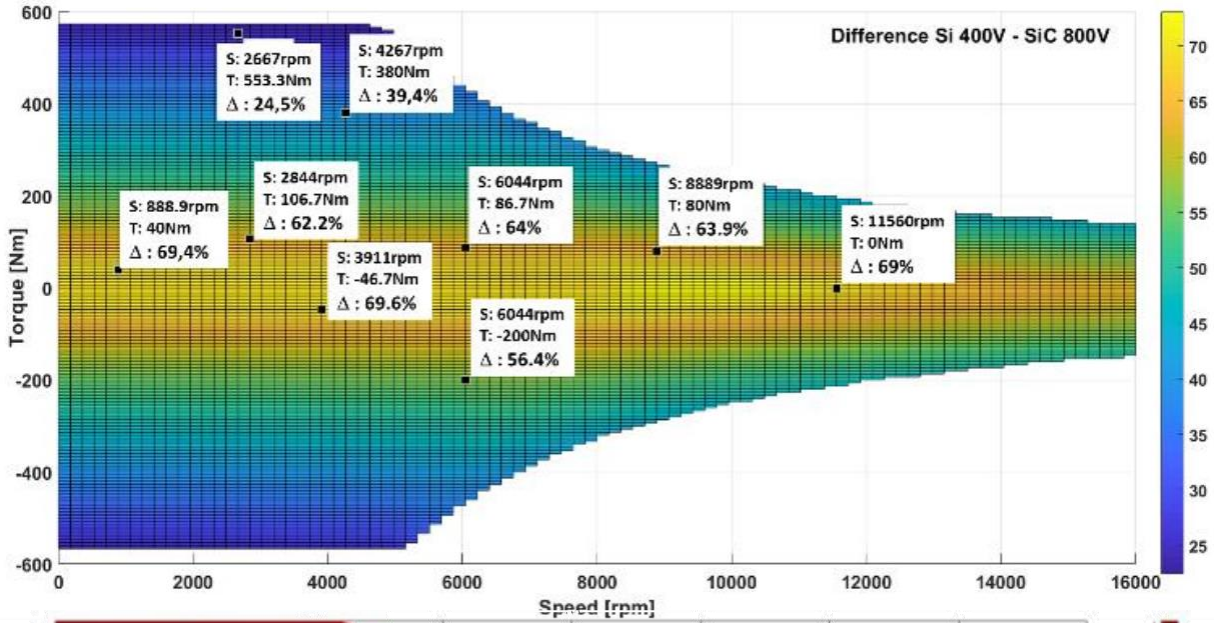
@FutureBEV focus Battery to wheel efficiency:

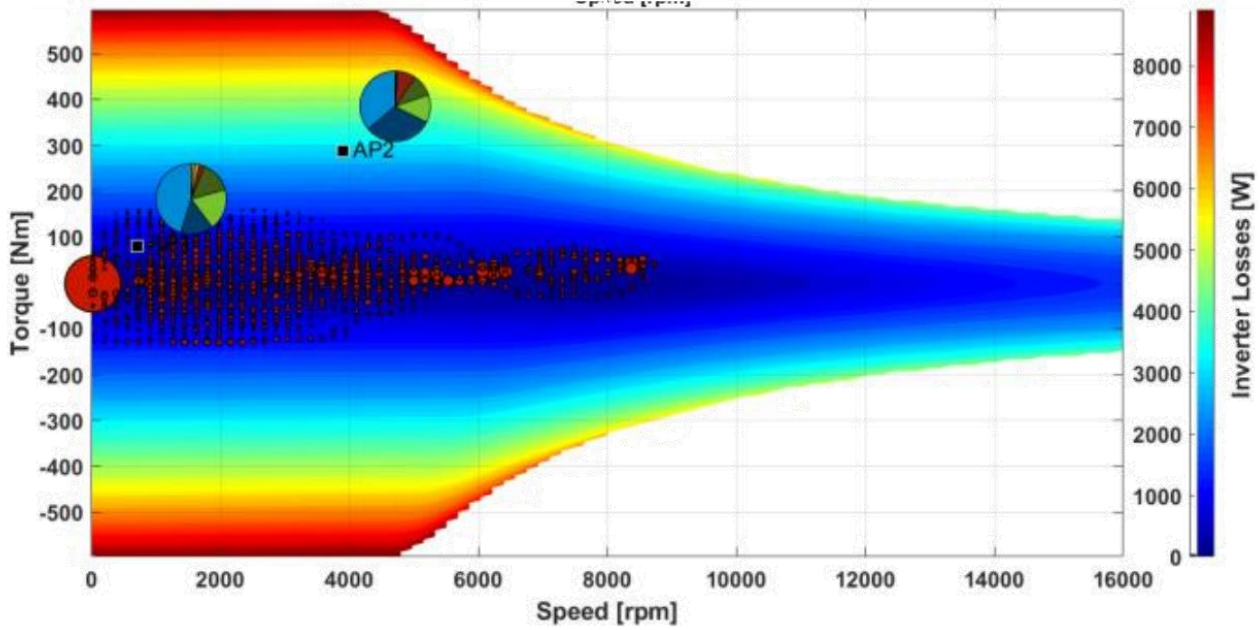
- Energy transmission 400V → 800V system benefits
- Energy DC → AC conversion and switch efficiency
- Electrical → Mechanical conversion, electric machines

