Technology trends in e-mobility and related business opportunities

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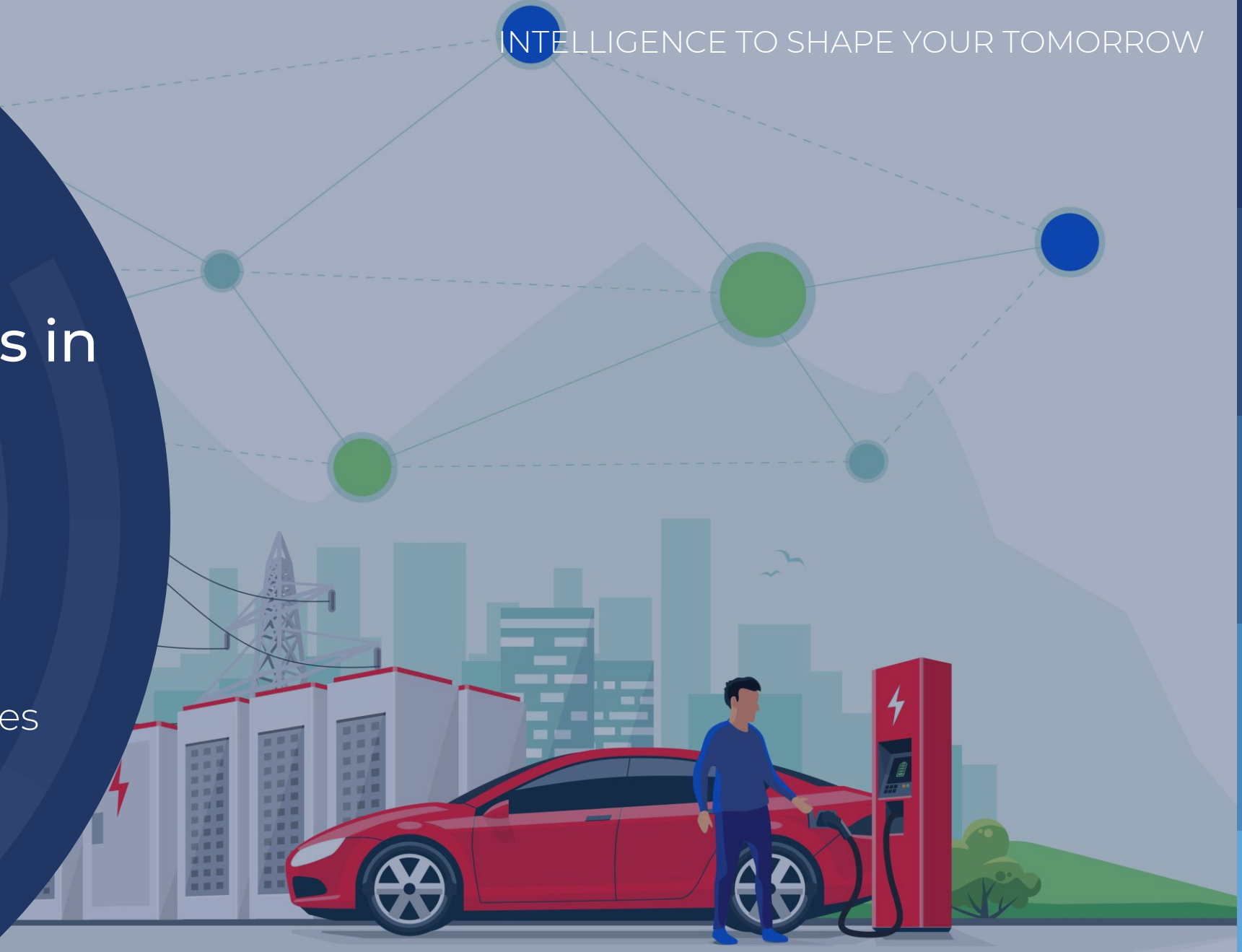


YOLE Intelligence

Electric Vehicle Conference
18th October 2022, Athens, Greece

OUTLINE

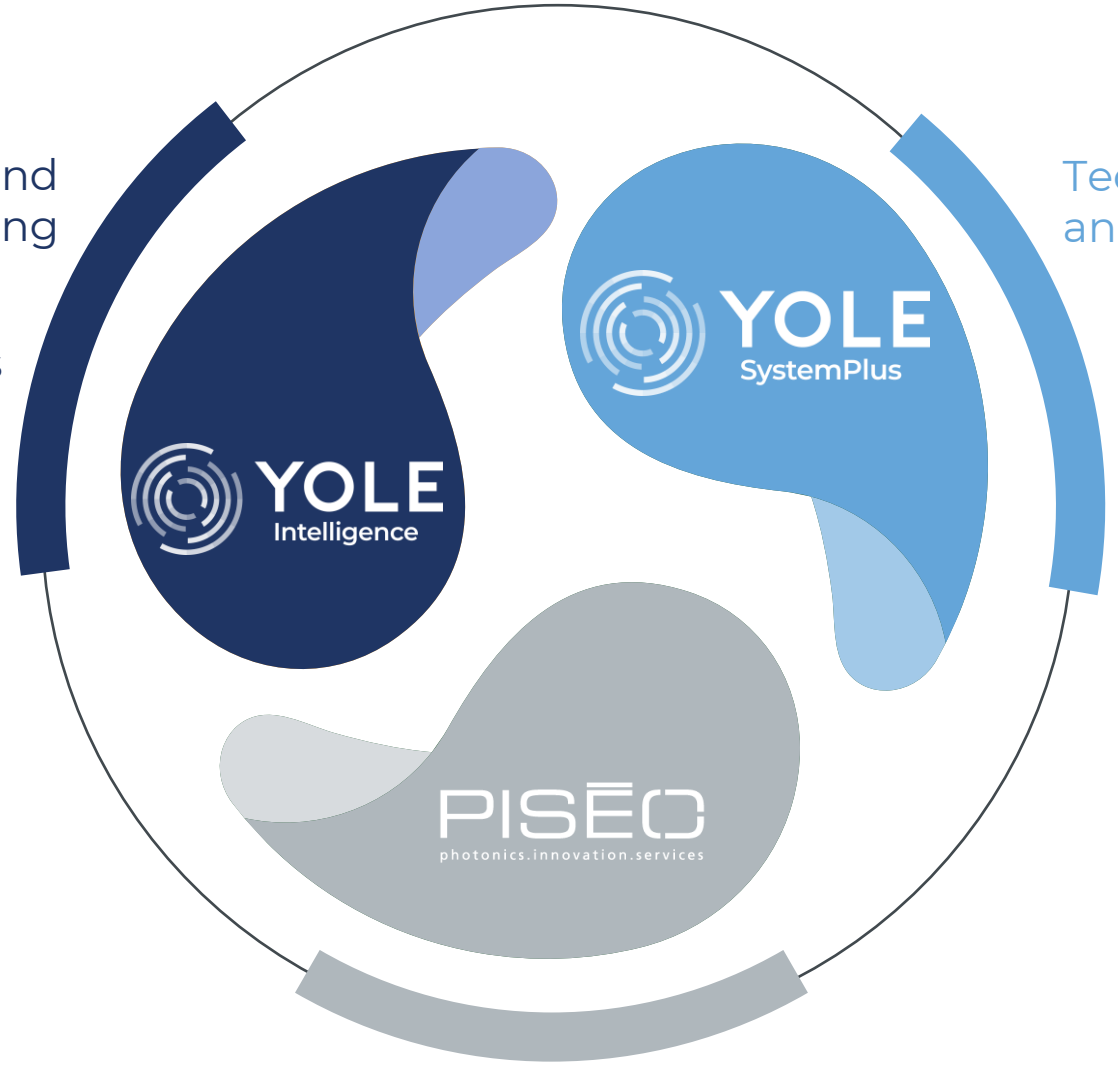
- Yole Group
- xEV drivers and market forecast
- Multiple choices in designing an electrified vehicle
- Focus on driving range
  - Battery
  - SiC
  - 800V
  - Dual motor
- Integration
- Synergies between different applications
- Conclusion & Outlook

