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Future CO_2 reducing technologies in VECTO

VECTO technology coverage and market uptake

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Contents

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Abstract

The software tool VECTO is used to determine the energy demand, fuel consumption and CO_2 emissions of new heavy-duty vehicles. The tool takes into account the relevant vehicle component technologies that affect fuel consumption and CO_2 emissions and should be updated when new relevant technologies are brought to the market. This work presents the results of a survey investigating the capability of VECTO to simulate new vehicle technologies, along with CO_2 reduction potential and the expected penetration rate in the market of these technologies. An in-depth analysis of these new technologies is presented in this work.

Many of the technologies demonstrating high potential in reducing CO_2 and market uptake in the near future (e.g. aero devices for trailers and bodies and hybrid electric powertrains) are currently being implemented in VECTO. The next steps can include zero-emission vehicles, such as fuel cell vehicles, and technologies that could be easily implemented.

1 Introduction

The European Commission has introduced regulation (EU) 2017/2400 [1] to determine the fuel consumption and CO_2 emissions of new heavy-duty vehicles to encourage the introduction of energy-efficient vehicles to the market for curbing the CO_2 emissions from heavy-duty vehicles. A simulation-based approach was chosen to take into account the extensive customisation possibilities inherent to heavy-duty vehicles. The fuel consumption and CO_2 emissions of new heavy-duty vehicles are simulated with the software tool VECTO (Vehicle Energy Consumption calculation TOol) as of January 2019. The simulated CO_2 emissions are also the basis for the CO_2 emissions performance standards [2]. VECTO was developed by the European Commission and requires the vehicle's component characteristics as input to calculate the fuel consumption and CO_2 emissions over standardised mission profiles [3,4]. To accurately determine the vehicle's fuel consumption and CO_2 emissions, the tool should consider the relevant vehicle component technologies that affect the fuel consumption and CO_2 emissions and the tool should be updated accordingly when new relevant technologies are brought to the market.

To assist with the further development of VECTO, the JRC has investigated the capability of VECTO to simulate new vehicle technologies, along with the technologies' CO_2 reduction potential and their expected penetration rate in the market. The investigation is based on the input provided by stakeholders through a survey. The survey was distributed in 2020 to receive expert feedback from vehicle and component manufacturers, universities and non-governmental organisations. The JRC has conducted a similar survey in 2016 [5], that was used as a basis for comparison with the results of the current survey.

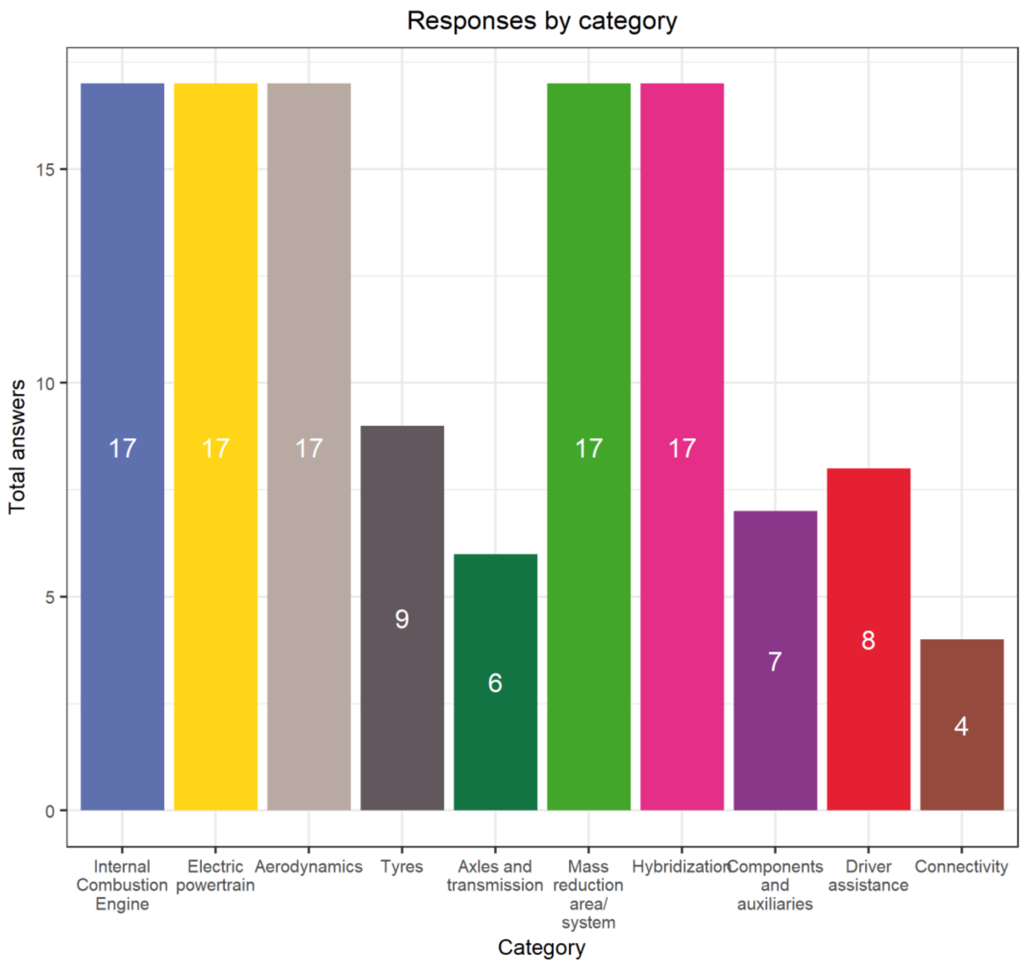
The current document presents the survey profile (Section 2), the technology coverage by VECTO (Section 3) and the CO_2 reduction potential and market penetration of new technologies (Section 4). Section 3, contains an overview of technologies being implemented in VECTO, a list of technologies expected to gain market share in the near future that are currently not covered by VECTO and a detailed overview of the survey responses with regards to VECTO coverage. Section 4 provides an in-depth analysis of the new technologies, with regards to their CO_2 reduction potential, market introduction and market penetration by 2025 and 2030.