Power electronics and smart software has a large role to enable 800V and reduced switching losses.

INVERTER NERD STUFF! (BRINGING IT TOGETHER)

- WLTP and relevance to technologies
- SiC and 800V enable next generation
- Technology X and how to bring this quickly to market
- Standardisation enabling implementation





Ref: Effects of a SiC TMOSFET tractions inverters on the electric vehicle drivetrain

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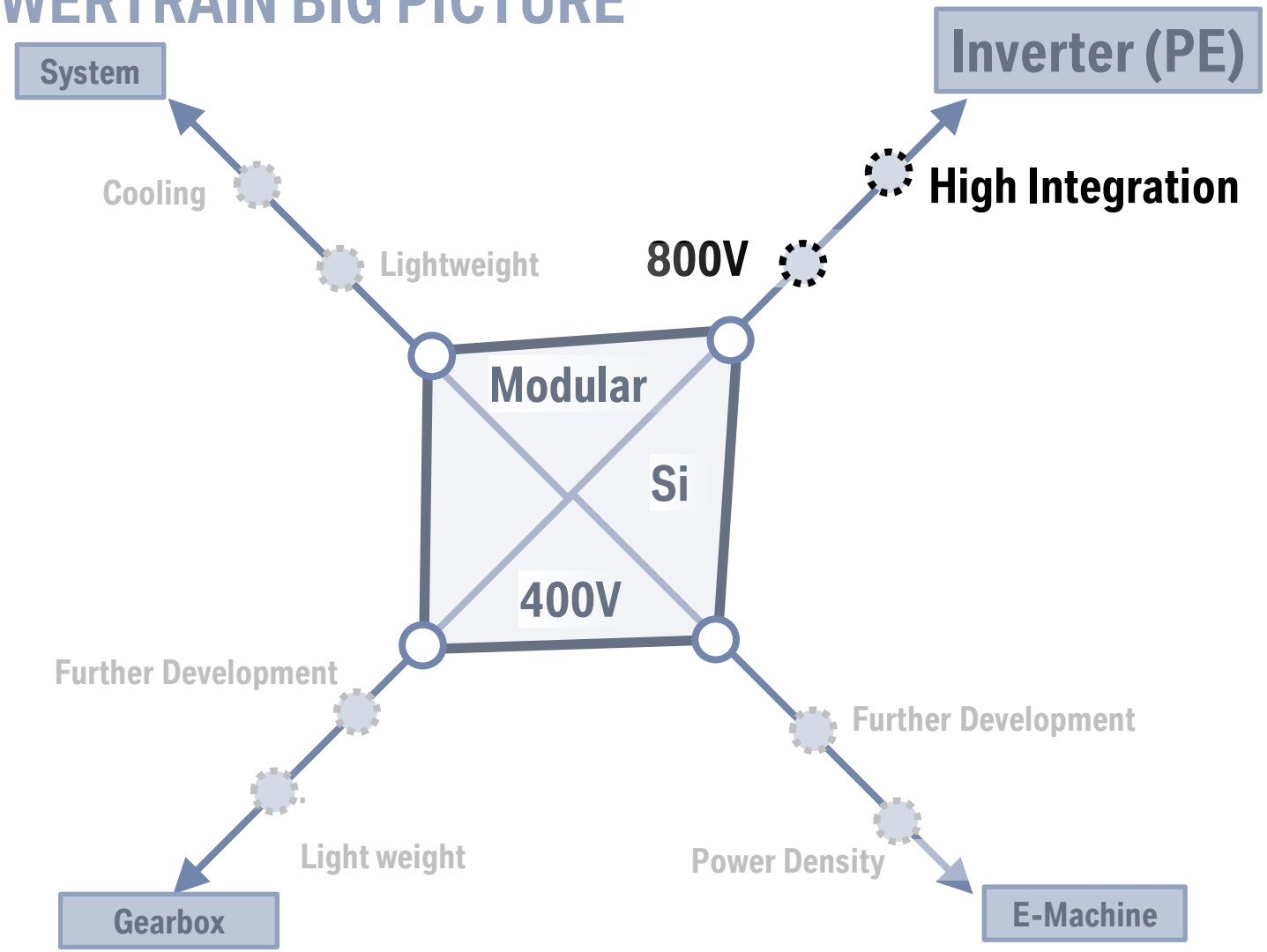
POWERTRAIN BIG PICTURE



