

Antitrust Guidelines



Antitrust Guidelines for Copper Industry Trade Association Meetings

The following guidelines with respect to compliance with antitrust laws of the United States, Japan and European Community¹ are intended to govern the conduct of participants in copper industry trade association meetings, both at the meeting itself and in informal discussions before or after the formal meeting.

Price: Competitors should not discuss future prices (including terms of sale) of their products. There is no blanket prohibition against the mention of or reference to current or past prices but limits must be observed. Such references or mentions should occur only when necessary in connection with the development of association programs. For example, reference to a particular price level in comparing the cost of a copper product to a competing product is permitted. Whenever possible, such references should be discussed in advance with legal counsel.

Competitive Information: Competitors should not discuss the market share of a particular copper producer or copper fabricator's products. Furthermore, nothing should be said at a meeting which could be interpreted as suggesting prearranged market shares for such products or producer production levels. The overall market share of copper products may be discussed with regard to competition with non-copper products and general market acceptance.

New Products: Competitors should not encourage or discourage the introduction of a new product by another competitor or reveal a particular copper company's plans to change the production rate of an existing product or to introduce a new product. No company should disclose to another company whether it is in a position to make or market a new product. New products may be discussed in a technical manner or from the standpoints of competition with non-copper products and general market acceptance. In addition, proposed methods for and results of field and laboratory testing can be considered.

The Role of Legal Counsel: Legal counsel attends association meetings to advise association staff and other meeting attendees regarding the antitrust laws and to see that none of the matters discussed or materials distributed raise even the appearance of antitrust improprieties. During the course of a meeting, if counsel believes that the discussion is turning to a sensitive or inappropriate subject, counsel will express that belief and request that the attendees return the discussion to a less sensitive area.

A paper entitled 'Copper Industry Trade Associations and Antitrust Laws' is available upon request.

10/92, 5/93, 10/10

1. Other foreign competition laws apply to International Copper Association, Ltd. (ICA)'s activities worldwide.

Legal Statement

The purpose of the information in this presentation is to guide ICA programs and provide members with information to make independent business decisions.

Copper Demand in Electric Traction Motors 2020 - 2030

March 2020

Dr Richard Collins, Principal Technology Analyst

IDTechEx Research

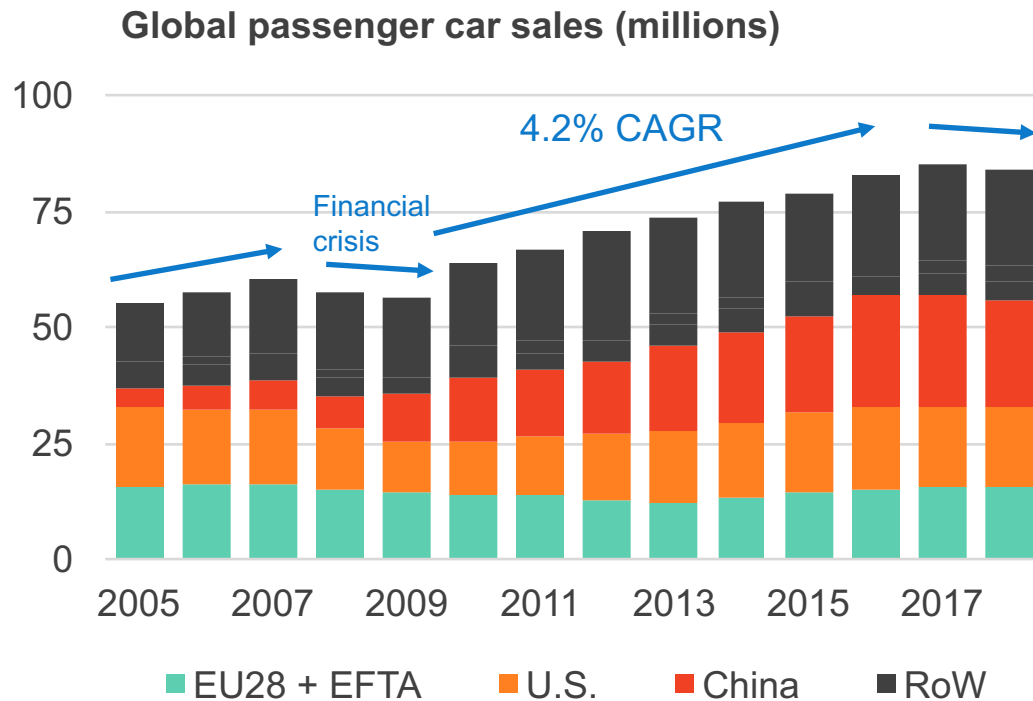
EV Electric Vehicles
Material
Opportunities



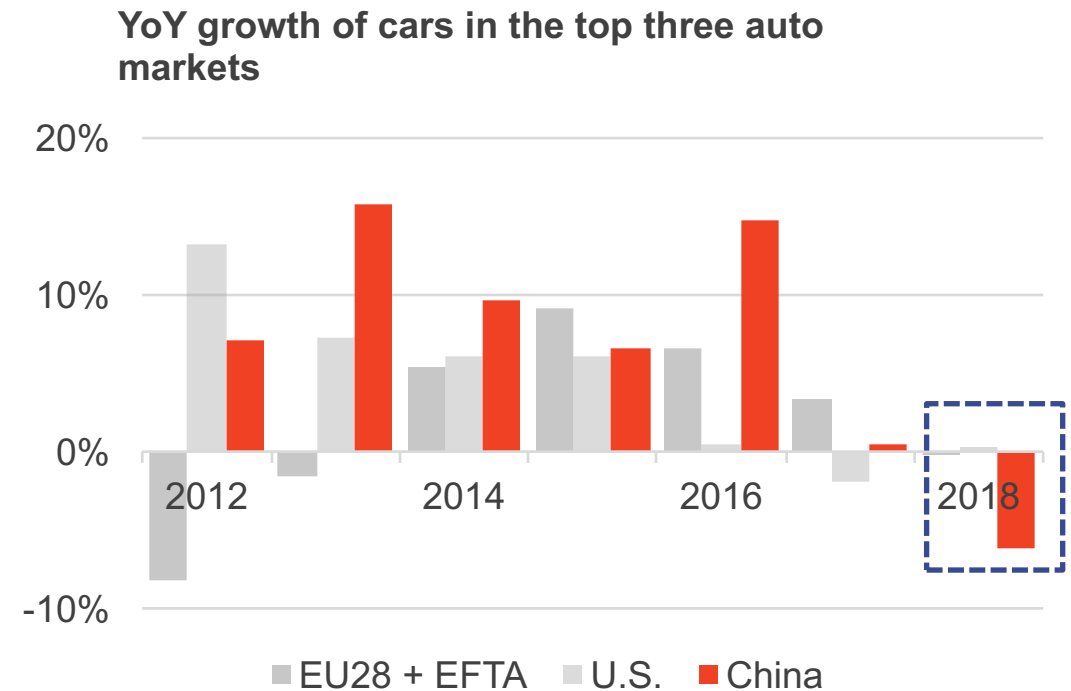
Image sources: Thor Trucks, Lucid Motors, IDTechEx

2017 Peak Car?

- China has driven car sales over the past decade as it has achieved the fastest economic growth in modern history and car purchases have come within reach for millions in the country for the first time (left). The decline of China's auto market in 2018, amid flat sales in the U.S. and Europe, is responsible for the recent decline (right).