YOLE GROUP'S MAJOR ACTIVITIES PER ENTITY

Market, technology, and strategy consulting

M&A and evaluation of companies

Direct acces to the analysts



Technology, process & cost analysis

Teardown and reverse engineering

Comparative analysis

Characterization of electro-optical performances and risks

Specification, design and industrialization of systems

FIELDS OF EXPERTISE COVERING THE SEMICONDUCTOR INDUSTRY

- Semiconductor Packaging
- Semiconductor Manufacturing
- Memory
- Computing and Software

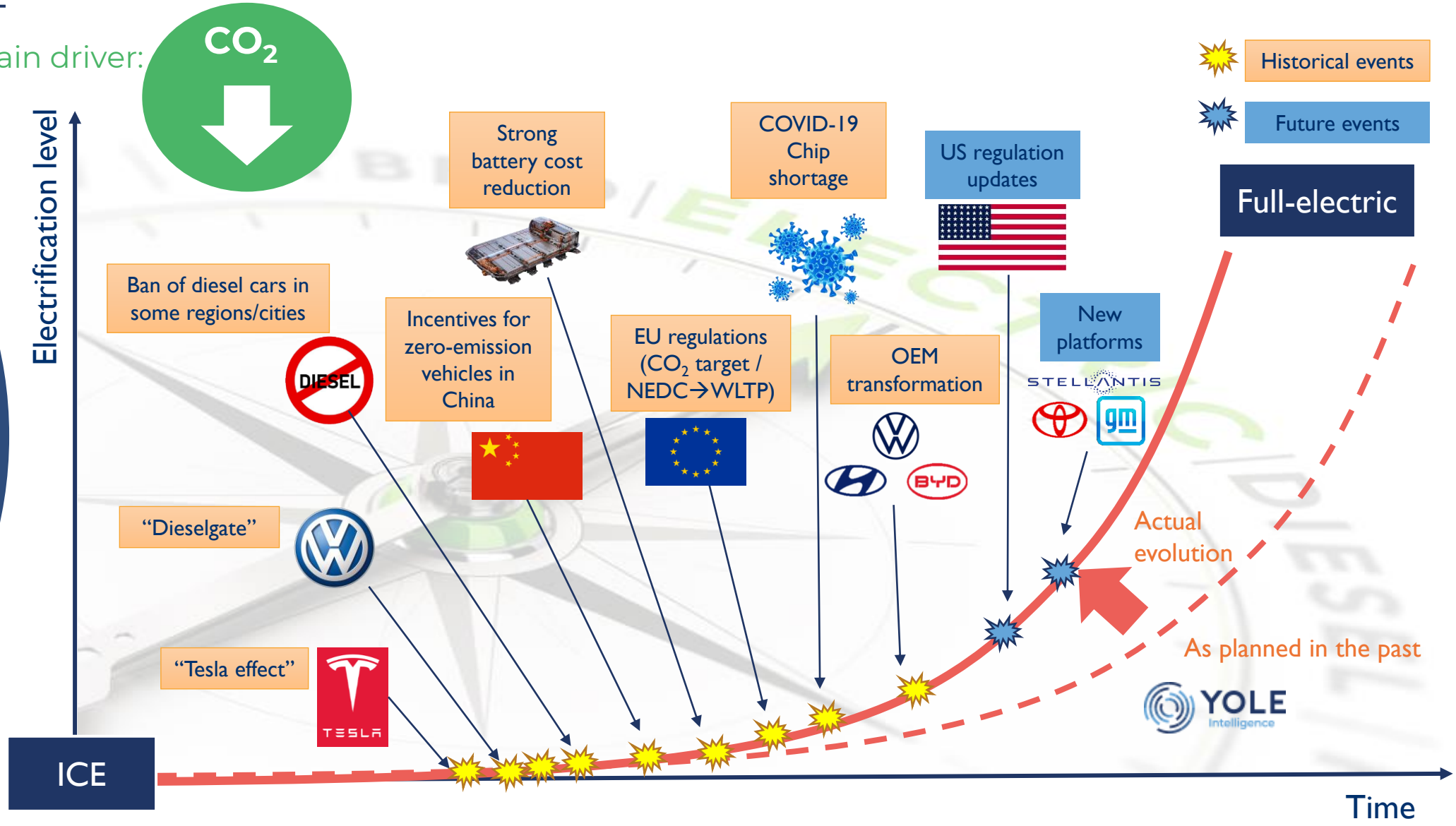
- Photonics & Lighting
- Imaging
- Sensing & Actuating
- Display

- Radio Frequency
- Compound Semiconductors
- Power Electronics
- Batteries

- Electronic Systems
- Emerging Technologies

SPEED OF ELECTRIFICATION IS BEATING ALL FORECASTS

The initial strategic path for vehicle electrification has been accelerated by several singular events.