2 Survey profile

The initial step was to compose a technology list for assessing the impact on the vehicle's fuel consumption and CO_2 emissions and the market introduction for heavy-duty vehicles. The technologies were grouped into categories and the survey respondents were asked to provide their insight into each category based on their expertise. Additionally, the respondents were given the possibility to add more relevant technologies to each category. The following list presents the technology categories, while the full list of technologies can be found in Table A1 of Annex 1. The number of respondents' answers per category is presented in Figure 1.

- Internal combustion engine
- Electric powertrain
- Aerodynamics
- Tyres
- Axles and transmission
- Mass reduction area/system
- Hybridisation
- Components and auxiliaries
- Driver assistance
- Connectivity

Figure 1. Number of responses by category



Source: JRC, 2020.

The survey was structured as follows:

Firstly, the respondents were asked whether the technology was accurately simulated by VECTO. For each technology they were offered the following options:

- Yes
- Under development
- Partially
- No
- I don't know / I am not sure

The technologies that are currently being implemented in VECTO were already marked with the option "Under development", with the possibility to be altered by the respondents. This provided a guide for the respondents less familiar with the current progress of the VECTO development and allowed feedback on the current development process.

In the next question, the respondents were asked to provide an estimate of the expected CO_2 reduction potential of each technology. For each technology they were offered the following options:

- <2%
- 2-5%
- 5-10%
- 10-15%
- 25-50%
- 15-25%
- >50%
- Carbon Neutral
- I don't know / I am not sure

Subsequently, they also provided the estimated year of the technology introduction in the market and the expected penetration by 2025 and 2030. They were offered with the following options on the technology penetration:

- Innovation <3%
- Low 3-10%
- Developing 11-30%
- Established 31-60%
- Standard ≥61%
- I don't know / I am not sure

The respondents provided additional technologies to the list per category. Technologies that were deemed identical or similar between respondents were grouped under a single generic technology name. For clarity reasons, as some of the technologies are named specifically, a list of the grouped technologies is provided in Table A2 in Annex 2. Survey results.

3 VECTO technology coverage

3.1 Technologies under development

There are currently a number of new technologies being implemented into VECTO, which are not yet applicable to new vehicles being registered now. These technologies were included in the survey with the marker "under development" aiming to inform stakeholders not familiar with VECTO development. Additionally, it was an approach for requesting feedback about the development from the involved stakeholders. These technologies are listed in Table 1.

Table 1. Overview of technologies being implemented in VECTO

Aerodynamics
Body/Trailer front end devices
Body/Trailer rear-end devices
Body/Trailer side skirts
Body/Trailer shape
Internal Combustion Engine
Waste heat recovery with organic Rankine cycle
Dual fuel injection, LNG
Electric powertrain
Battery electric vehicle
Hybridisation
48V electric architecture
24V brake energy recovery
Integrated mild hybrid
Kinetic hybrid powertrain
Plug-in charging
Electric hybrid powertrain with serial architecture
Electric hybrid powertrain with parallel architecture
Electric hybrid powertrain with power-split architecture
Hybridised trailer
Trailer energy recuperation
Mass reduction area/system

Trailer body

Source: JRC, 2020.