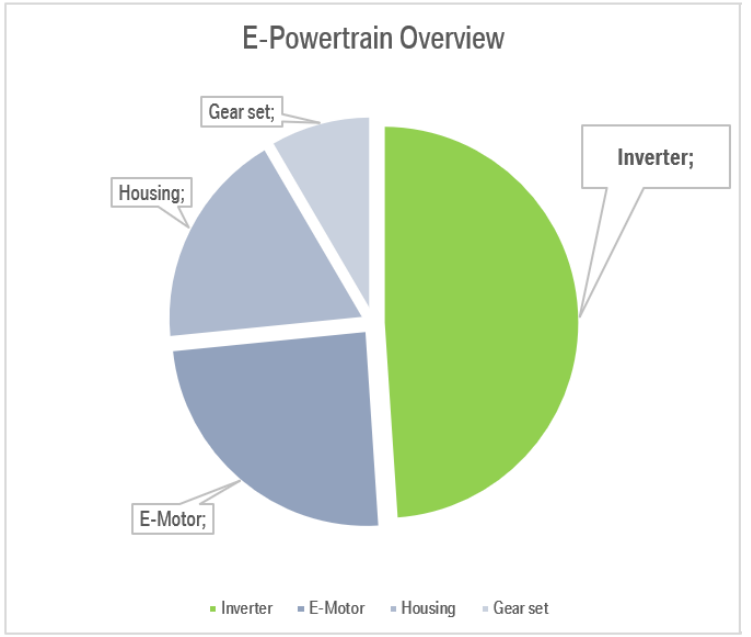
Main targets:

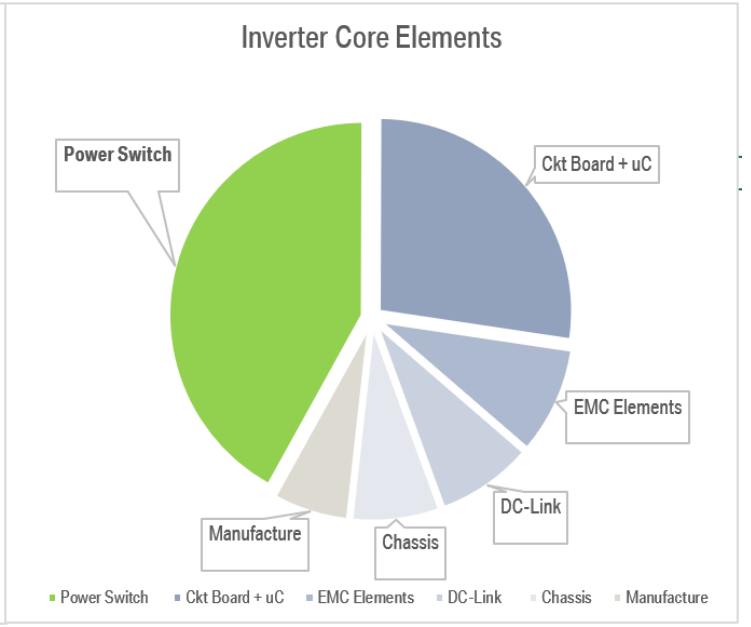
- Efficiency ↗
- Performance ↗
- Cost ↘
- Weight ↘