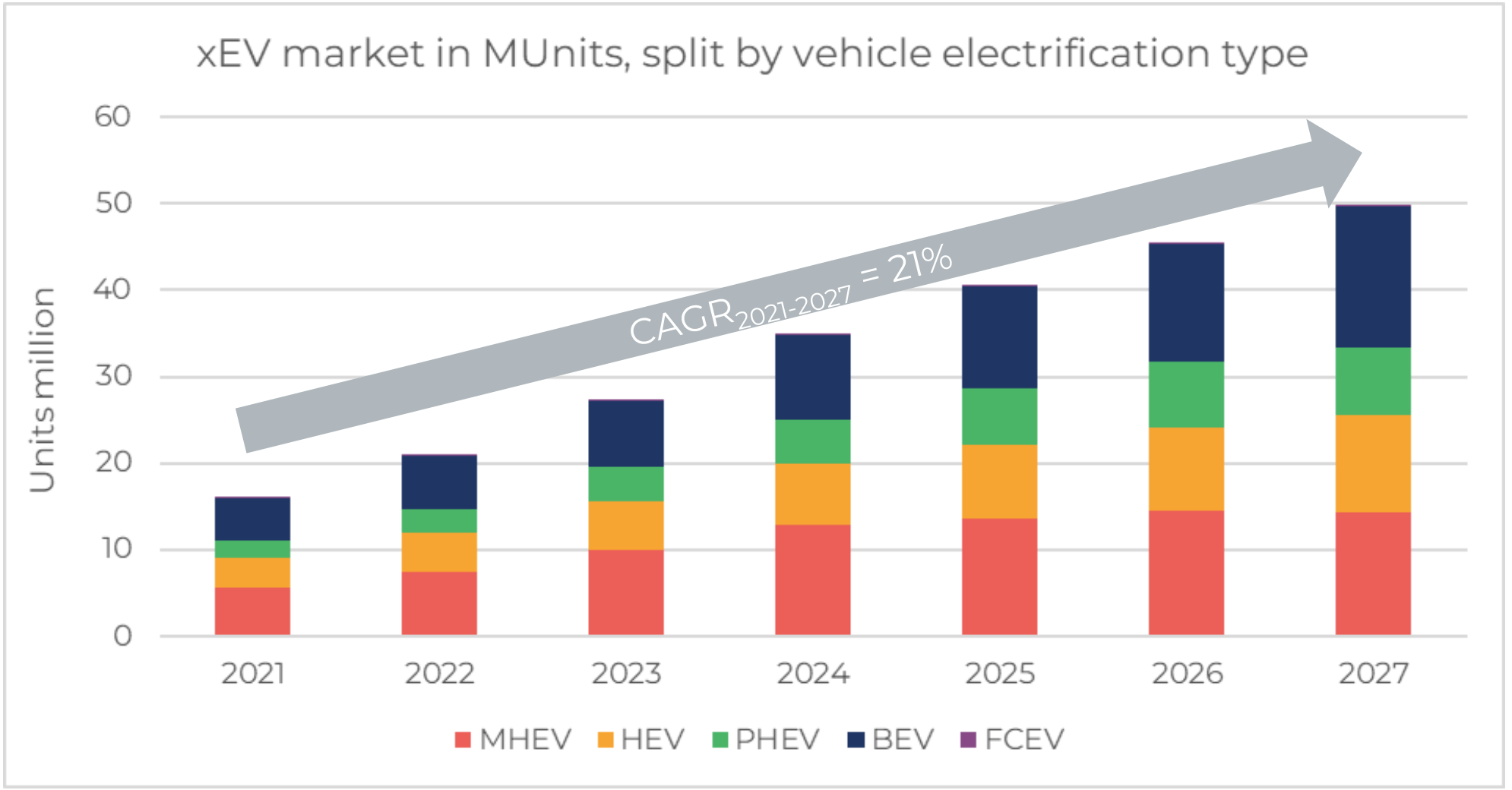


Source: Yole Intelligence

NEDC: New European Driving Cycle
WLTP: Worldwide Harmonized Light Duty Vehicles Test Procedure

XEV MARKET

The xEV market will reach 50 million globally by 2027, taking more than 50% of the total passenger and light commercial market since 2026.



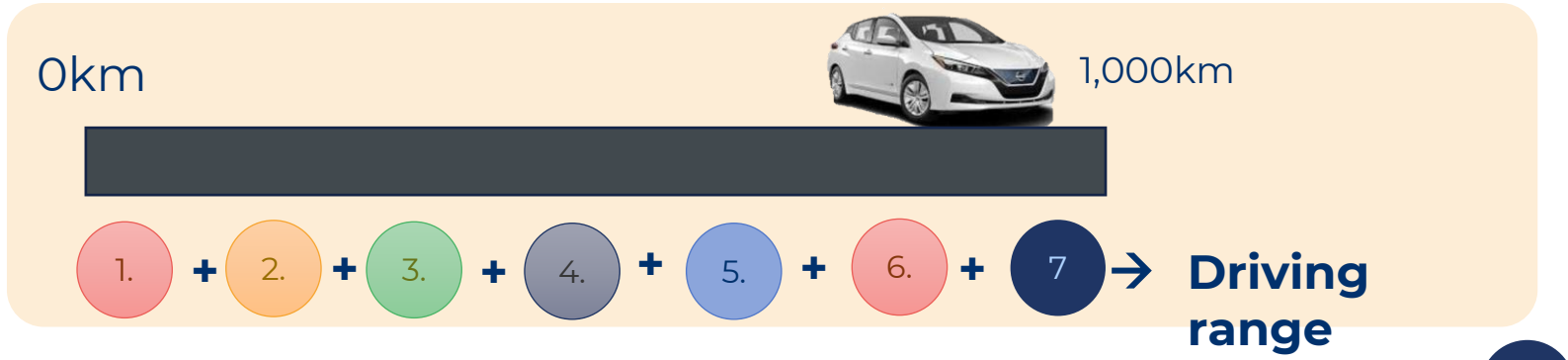
WHAT DOES THE ELECTRIC VEHICLE OWNER DESIRE?

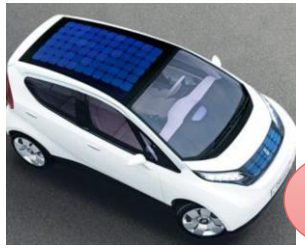
- Driving range
- Affordable cost
- Nice design
- User comfort
- Driving dynamics
- Convenient charging
- Low electricity consumption

DIFFERENT APPROACHES TO INCREASE CAR DRIVING RANGE

There are multiple approaches to increase the driving range / reduce system costs.

All these approaches need to be balanced when evaluating a technology change.





1d.

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3b. Other converters

5. Loads

Auxiliary loads (HVAC, ADAS, lighting, entertainment…

7 Autonomous driving

6a.

Tire rolling resistance

Traction inverter

3a. DC / AC

4. AC motor +gearbox

6b.

1a. 1b. 1c. (+ / -)

2.

More cells → larger battery capacity (kWh)

Enhanced cell technology / design

Enhanced cell-to-pack assembly

Additional electricity source: PV roof

Higher circuitry voltage (such as with 800 V battery)

Shorter electrical interconnections

Enhanced inverter topologies

Use of SiC / GaN instead of silicon

High-efficiency motor

High power-density motor (ex.: axial motor)

Using less powerful motors

Car aerodynamic drag

HOW TO REACH A LONGER DRIVING RANGE?

100% (energy available in the battery) → Losses from battery to wheels → Energy remaining for car propulsion

Within a short development period and for an affordable cost

SOLUTION FOR FUTURE BEV IS IN COMBINATION OF IMPROVEMENTS IN SEVERAL EV SYSTEMS

A new "miraculous" battery is not a solution to BEV issues about cost, driving range and fast charging capability.

The improvements of other systems in vehicle are required.

Gen N

Big Δ

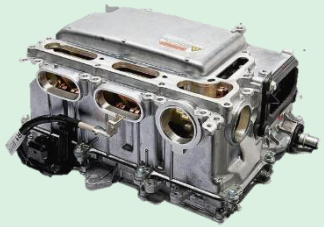
Gen N+1

Enhanced cells and packs

Small Δ

- Ni-rich cell chemistry
- Co-free cell chemistry
- Cell-to-pack (C2P)
- Cell to chassis (C2C)
- Enhanced cooling
- Wireless Battery Management System (BMS)