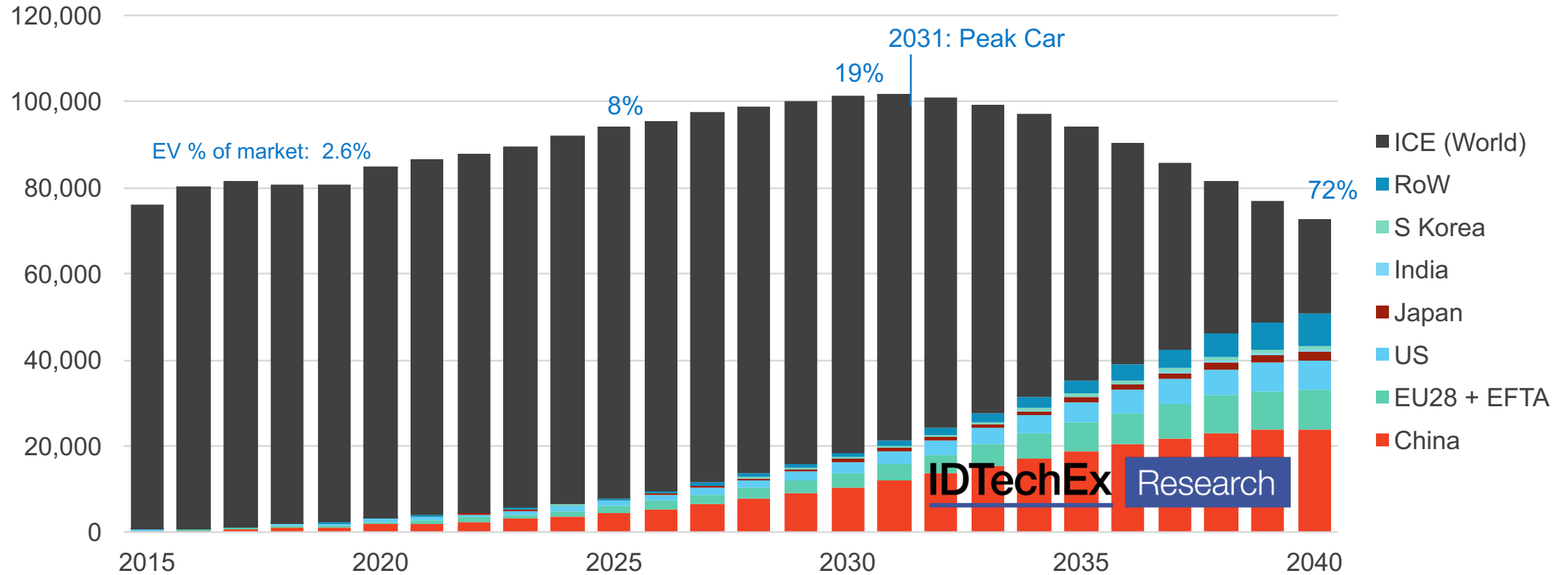


Data source: OICA, CAAM, U.S. DoT, ACEA, IDTechEx



The Global Race for Electric Cars Amid Peak Car

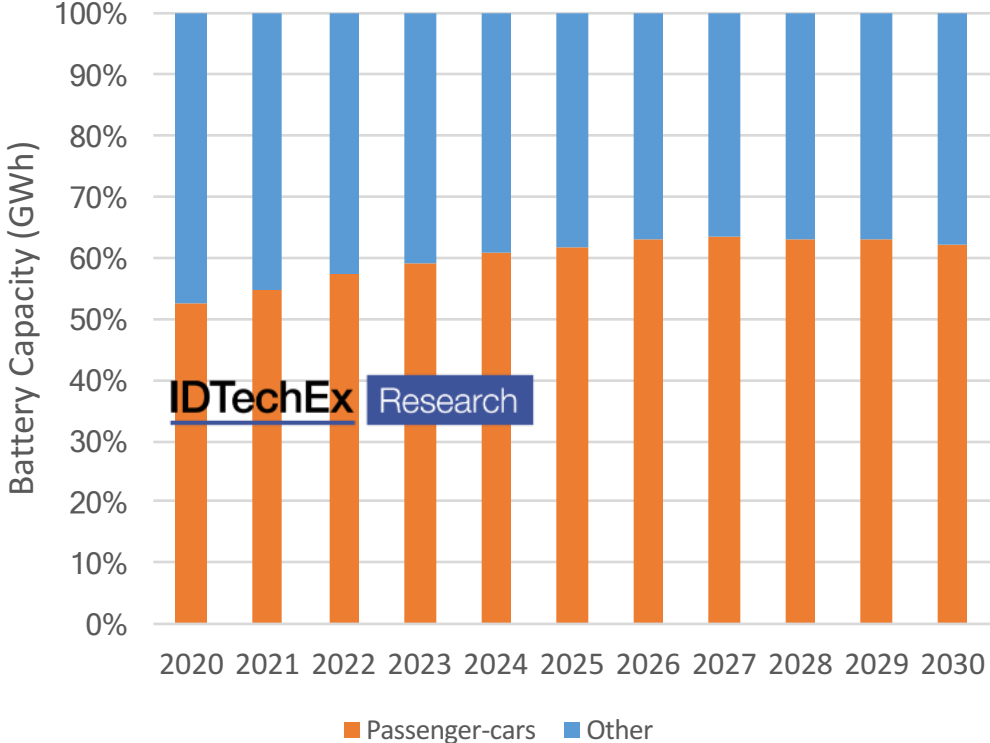
Plug-in electric cars extract value from a declining car market (cars, thousands)