POWERTRAIN FOR BEV AND ASSOSIATED TECHNOLOGIES

Wheel to Battery:

- Power converter (Inverter)
  - Switching technologies MOSFET → Si → SiC → ?
  - Modulation methods past SVPWM
  - Filtering
  - Voltage classes
- Power transmission
  - Cables and connectors
- Efficiency in gearbox
  - New gear geometry and coatings for lower friction and reduced losses
  - Reduced weight, overall vehicle mass targets
- Electric Machine (motor) efficiency
  - Mapping of drives for high efficiency operation
  - Bearing technologies and small high speed machines
  - Alternate EM types ASM/PSM/SSM/Hybrid





VEHICLE TRENDS

Power Density of Power Electronic (PE) system and core targets:

• Package availability in vehicle for PE	↓ See APC targets taking PE to >80kw/L
• Mass target / power density	↓ See APC targets taking PE to >80kw/kg
• Available power	↑ Vehicle specific from100kW and up
• Voltage class	↑ Shift to 800V systems to enable fast charge
• Efficiency target	↑ WLTP new measurement with ever reducing loss targets
• Cost	↓ Linked to volumes and high level of competition

TRENDS IN POWER ELECTRONIC DESIGN & MANUFACTURING

Current Solutions: Traditional linear manufacturing and integration of components = **15→30kW/Kg**

Si Epilayer	Si Fabrication	Device Packaging	Module Integration	Module Packaging	Sub-system Integration	Sub-system Packaging	System Integration

Drive for Faster, Cheaper, Smaller, Lighter, Smarter

Future : Highly flexible miniaturisation, integration and manufacturing breaking the concept of components = **30→100+kW/Kg**

WBG Epilayer	WBG Fabrication	Flexible Integrated Module and Sub-System Manufacturing	System Integration