Inverter



Small Δ

- Enhanced topology
- Silicon IGBT → SiC-MOSFET

Enhanced motor technologies

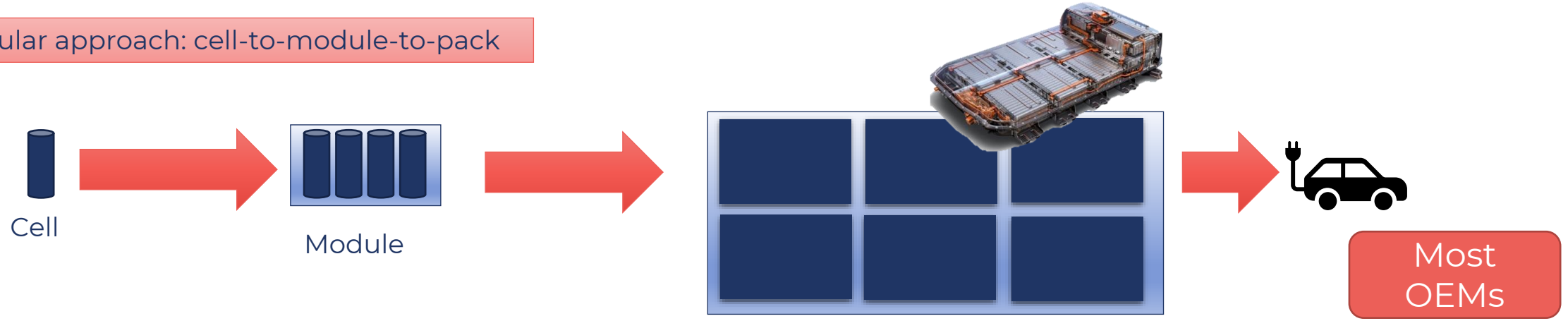
Small Δ

- Hairpin winding
- Near wheel motors
- Axial flux motors

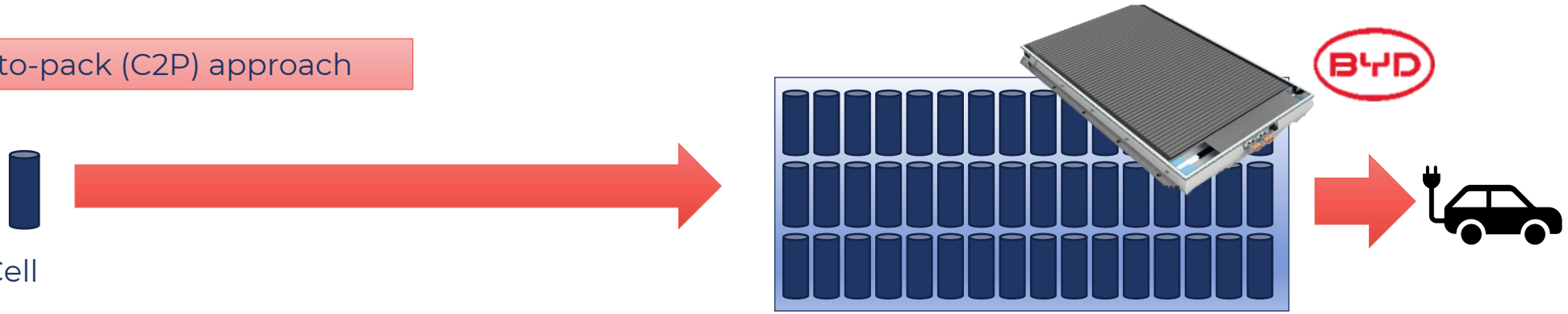
Big Δ

MODULAR BATTERY PACK VS. CELL-TO-PACK APPROACH

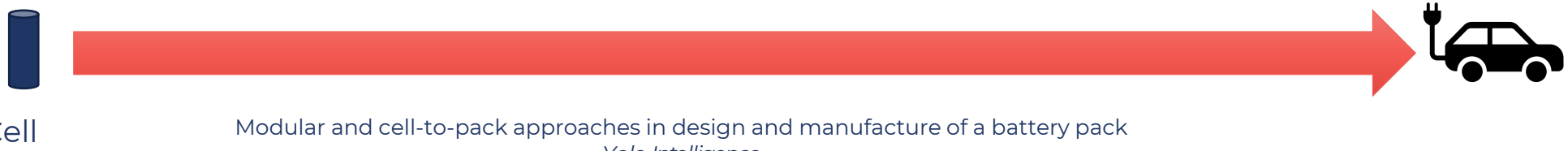
1.Modular approach: cell-to-module-to-pack



2.Cell-to-pack (C2P) approach



3.Cell-to-chassis (C2C) approach



Modular and cell-to-pack approaches in design and manufacture of a battery pack
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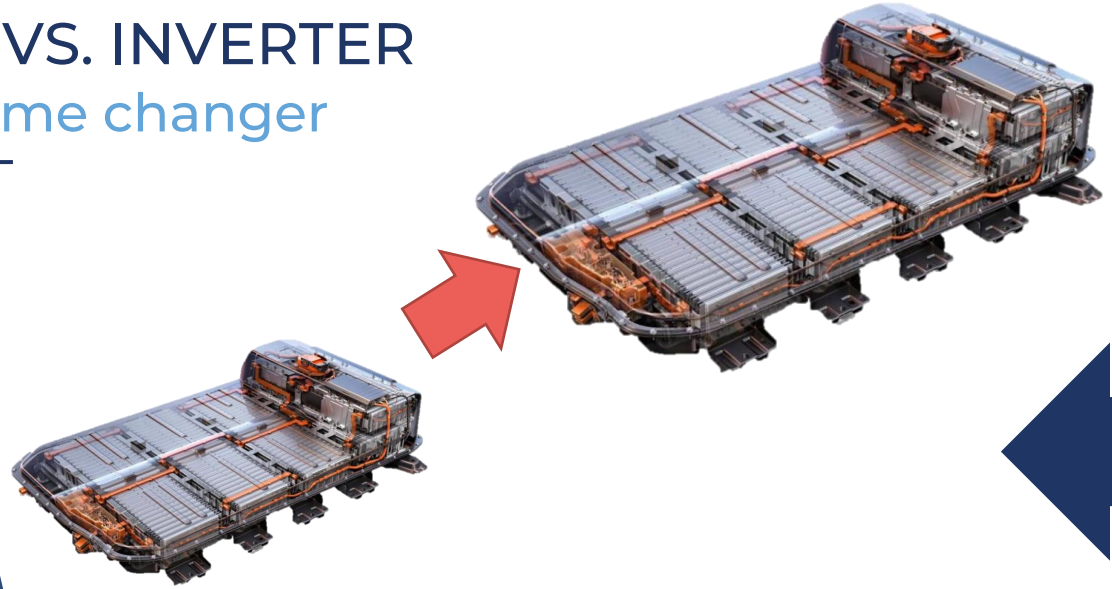
BATTERY VS. INVERTER

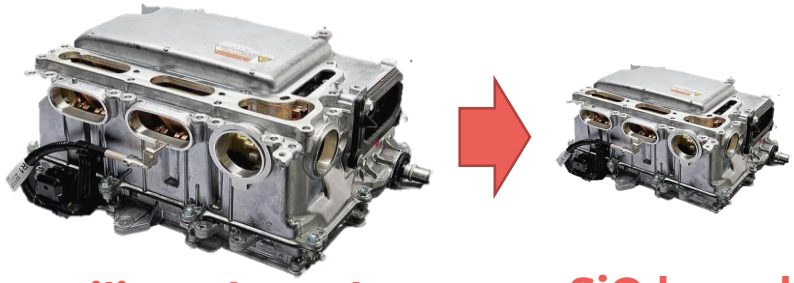
SiC as a game changer

When different ways of improvement exist, the choice has to be done based on a global technology and cost analysis...

...together with market environment and supply chain analysis.



- Easy upgrade
- More energy capacity in kWh per car =
  - ☹ Higher weight
  - ☹ Higher volume
  - ☹ Poorer car driving behavior
  - ☹ Higher cost
  - ☹ Longer charging time
  - ☹ Higher dependence on raw materials (lithium, cobalt...)