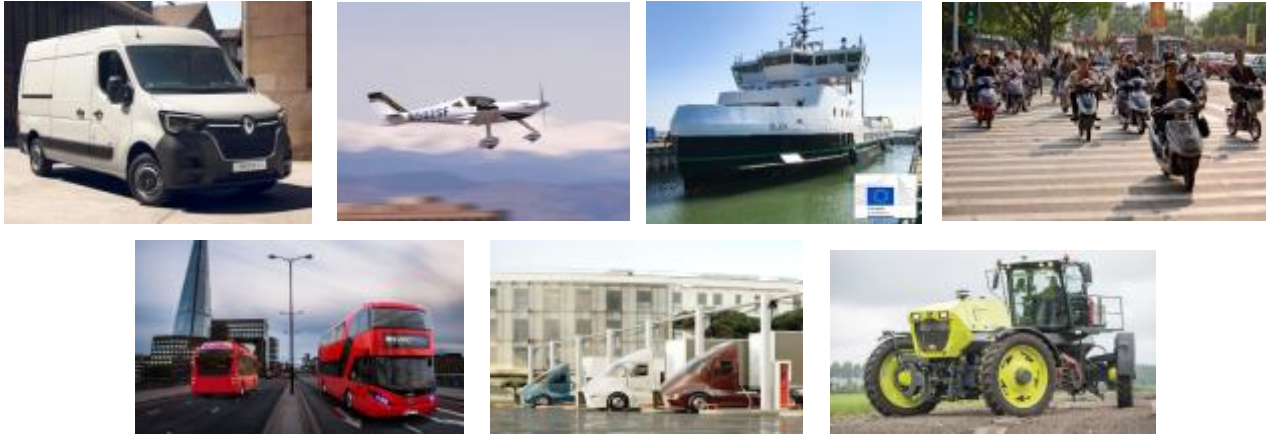
All coloured bars are plug-in electric. Black bars are ICE = internal combustion engine. Source: IDTechEx

Electric Vehicles: GWh Outlook

Battery Capacity (GWh) - All Electric Vehicles



Source: IDTechEx



Renault, E-ferryproject.eu, Bye Aerospace, Wikipedia, Michael velderman, XOS Trucks, Alexander-Dennis

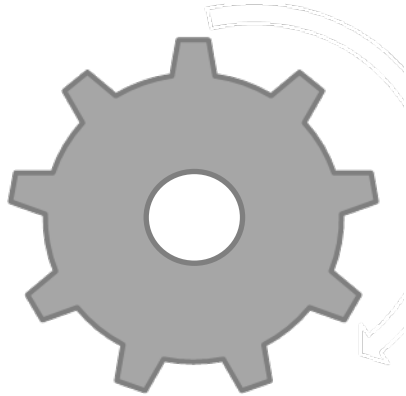
Electric Traction Motors: Important Rotors

Synchronous Reluctance

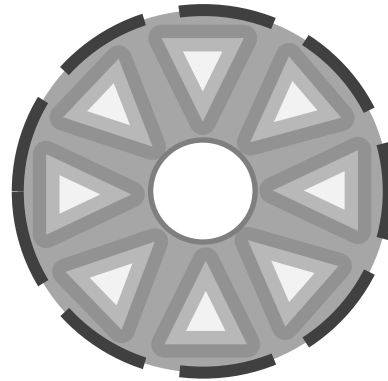


- **No Copper or magnets.**
- Continuous rotating field from stator windings.
- Torque: principle of minimizing reluctance (magnetic resistance) in the steel rotor.
- Fundamentally different to other motor types, as no permanent or induced magnets generate the torque.

Switched Reluctance (SR)

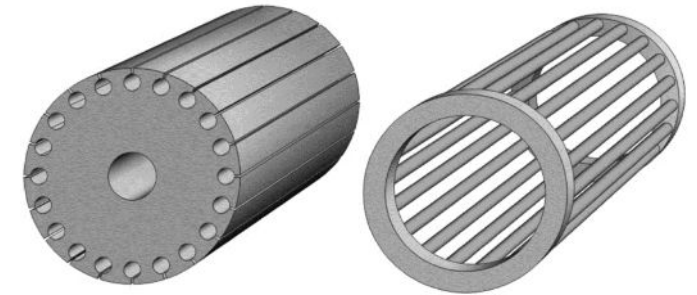


Permanent Magnet (PMSM)



- **Magnets, no Copper.**
- Magnets typically mounted on outside edge.
- Continuously rotating radial magnetic field from AC power to stator windings.
- Rotor rotates at same speed as revolving field.

Induction (ACIM)

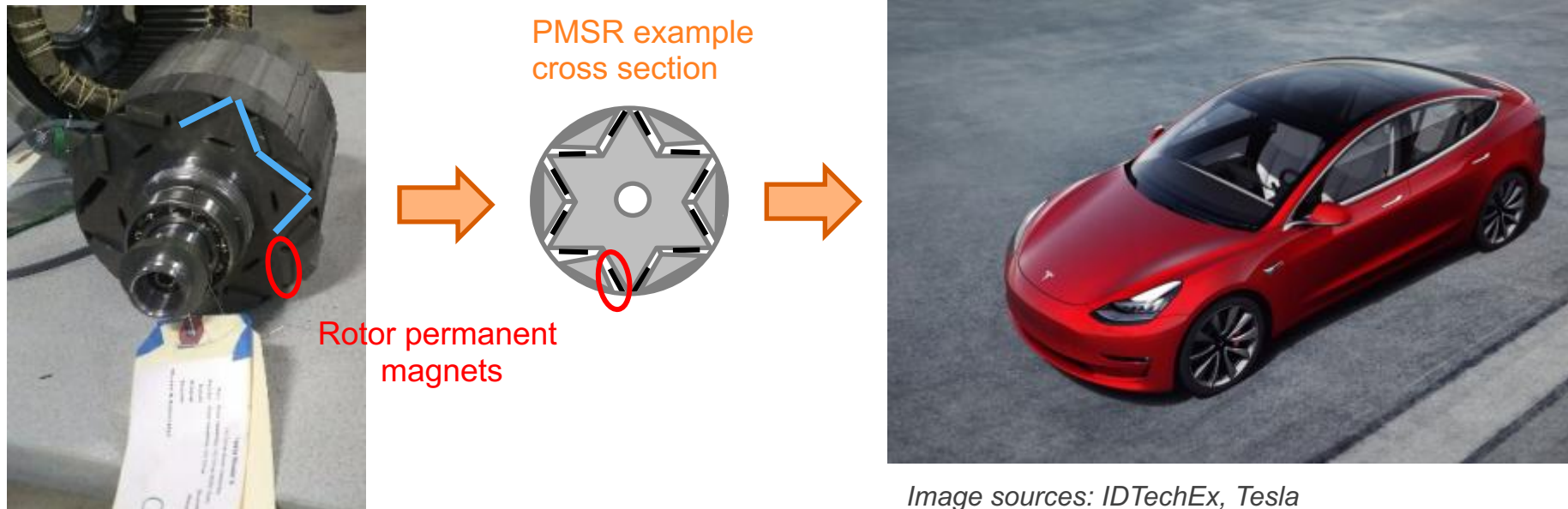


- **Copper, no magnets.**
- Continuous rotating field from stator windings.
- Copper windings in laminated slots (left) or copper bars with end rings to form short circuit (right).
- A current is induced in copper bars or windings creating an electromagnet.
- Rotor rotates can never quit catch the field (asynchronous).

