Rare Earth Free e-Drives Featuring Low Cost Manufacturing

ReFreeDrive

Collaborative Project
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Abbreviations

In this deliverable, the following acronyms are used.

- **AWD**: All Wheel Drive
- **BEV**: Battery Electric Vehicle
- **BOM**: Bill of Materials
- **BOP**: Bill of Processes
- **CRM:** Critical Raw Materials
- **EM:** Electric Motor
- **EV:** Electric Vehicle
- **GA:** Grant Agreement
- **IM**: Induction Motor
- **IP**: Intellectual Property
- **IPR:** Intellectual Property Rights
- **LCV:** Light Commercial Vehicle
- **LDV:** Light Duty Vehicle
- **NdFeB:** Neodymium-Iron-Boron
- **OEM:** Original Equipment Manufacturer
- **PHEV:** Plug-in Hybrid Electric Vehicle
- **PM**: Permanent Magnet
- **REE**: Rare Earth Elements
- **SWM**: Switched Reluctance Motor
- **SynRel:** Synchronous Reluctance
- **WP:** Work Package

Executive Summary

The present report details all activities related with the exploitation and commercialization of the technological solutions developed during the project. D8.4 takes as starting point the First version of the ReFreeDrive Exploitation Plan (D8.3) already delivered in M18, this previous deliverable outlines the exploitation strategy of the project outcomes and performs a preliminary market analysis and technological watch.

In comparison with D8.3, this Final Exploitation Plan provides:

- A more comprehensive market analysis, covering the Electric Vehicle (EV) market evolution and prospects for the next decade; the trends of customers' needs and the solutions provided by potential competitors; and a review of the Critical Raw Materials (CRMs) availability from a European perspective, with a special focus on Rare Earth Elements (REE) used in Permanent Magnets (PM).
- An Intellectual Property Rights (IPR) strategy, which ensures that all relevant Intellectual Property (IP) information is tracked, hence guaranteeing that any dissemination or exploitation action carried out after the project will not result in conflicts between the interested partners.
- A summary of the techno-economic analysis developed within Task 8.1, comparing each motor technology with the current benchmark technology (Neodymium-Iron-Boron (NdFeB) PM magnets) in terms of performance (extracted from Work Package 7 (WP7) tests) and cost (taken out from WP6 – prototypes manufacturing) under different market uptake scenarios.
- A Commercialisation strategy looking for the best pathways to market after the project.
- An Exploitation plan which gathers, for each partner, the exploitation interests of the different assets (either physical or intellectual) generated during the project in fields such as research, academy or industry.

D8.4 fulfilled its objectives and it was not affected by any specific deviation with respect to what was set in the Grant Agreement (GA) regarding its scope or timing, apart from the deadline extension due to Covid-19 pandemic.

The EV market has experienced an exponential growth in the last decade, with a sustained average growth of 60% in the period 2014-2019. As a result, at least 20 countries reached market shares of EVs above 1% in 2019. China stands out as the biggest EV market in the world, accounting for the 45% of the global EV market (two- and three-wheelers excluded). Future prospects estimate that the global EV stock will expand in this decade up to a number between 140 and 245 million vehicles by 2030 (between 50 and 80 by 2025) depending on the reference scenario, as shown in Figure 1.

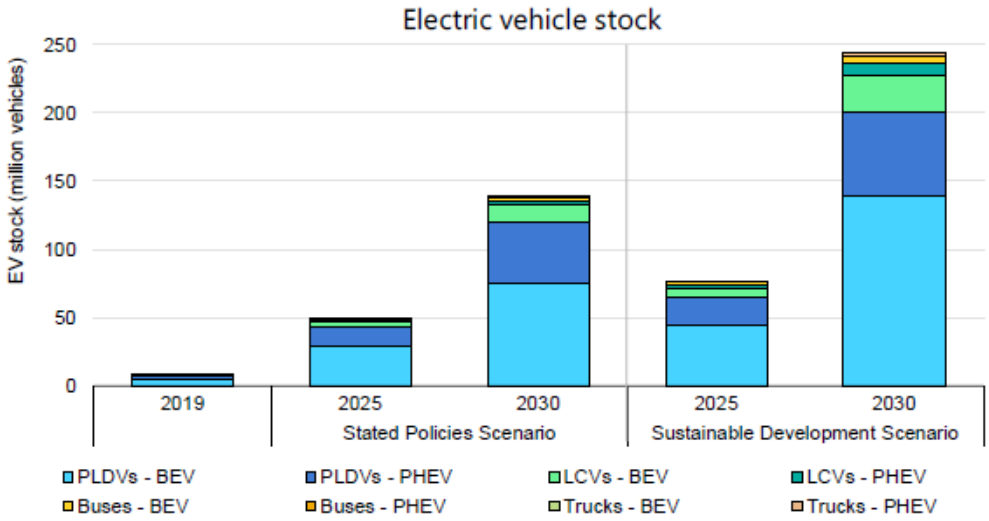

Figure 1. Global EV stock by scenario, prospects for 2025 and 2030.