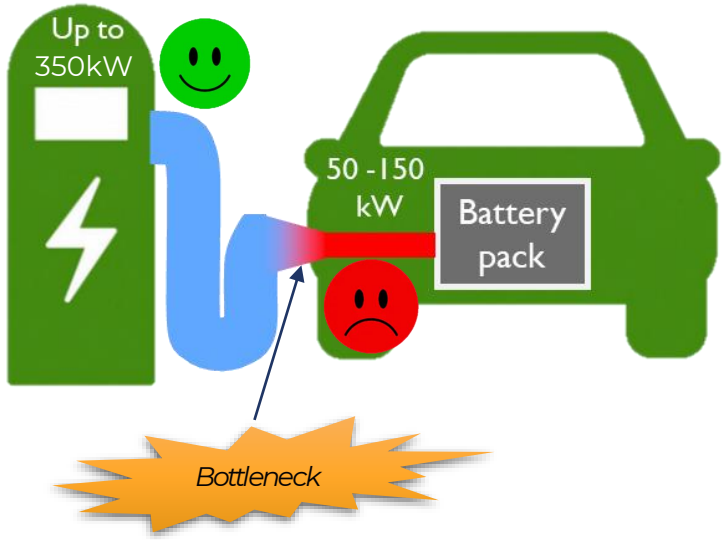


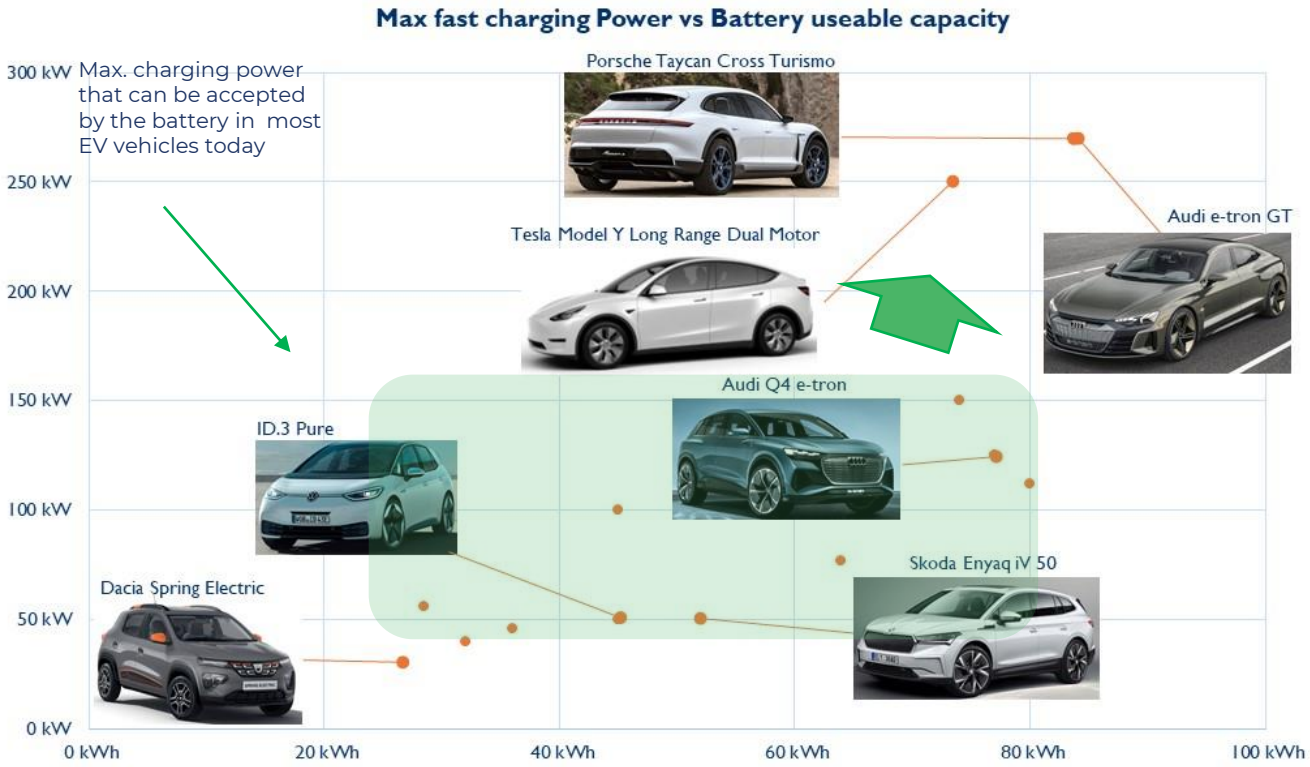
Silicon-based **SiC-based**

- ☺ Lower weight
- ☺ Smaller volume
- ☺ Greater car driving behavior
- ☺ Lower dependence on raw materials (cobalt, lithium, nickel...)
- ☺ Lower energy consumption (kWh/100km) → reduced environmental impact
- ☺ Shorter charging time (min/100 km)

BATTERY AS A CHARGING SPEED BOTTLENECK

Irrespective of the maximum power output of the charger, the final charging power (and thus charging speed) is determined by the vehicle itself.





To do list:

- Enhance cell chemistry
- Enhance cell design and format
- Enhance battery management system (BMS)
- Enhance battery thermal management
- **400V battery → 800V battery**
- High-power interconnects

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800V SYSTEMS: ADOPTION SPEED & MILESTONES

2019/2020: first 800V system Porsche Taycan

Forecast of 800V system production share in BEV

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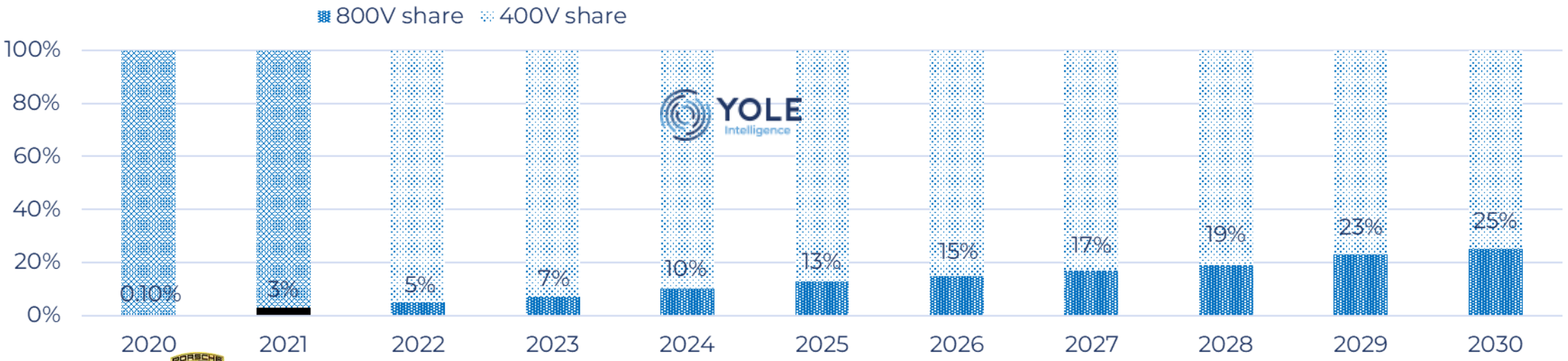
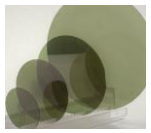