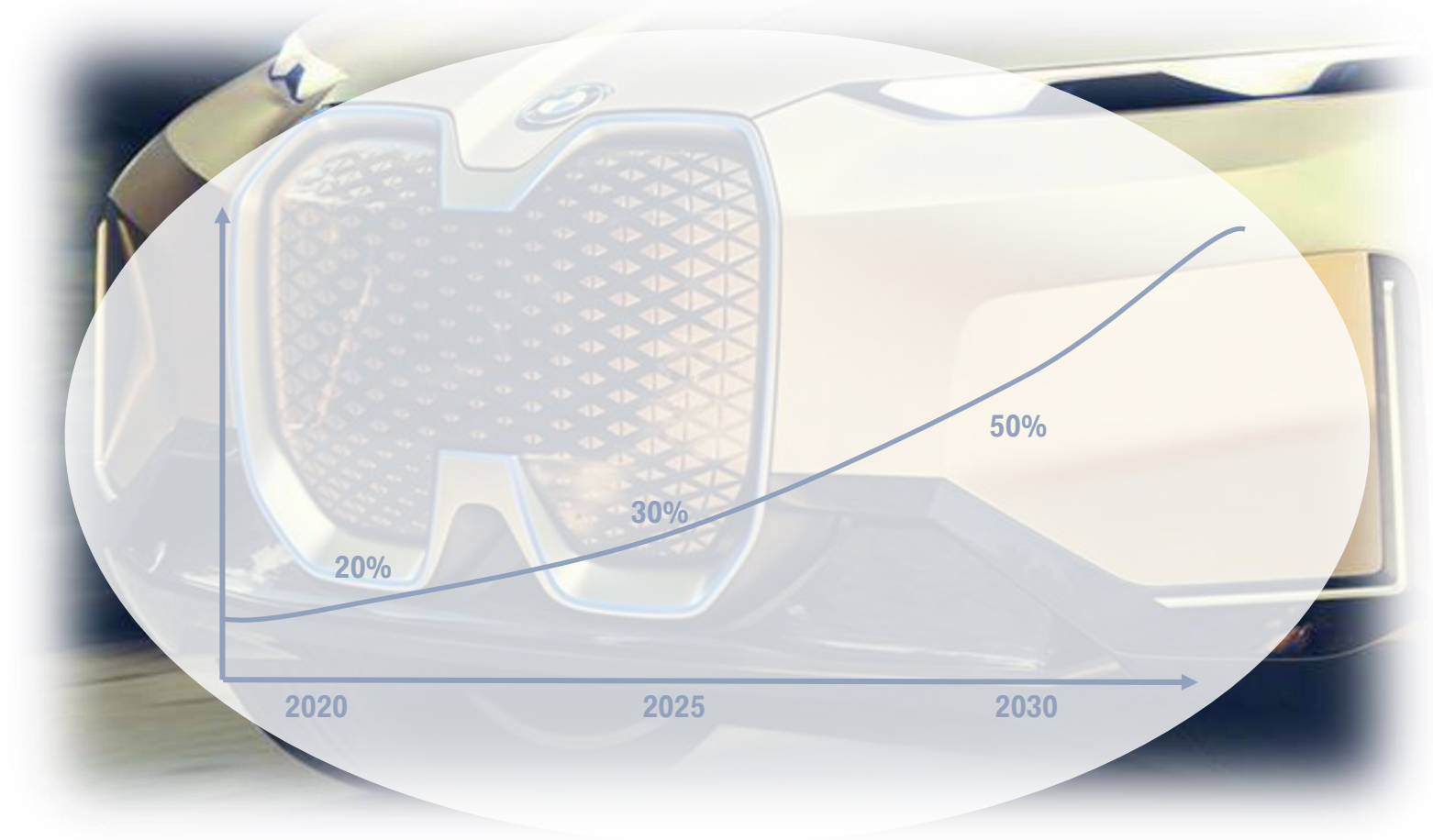
BEV SOLUTIONS

- **Shift from Si → SiC**
  - Reduced switching losses with faster switching
  - Ability to maintain switching speeds with higher voltages
- **Higher Integration**
  - PE moving closer to the electric machine
  - PE elements designed for use
    - Switches designed around automotive requirements
    - Cooling systems and interfaces designed together
    - Power transmission design with reduced cables and designed for reduced EMC
    - Designed for safety
- **NEW Switch Technologies**
  - Standardised designs for power modules
  - Low loss devices with higher switch speeds
  - New connection technology ready
  - Flexible architecture for rapid deployment of emerging technologies

DRIVING TECHNOLOGIES

- **Shift from Si → SiC**
  - Faster switching and dv/dt requires low inductance packaging
  - Thermal path switch to case to ensure best use of die
  - Capacitive coupling management for EMC
  - HV connection system, good bye bolt!
  - Added features?
  - Low cost
  - Standardisation of mechanical packaging
- **Higher Integration**
  - Working as part of a total powertrain system from integration
- **NEW Switch Technologies**
  - Flexible architecture for rapid deployment of emerging technologies

Powertrain Solutions Continuous increase in demand for low CO2 (ICE → BEV)



How to align development cycle to emerging technologies?

Future-proofing vehicle architecture for emerging technologies?

Reduction of high development cycle time and qualification, acceleration to market?

Customer acceptance, transparent technologies, “Freude am Fahren” “Sheer Driving Pleasure”

Material optimisation and plan for EOL, sustainable solutions

OUR COMMITMENT

- Chairman of the Board of Management of BMW AG Oliver Zipse will gave the keynote speech for the three-day event in Glasgow 2021, setting clear priorities:
  "The key to sustainability lies in innovation: in innovative technologies, but also in innovative thinking that accepts no boundaries. Most importantly, together we must choose and follow a binding path with clear goals. Always according to the motto: No more waiting. No more clever tactics. It's time to act. Now."