Cross sections of various rotor types. Image sources: IDTechEx, *Electric Motors and Drives 5th Edition*

Shift Towards PMSR

- Tesla introduced a 'permanent magnet switched reluctance' motor in the Model 3, which as the name suggests is a hybrid of permanent magnet synchronous motors and switched reluctance motors.
- While it brings permanent magnets to Tesla's line-up, it makes valuable efficiency gains: 97% versus 93% in the Model S induction motor.



Other Traction Motor Types



Renault
WRSM
Rotor



Wound Rotor Synchronous Motor (WRSM)

- Currently used by one OEM, Renault.
- Rather than permanent magnets on the coil, electromagnets are used: Copper windings are fed with a separate DC current to the three-phase AC current fed to the stator.

Image sources: Renault, Bosch



Bosch
250W
BLDC e-
bike motor

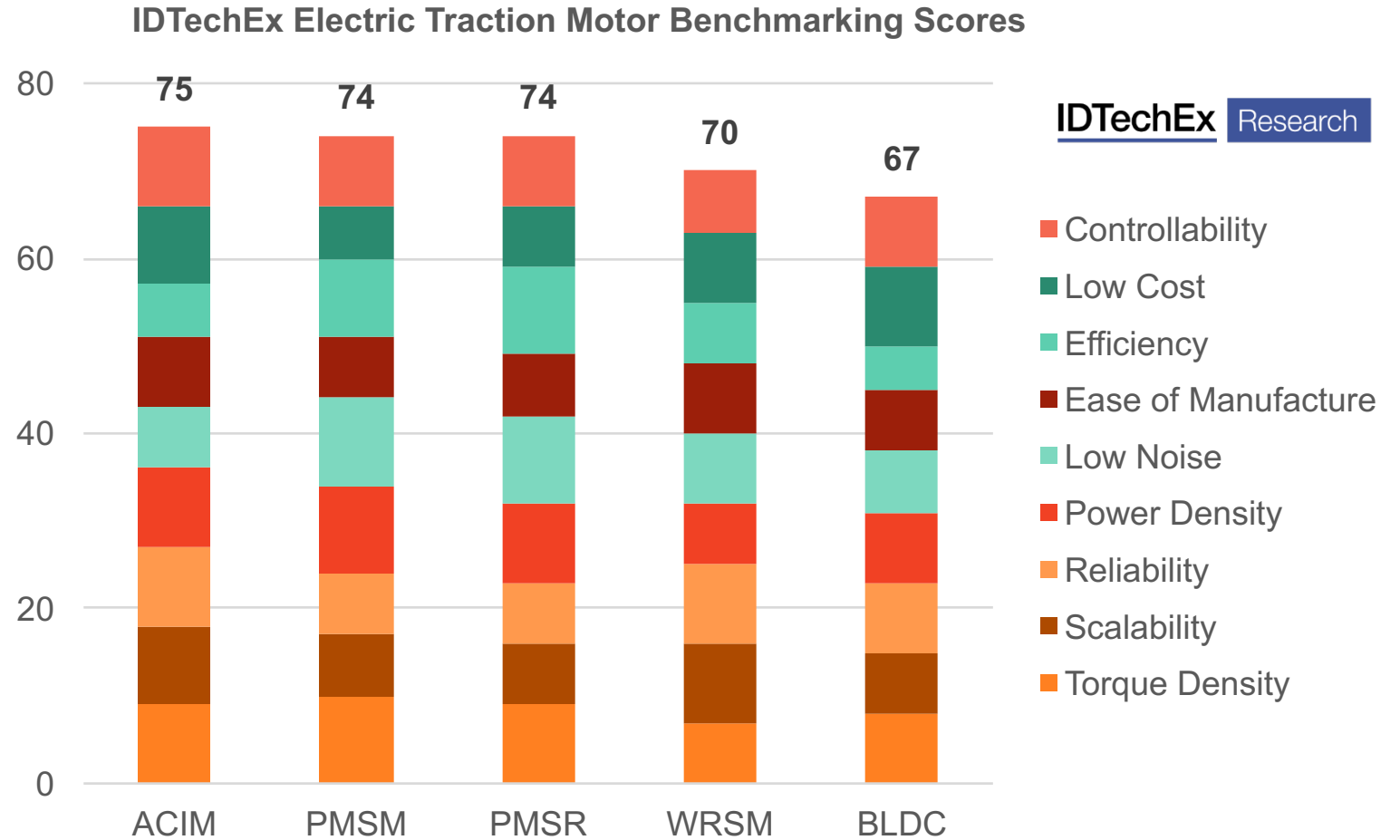


Brushless DC Motors (BLDC)

- Similar working principle to PMSM but trapezoidal current fed to stator (rotating radial B field with discrete steps, not continuous).
- Produced *en masse* in China and supplied globally, economies of scale make them a cheaper alternative to PMSM with similar advantages (although lower performance). They are used widely for micro electric vehicles that have space limitations, require less performance (than a car) and are sold in more price-sensitive markets.

Benchmarking Electric Traction Motors

- PMSR, PMSM and ACIM are neck and neck, each with slightly different strengths such as efficiency or reliability.
- In the markets, PMSM and PMSR currently take the lead due to the importance of having higher power density and efficiency. However, they can be sensitive to price hikes of permanent magnets found predominantly in China.