2026: Volkswagen Trinity/SSP platform

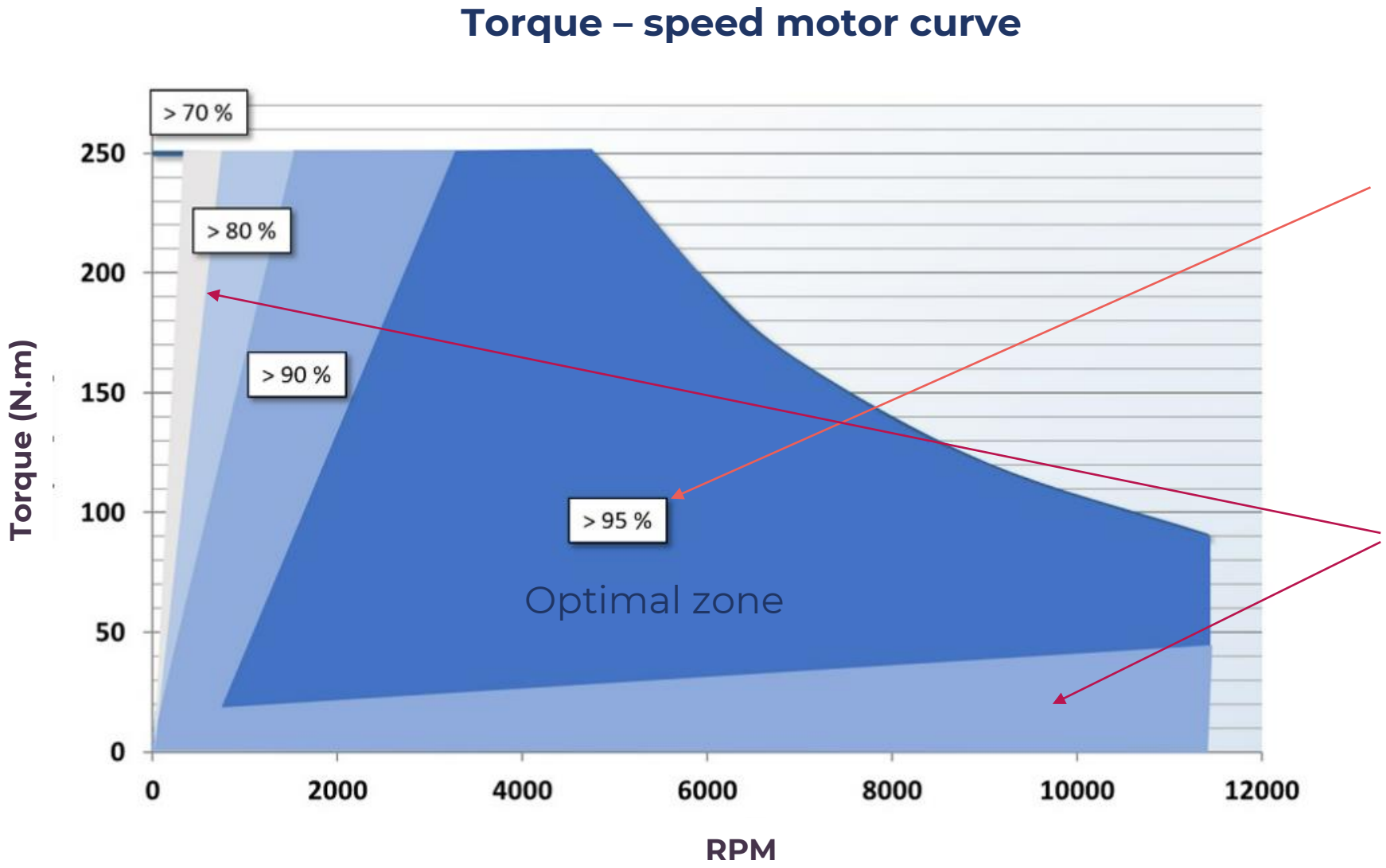
2021: launch of Hyundai-Kia E-GMP platform

2022: ramping up of GM BET platform



2024/2025: launch of various Chinese OEMs + cost reduction due to scaling up of SiC + ultra-high-power DC charging

MOTOR EFFICIENCY CURVE



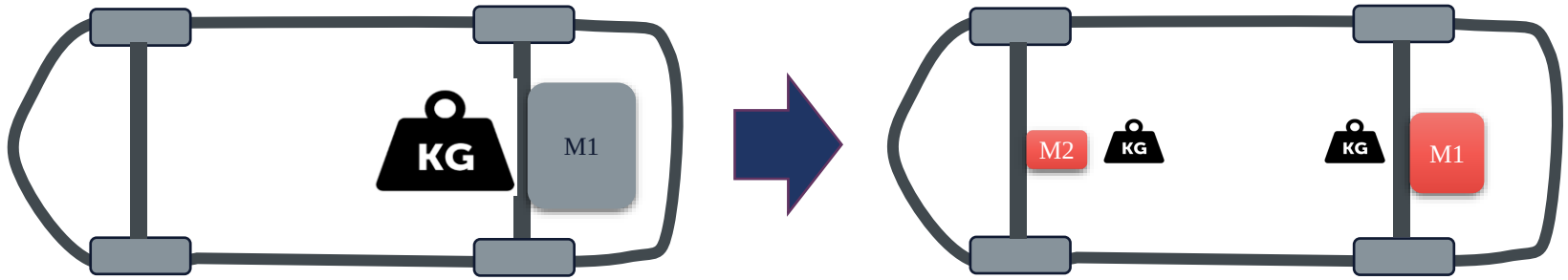
Optimally one should use a given motor in torque/speed area with the highest efficiency.

But what to do when different torque speed values are needed?

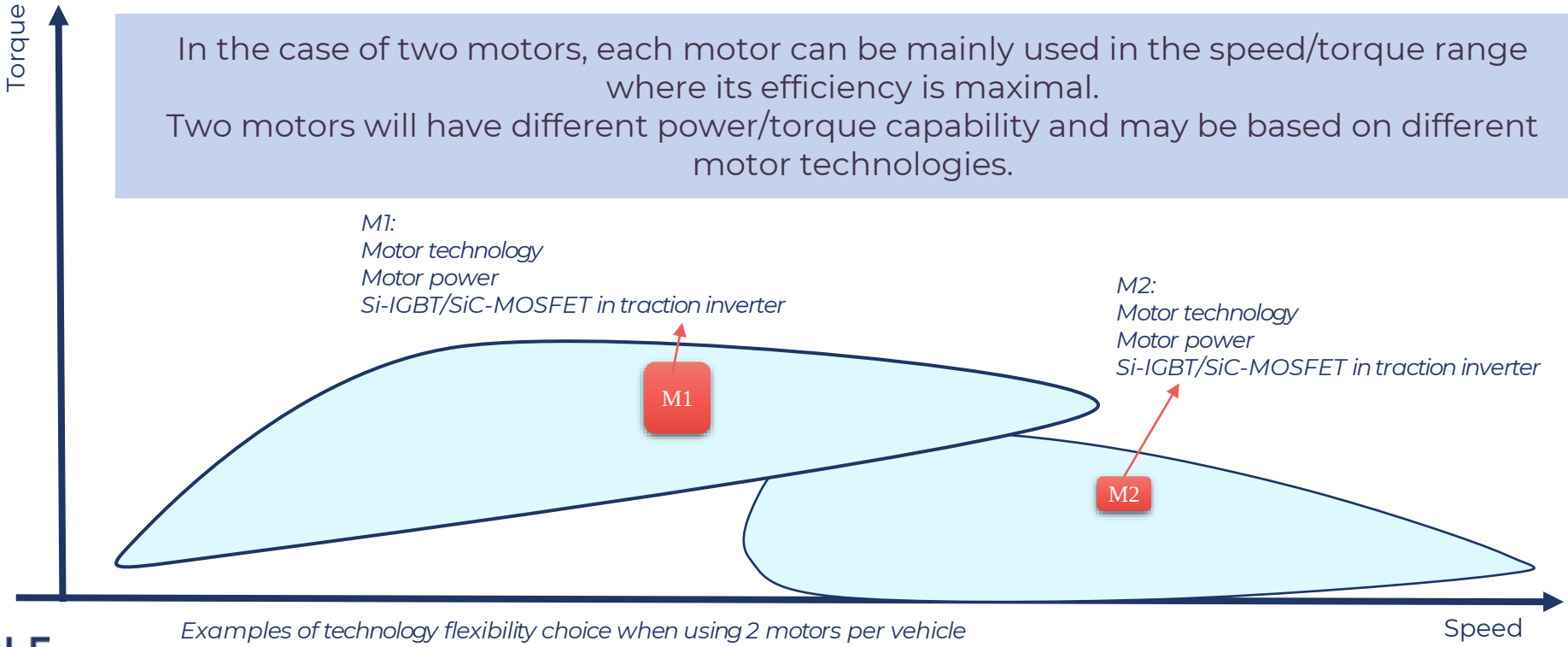
Torque-speed curve and efficiency values for a BEV electric motor (illustrative image and values only)