- **Every gram of CO2 counts** – no matter where it is emitted. All available technologies for reduction must be utilised. The BMW Group has set itself a firm and verifiable interim goal for 2030 throughout its entire value chain: to reduce CO2 emissions from its vehicles by at least 40%

- The BMW Group released the first electric car produced in Germany on a large scale, the BMW i3, back in 2013. By 2030, more than 50% of its annual vehicle sales will be fully electric. Furthermore, its two British brands, Rolls-Royce and MINI, will be exclusively all-electric from the early 2030s onwards

- The BMW Group already held a stakeholder dialogue on the subject of the circular economy in Glasgow on 7 November. BMW Group vehicles currently average around 30% secondary materials. Going forward, the company aims to increase this amount to 50%

Oliver Zipse gives keynote speech at the Sustainable Innovation Forum

BMW GROUP SUSTAINABILITY STRATEGY

- 2021 IAA Mobility show, the BMW Group demonstrated its commitment to sustainability by joining the "**Race to Zero**", as decarbonisation and circularity were further embedded into business. Includes commitment to achieving the "Business Ambition for 1.5°C of the Science Based Targets Initiative", becoming the first German manufacturer to do so.

- The BMW Group is accelerating the pace of its efforts to combat climate change. Looking ahead to the introduction of the "**Neue Klasse**" in 2025 - BMW Group's new vehicle architecture which **is electric**, whether with battery power or hydrogen - further strengthening its objectives to reduce CO2 emissions significantly. The "**Neue Klasse**" will see the BMW Group increase its use of secondary materials with a firm focus on the principles of the circular economy, whilst also promoting better framework conditions for establishing a market for secondary materials.

- To achieve a further reduction in CO2 emissions, the focus is on the driving phase of vehicles, which accounts for 70% of the BMW Group's CO2 footprint. By 2030, the CO2 emissions per vehicle and kilometre driven will be at least halved from 2019 levels. The commitment of all manufacturers when it comes to combatting climate change can best be compared when looking at the entire life cycle of a vehicle, including production and upstream supply chain. Here, the **BMW Group is planning a reduction of CO2 emission per vehicle of at least 40%**.

- The most powerful driver on this path to net zero is electric mobility, with the BMW Group's **Neue Klasse** set to provide significant further momentum to the market. **As early as 2030, at least half of global BMW Group sales will be all-electric vehicles**, with the MINI brand offering exclusively all-electric vehicles from 2030.

YOUR POWERTRAIN NEEDS YOU!

- Input power transmission technologies
  - Deliver customer expectation, efficiency → range
  - Understand the new BEV powertrains
  - 400V → 800V drivers
  - Si → SiC and standardisation of powertrain
- Efficiency driven systems
  - System driven designs from cradle to grave design
- Customer Education
  - Managing fear of change
  - Enabling acceptance and take-up
- Futureproof designs
  - Standardising core elements
  - Enable rapid deployment of emerging technologies
  - EOL planning

QUESTION ?

- BEVs have significant efficiency deltas to ICE why do we push to be better?
- Why fight for 1W?
- What does 1W contribute over life?

QUESTION?

- What does 1W of reduced losses really mean?

- Expected run time for 1 car = 10,000 hours
- Over life each car with a 1W power reduction would save 10kWh
- 10kWh is approximately same as 1L of Diesel

- Build 1,000,000 cars a year with 1W saving
- Reduction of 1M Litres of Diesel or 10m³
- 2,680,000 kg of CO2!

- For 1W!

- Our target is to reduce the switching losses and powertrain for next generations
- But every watt counts on our road to our commitment

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THANK YOU

YOUR PE NEEDS YOU!

- Input power transmission technologies
  - Contact systems for HV distribution
- EMC filtering and EMC design for reduced losses
  - Power transmission design that reduces EMC generation
- Power switching and reduced loss systems
  - Next generation low on resistance switches
- Controllers and power supplies for lower power operation
  - Low power controller
  - New novel modulation methods to reduce losses
  - SiC based SMPS supplies for wide voltage range operation
- Gate drive controllers and safety systems
  - Flexible topology with high integration, gate drive with added feature that can dive multi chip solutions
- Sensors and sensor resolution
  - High resolution low cost sensors, resolution and speed of sensors allow use of full HW capability
- Components for wide operation temperate
  - Reduced platform cooling requirements = reduced system power requirements = better effeciency

BEV Enabling Technologies

Goals v Technologies

Effective range and WLTP, real world benchmarking
Efficiency Wh / km, every Watt counts
Delivering range by efficiency or powertrain, an eye to energy use

@FutureBEV focus Battery to wheel efficiency:

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