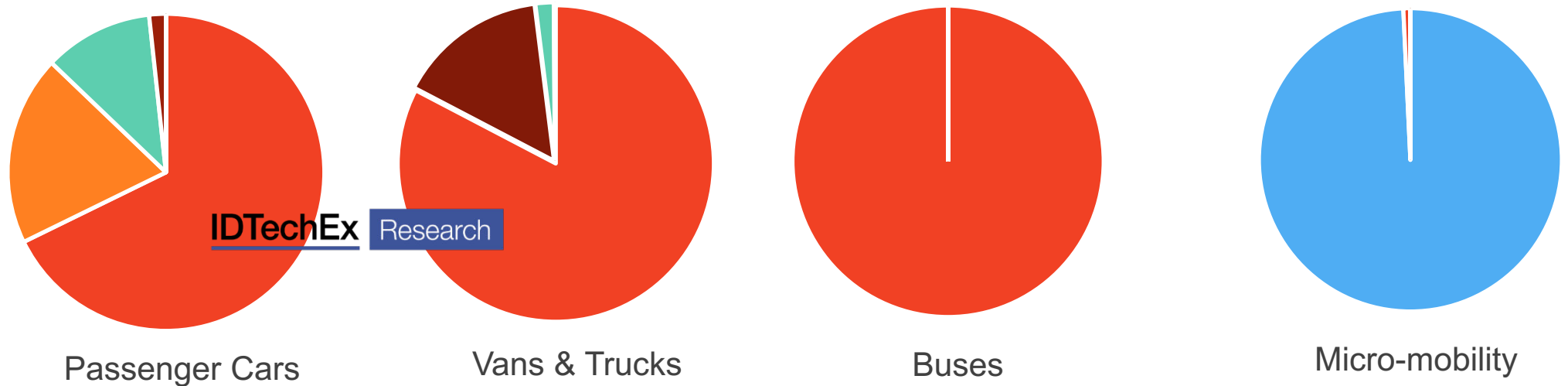
Notes: Each parameter scored out of ten (1- poor 10 - best in class). Source: IDTechEx

Electric Motor Market Share (2019)

- Permanent magnets dominate in sales of electric traction motors due to efficiency, performance and currently acceptable magnet prices.



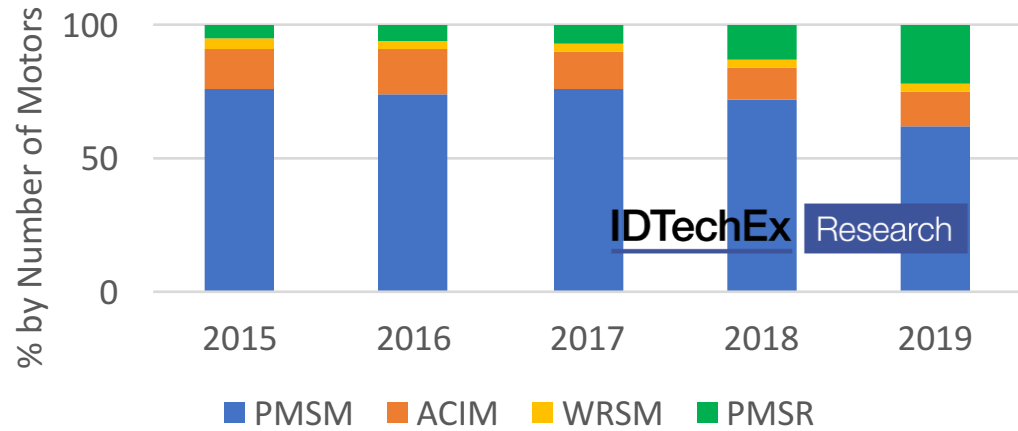
PMSM
 PMSR
 ACIM
 WRSM
 BLDC



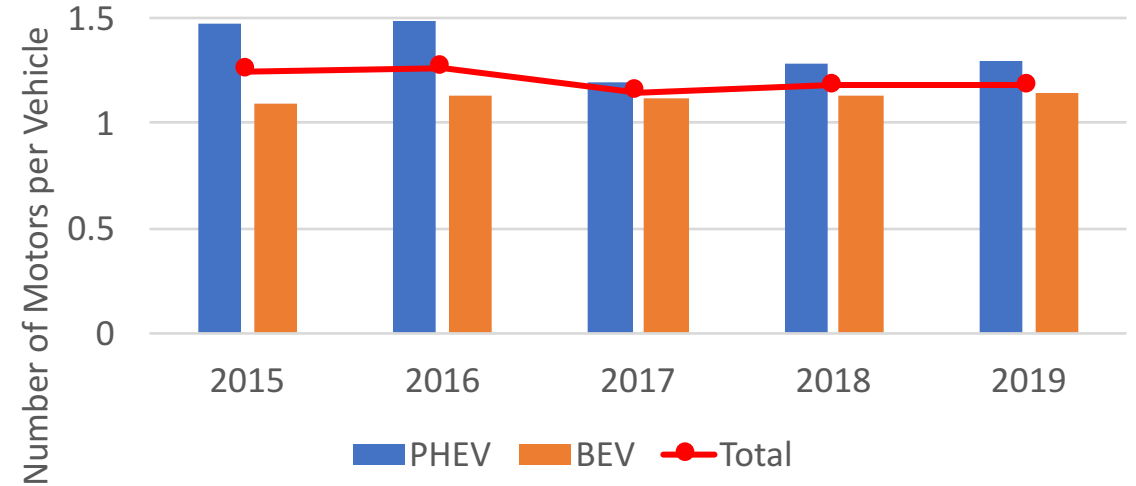
Market shares based on accumulated GWp. Source: IDTechEx

Global Trends

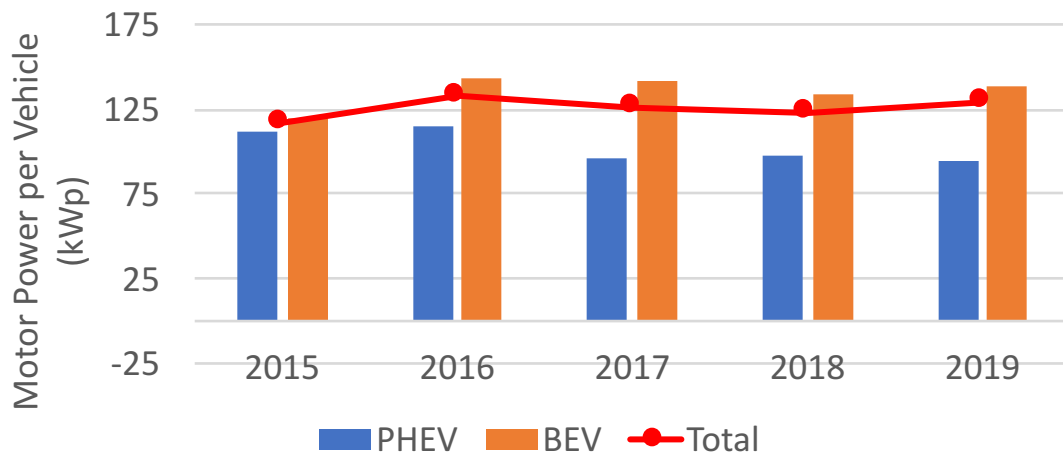
BEV and PHEV Motor Types for Passenger Cars



Global Motors per Vehicle



Global Motor Power Output per Vehicle



Best Sellers	Model	Motor Type	Number	Motor Output (kWp)
2015	BYD Qin PHEV	PMSM	1	110
2016	BYD Tang PHEV	PMSM	2	220
2017	BAIC EC-Series	PMSM	1	45
2018	Tesla Model 3	PMSR	≈1.3	≈297
2019	Tesla Model 3	PMSR	≈1.3	≈297