SINGLE MOTOR VS. TWO OR MORE MOTORS PER VEHICLE

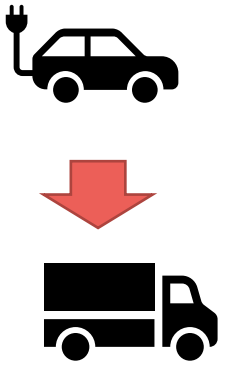
Two (smaller) motors are easier to be integrated in the vehicle compared to one (big) motor and the weight of motors is more equally distributed across the vehicle.



In the case of two motors, each motor can be mainly used in the speed/torque range where its efficiency is maximal.
Two motors will have different power/torque capability and may be based on different motor technologies.

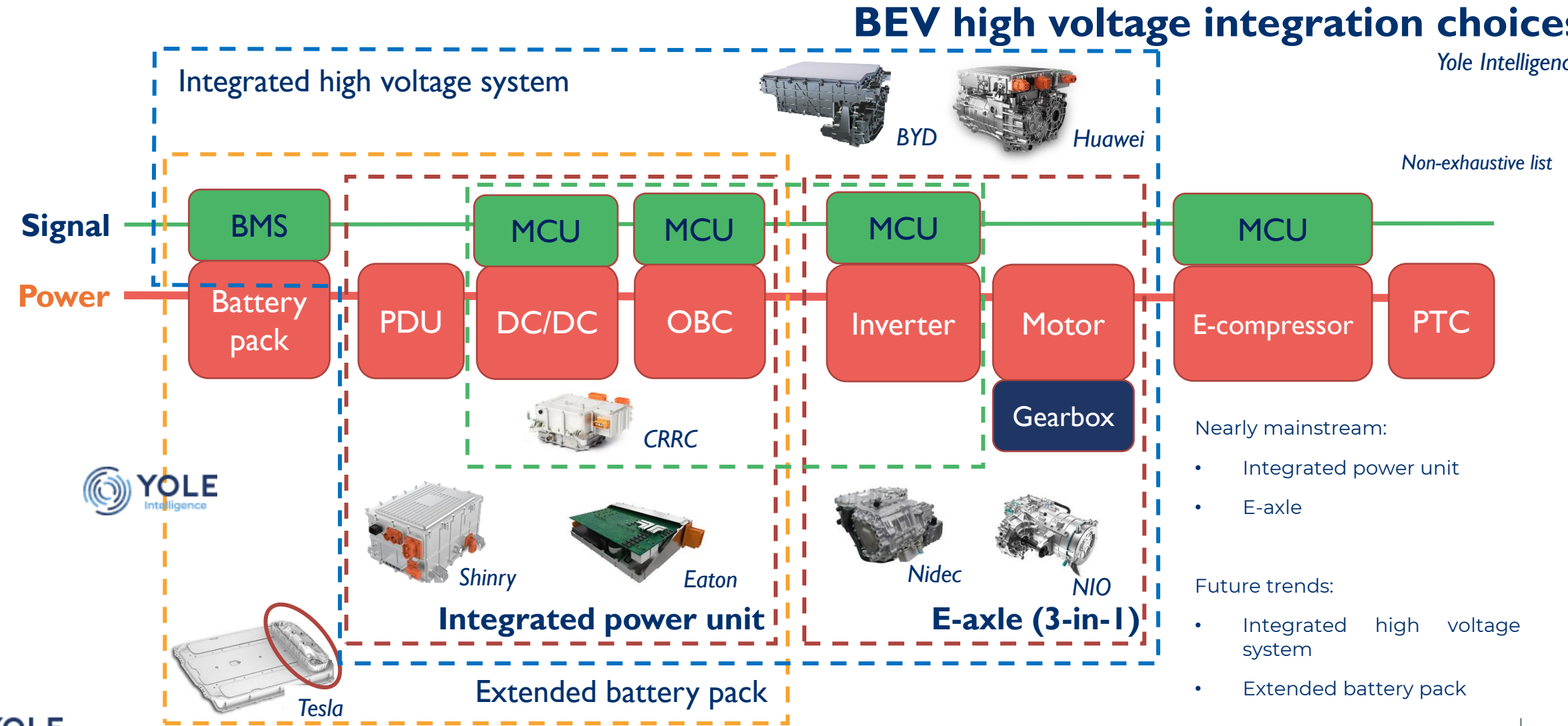


Examples of technology flexibility choice when using 2 motors per vehicle



INTEGRATION CHOICES IN BEVS

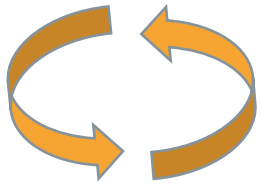
There are different options for integration. Trade-offs are needed including factors, such as compactness, performance, cost-saving, serviceability, supply chain management, flexibility, etc.



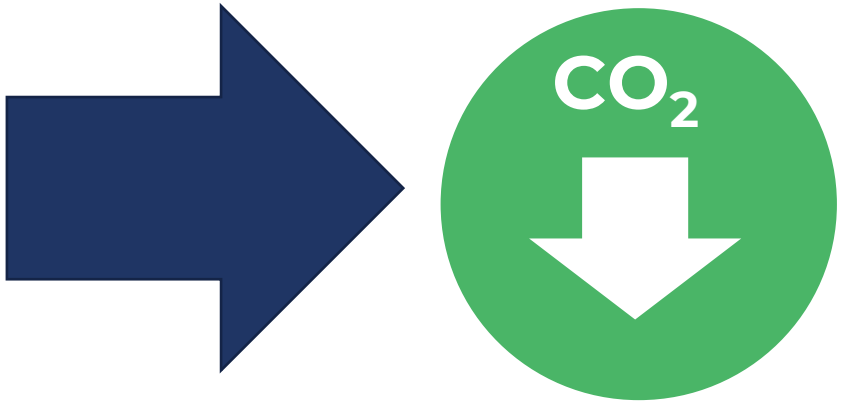
EV CHARGING INFRASTRUCTURE AS A KEY TO ACHIEVE CO2 REDUCTION TARGETS

EV charging infrastructure deployment must go hand-by-hand with EV deployment.

Electrification of the vehicle fleet is key to reach the governments' CO_2 emission reduction targets.