So far, EV deployment has been strongly driven by policy. That is the reason behind the great uptake of EVs in some European countries such as Norway (56% market share), the Netherlands (15%) and Sweden (12%). For example, in the Norwegian case, its government issued a law according to which all-electric cars are exempt from all non-recurring vehicle fees, including purchase taxes, while at the same time making them high for conventional vehicles. This strong political push to the electric mobility has also had a significant impact on Original Equipment Manufacturers (OEMs) commercial strategies. Consequently, it is estimated that in 2019, 279 EV models were available globally, a 26% increase from 2018. In line with EV sales figures, China presents the largest number of available models at 171, followed at a certain distance by the European Union with 45 and the United States with 49.

From the customer's point of view, their concerns in regards to EVs are focused on the following topics: cost/price premium, reliability, driving range, and the potential lack of electric vehicle charging infrastructure.

A critical component of EVs is obviously the motor. Currently the most expanded motor solutions rely on PM technology, using rare-earth magnets. However, the high and volatile cost of raw materials for magnets makes uncertain their long term availability. Therefore, it has become mandatory to find alternative solutions, that include rare earth free machines or reduced rare-earth PM machines. Several types of motors have been under study for propulsion applications, including low-cost PM, Induction Motors (IM), Switched Reluctance Motors (SWM) and synchronous reluctance (SynRel) motors. ReFreeDrive research has demonstrated that the induction motors, ferrite magnet assisted and synchronous reluctance motors represent valid alternatives, though care must be taken during the motor sizing and selection of electrical steel in order to satisfy the hard requirements and avoid an increasing on the system costs. Table 1 presents a high-level comparison among the different technologies explored within the project.

Table 1. High performance electric motors for automotive applications: comparison of motor technologies

	PM motor	IM	SyR
Cost	highest	moderate	low
Power density	highest	moderate	moderate
Efficiency	good	good	moderate
Noise & vibration	good	good	challenging
Manufacturability	difficult	mature	easy

Regarding the market application of Electric Motors (EM), the majority of EVs have a centralized on-board powertrain layout with one motor, which is connected to the two wheels through a mechanical transmission with differential, half-shafts, and constant velocity joints. For premium segment EVs, All-Wheel-Drive (AWD) configurations with two electric machines (one per axle) are the latest trend, because of their intrinsically better traction and handling performance. In these configurations, the two machines can target different objectives, e.g., one machine can be optimized for energy efficiency during normal use, while the second one provides the required traction torque/power performance.

As stated in the GA, D8.4 has defined and implemented a methodology aiming at controlling the transfer of knowledge and IP rights from the beginning of the project. Hence the background and foreground knowledge have been defined and managed in such a way that enables a favorable environment for the exploitation of results, described within the Exploitation Plan.

A commercialization strategy has also been developed (Figure 2), in which different target markets according to the expertise of ReFreeDrive's partners have been defined. Starting from a comprehensive Bill of Materials (BOM) and Bill of Processes (BOP) for two production volumes (30000 and 100000 units per annum), a should-cost model for each motor technology and power level has been built.

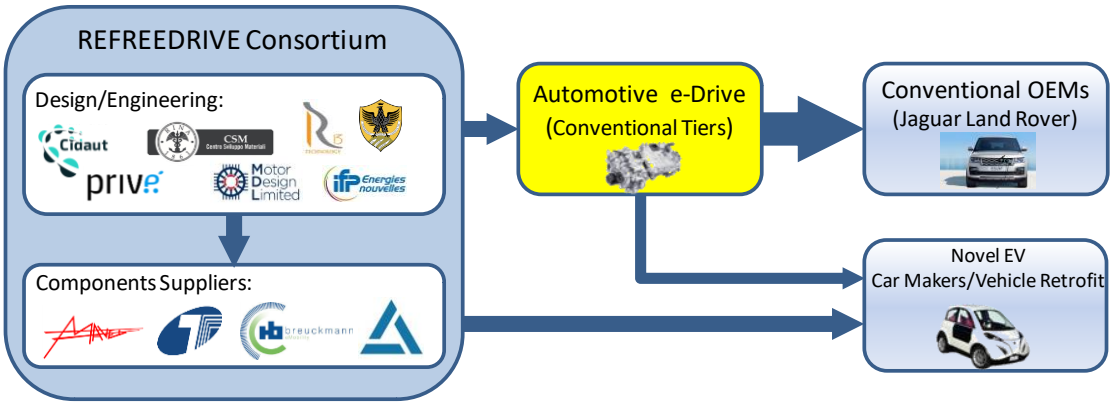

Figure 2. Players involved in the ReFreeDrive commercialization strategy.