Automakers' Motor Choices

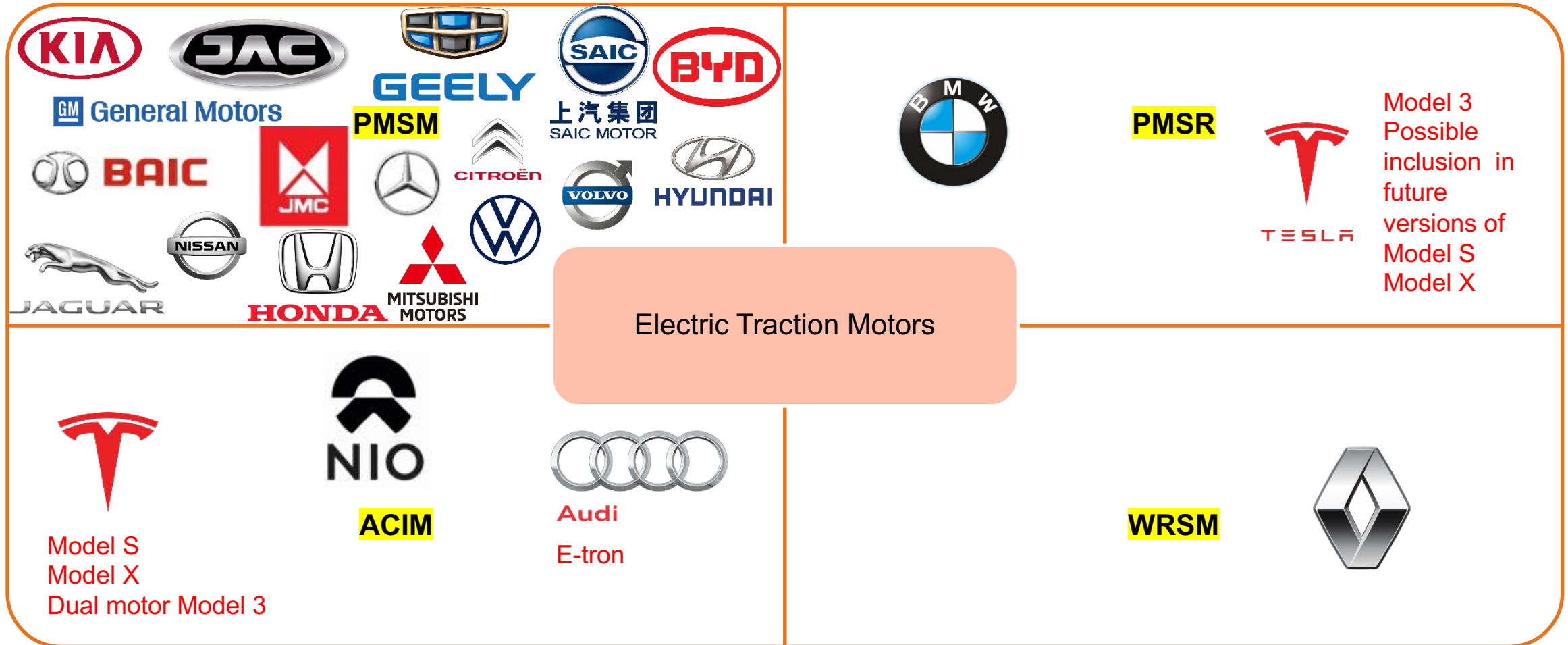
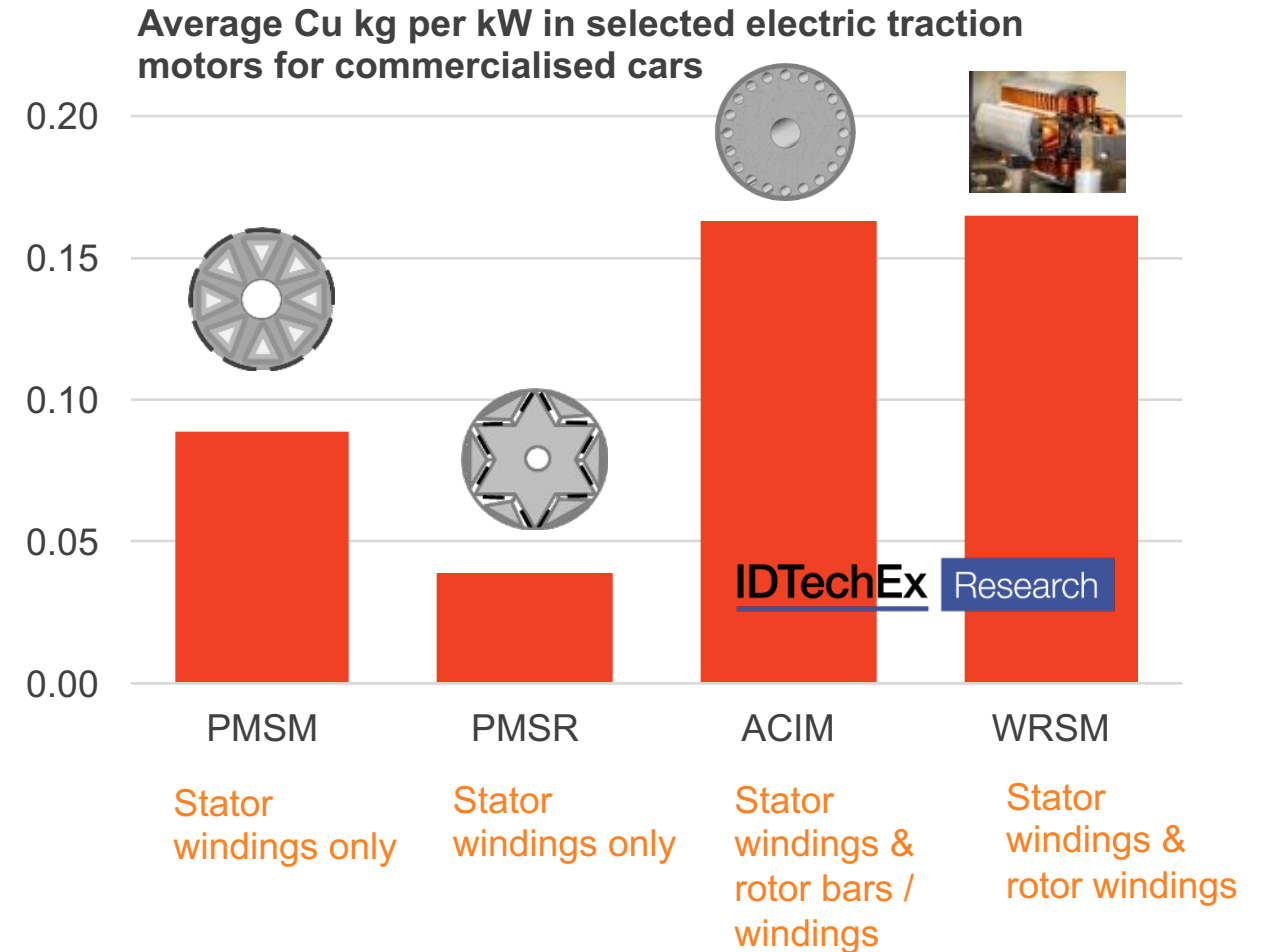