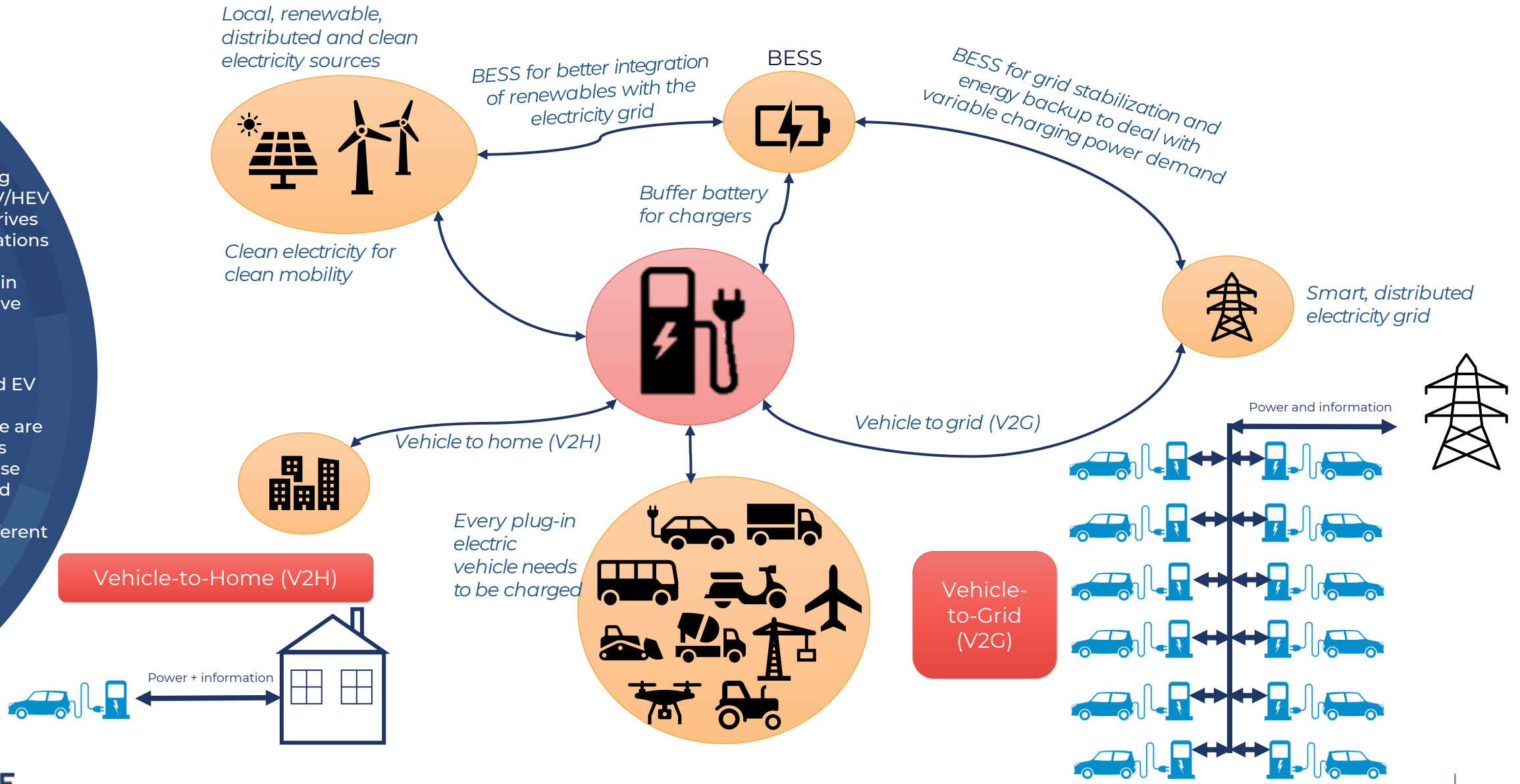
Charging infrastructure is directly linked to electric vehicle market growth. As more vehicles need charging, more substantial charging infrastructure is required.



CHARGING INFRASTRUCTURE AS A KEY ELEMENT OF "INTERNET OF ENERGY"

Due to strong synergies, EV/HEV boom also drives other applications while other applications in their turn drive EV/HEV deployment.

Batteries and EV charging infrastructure are key elements enabling those synergies and energy flow between different applications.



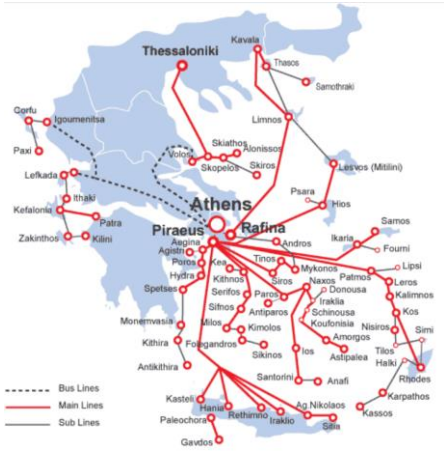
BATTERY/ELECTRIC POWERTRAIN OPPORTUNITIES GO BEYOND JUST THE PASSENGER VEHICLES

Sea – a common way to transport goods...

Piraeus container port

Battery-powered electric harbor cranes. *Source: Konecranes*

...and people



Ferry lines between Italy and Greece and in Greece

Example of an electric ferry in Norway

CONCLUSION & OUTLOOK

- xEV is a large and rapidly growing market.
- Full vehicle electrification is faster than expected in the past.
- New battery technologies will not solve the challenges of electric vehicles. Improvements on multiple vehicles systems are needed – battery, motor, traction inverter, electric circuitry…
- Integration brings advantages in costs, volume, weight.
- Charging infrastructure market is strongly correlated to BEV market.
- See beyond passenger vehicles. Passenger vehicle market is huge but there are opportunities batteries and power conversion systems also in
    - Electric buses, trucks, boats, aircrafts…
    - EV charging infrastructure, electricity production and distribution, stationary battery storage systems, service to the grid…

YOLE GROUP OF COMPANIES RELATED REPORTS

DC Chargers for Plug-in electric Vehicles

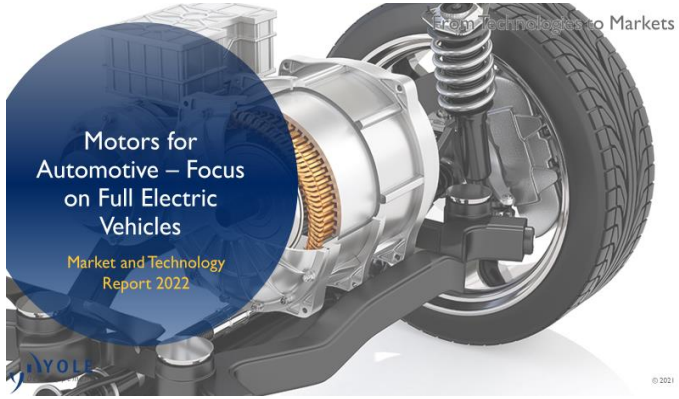
Power Electronics for Automotive 2022

Power SiC

Status of the Rechargeable Li-ion Battery Industry

Status of the Power Electronics Industry

Motors for automotive – focus on Full Electric Vehicles



Thank you for your attention!

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Dr. Rosina has 20 years of scientific, industrial, and managerial experience in equipment and process development.

He also has experience in due diligence, technology, and market surveys in the fields of renewable energies, EV/HEV, energy storage, batteries, power electronics, thermal management, and innovative materials and components.

Dr. Rosina received his Ph.D. degree from National Polytechnical Institute (Grenoble, France). He previously worked for the Institute of Electrical Engineering in Slovakia; Centrotherm in Germany; Fraunhofer IWS in Germany; CEA LETI in France; and the French utility company ENGIE.

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