Image sources: Wikipedia

Copper Content in Motor Types

- ACIM and WRSM have greater copper intensity due to copper presence in both stator and rotor.
- As a result, any shift away from ACIM and WRSM could lower overall copper demand.



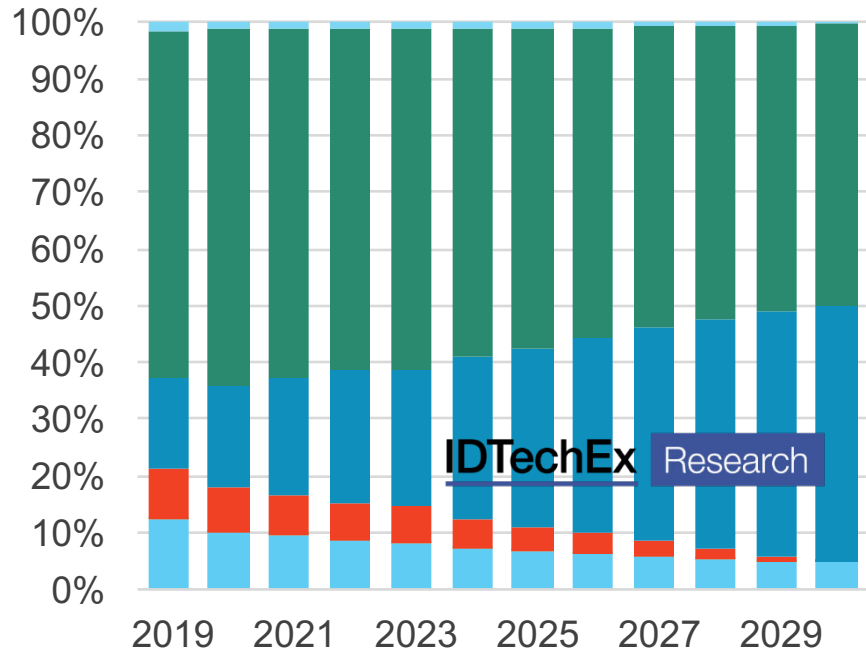
Copper present in:

Notes: PMSM averages historic data from models dating back to 2004, including HEV and BEV models. PMSR electric traction motors are newer to the market and are based on Cu kg estimates from the Model 3 released in 2017. Source: IDTechEx

Electric Traction Motor Demand (GWp)

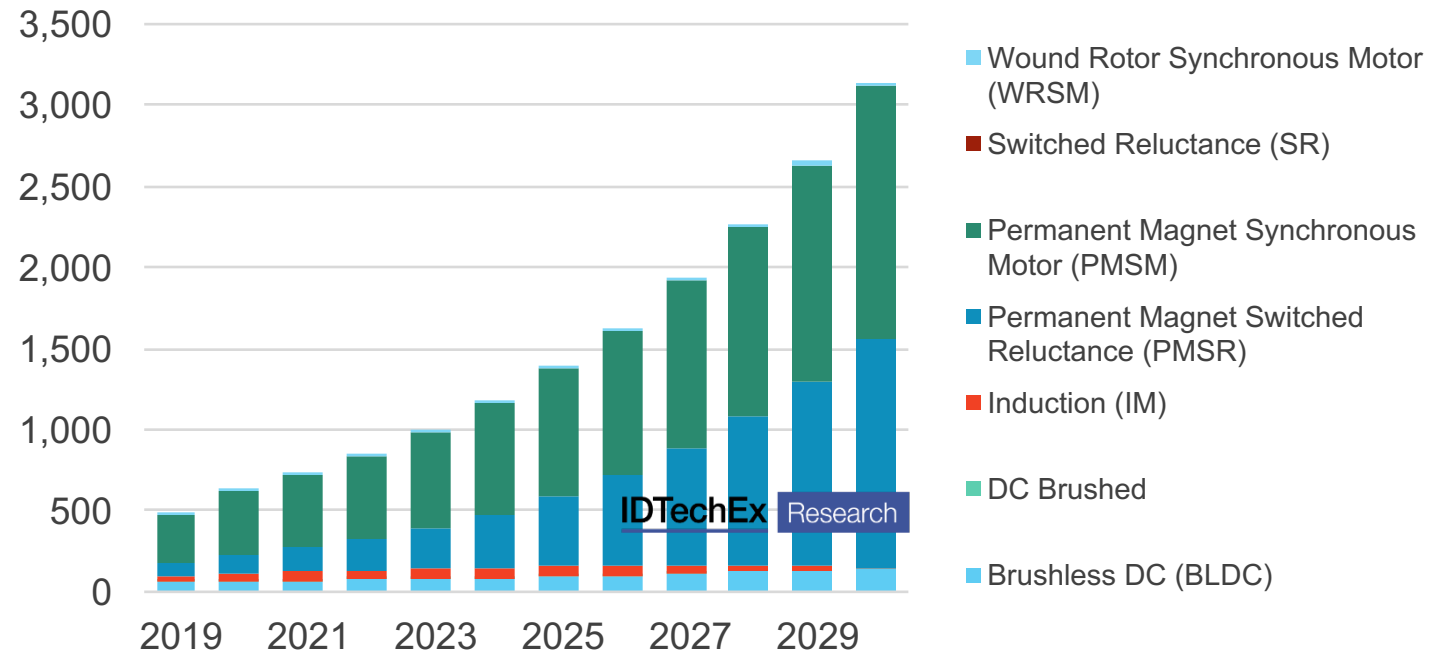
- PMSR and PMSM gain market share at the expense of ACIM and WRSM due to greater efficiency and performance. BLDC motors remain the technology of choice for micro-mobility, but growth in this segment is slower than for cars (market share declines).

Electric traction motor market share (based on GWp)



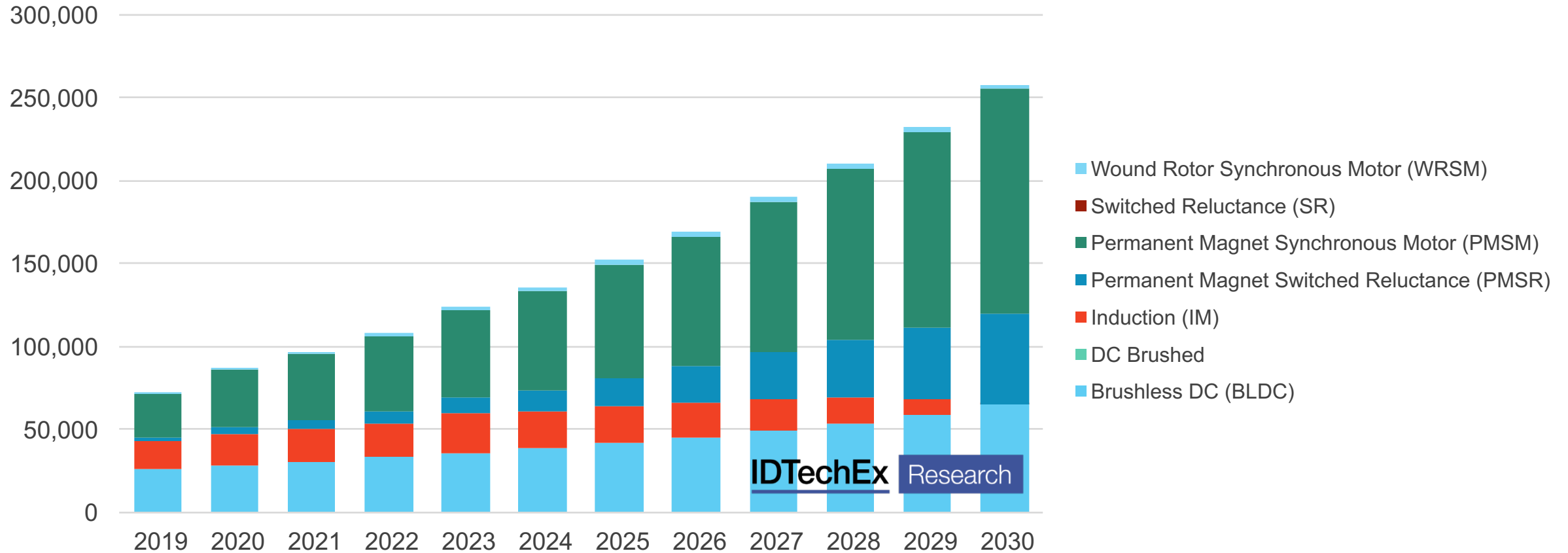
Source: IDTechEx

Electric traction motor forecast in on-road electric vehicles (GWp)



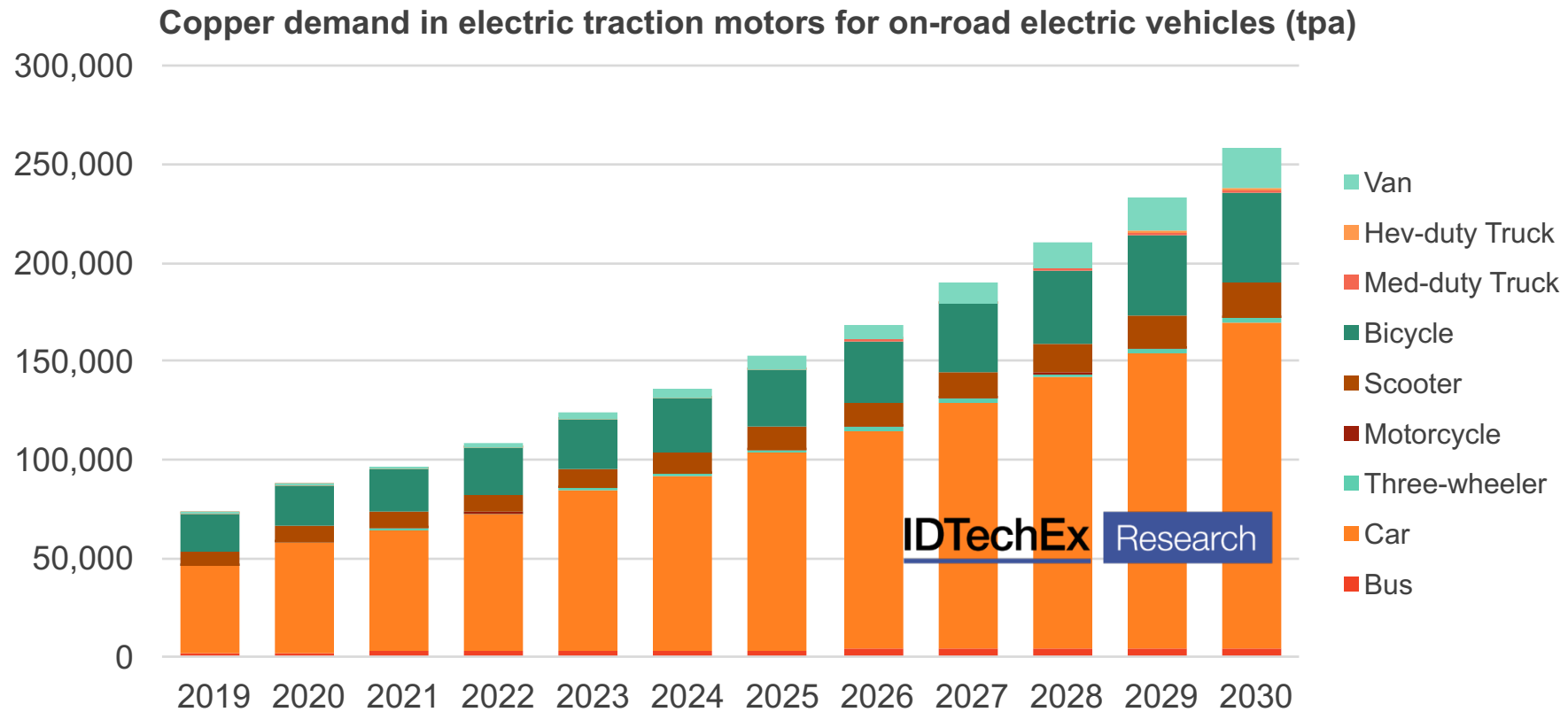
Copper Demand by Electric Traction Motor Type in On-road Electric Vehicles (tpa)

Copper demand by electric traction motor type in on-road electric vehicles (tpa)



Source: IDTechEx

Copper Demand from Electric Traction Motors for On-road Electric Vehicles (tpa)



Source: IDTechEx