3.2 Technologies not covered by VECTO

The technologies identified as not or only partially covered by VECTO and expected to gain market share in the near future are summarised in Table 2. Only the technologies that the majority of respondents classified as **not or only partially covered by VECTO** are presented. Moreover, only technologies with a **market introduction until 2024** and a **"developing" market penetration (11-30%)** are listed. The reported market introduction, market penetration and CO_2 reduction values cover the entire range of respondents' answers.

Additionally, the stakeholders provided comments as free text. This was used to express the desire to prioritise the development of the following four technologies in VECTO:

- Battery electric vehicles
- Fuel cell electric vehicles
- Electrified trailers
- Trailer aerodynamic devices

Table 2. Overview of technologies expected to gain market share in the near future currently not covered by VECTO

Technology	Market introduction	Market penetration by 2025	Market penetration by 2030	CO_2 reduction (%)
Internal Combustion Engine				
Cylinder Deactivation	2024	Established 31-60%	Standard ≥61%	2-5%
Waste heat recovery with organic Rankine cycle	2024	Developing 11-30%	Established 31-60%	2-5%
Aerodynamics				
Active Body/trailer lowering	2024	Developing 11-30%	Established 31-60%	<2%
Cross-wind optimization	already on the market	Developing 11-30%	Developing 11-30%	2-5%
Tyres				
Active Pressure Inflation	already on the market	Developing 11-30%	Established 31-60%	2-5%
Real Rolling Resistance of trailers' tyres	already on the market	Standard ≥61%	Standard ≥61%	-
Tyre and Rim Inertia Real value	already on the market	Standard ≥61%	Standard ≥61%	<2%
Axles and transmission				
Active Caliper Release	2021	Standard ≥61%	Standard ≥61%	<2%
Engine/transmission deep-integration	2024	Standard ≥61%	Standard ≥61%	2-5%
Wheel bearings	already on the market	Developing 11-30%	Standard ≥61%	<2%
Hybridisation				
Integrated mild hybrid	2024	Developing 11-30%	Developing 11-30%	2-5%
Components and auxiliaries				
Electric Power Steering	2024	Established 31-60%	Standard ≥61%	<2%
Electrified engine auxiliaries: oil pump, water pump	2024	Standard ≥61%	Standard ≥61%	<2%
Parking Heater/cooler	2020	Established 31-60%	Established 31-60%	<2%
E-Dual displacement pumps	2024	Developing 11-30%	Established 31-60%	<2%
High efficiency alternator	2020	Established 31-60%	Standard ≥61%	<2%
Improved air compressor/Compressed air use reduction	2024	Developing 11-30%	Established 31-60%	<2%

Technology	Market introduction	Market penetration by 2025	Market penetration by 2030	CO_2 reduction (%)
Driver assistance				
Adaptive cruise control	already on the market	Standard ≥61%	Standard ≥61%	<2%
Advanced Driver Assistance Systems	2022	Developing 11-30%	Established 31-60%	<2%
Clutch torque during Eco-Roll	2020	Established 31-60%	Standard ≥61%	<2%
Curve, crossing, roundabout Eco approach	2024	Established 31-60%	Standard ≥61%	<2%
Driver Drowsiness	2023	Standard ≥61%	Standard ≥61%	<2%
Driver Performance Assistant	2020	Standard ≥61%	Standard ≥61%	<2%
Eco/Max speed limiter	2020	Standard ≥61%	Standard ≥61%	<2%
ISA Limitator (Camera, Map, Connectivity)	2024	Standard ≥61%	Standard ≥61%	<2%
Other (Fuel optimized longitudinal steering)	2024	Established 31-60%	Standard ≥61%	2-5%
Predictive Eco-Roll	2020	Established 31-60%	Standard ≥61%	<2%
Predictive Shifting Strategy	already on the market	Standard ≥61%	Standard ≥61%	2-5%
Predictive cruise control	already on the market	Established 31-60%	Standard ≥61%	2-5%
Predictive Curve/SpeedLimit Assist/CoastControl	2022	Established 31-60%	Standard ≥61%	<2%
Pulse and glide	already on the market	Established 31-60%	Standard ≥61%	<2%
Stop and Go Assist	2022	Established 31-60%	Standard ≥61%	<2%
Traffic Jam Assist (incl. Connectivity)	2024	Standard ≥61%	Standard ≥61%	<2%
Vehicle Acceleration Limiter	2021	Standard ≥61%	Standard ≥61%	<2%
Vehicle speed limiter	already on the market	Developing 11-30%	Developing 11-30%	<2%
Connectivity				
Eco-driving	2024	Established 31-60%	Standard ≥61%	2-5%
Smart infrastructure V2I & I2V (or G2V)	2024	Established 31-60%	Standard ≥61%	2-5%

Source: JRC, 2020.

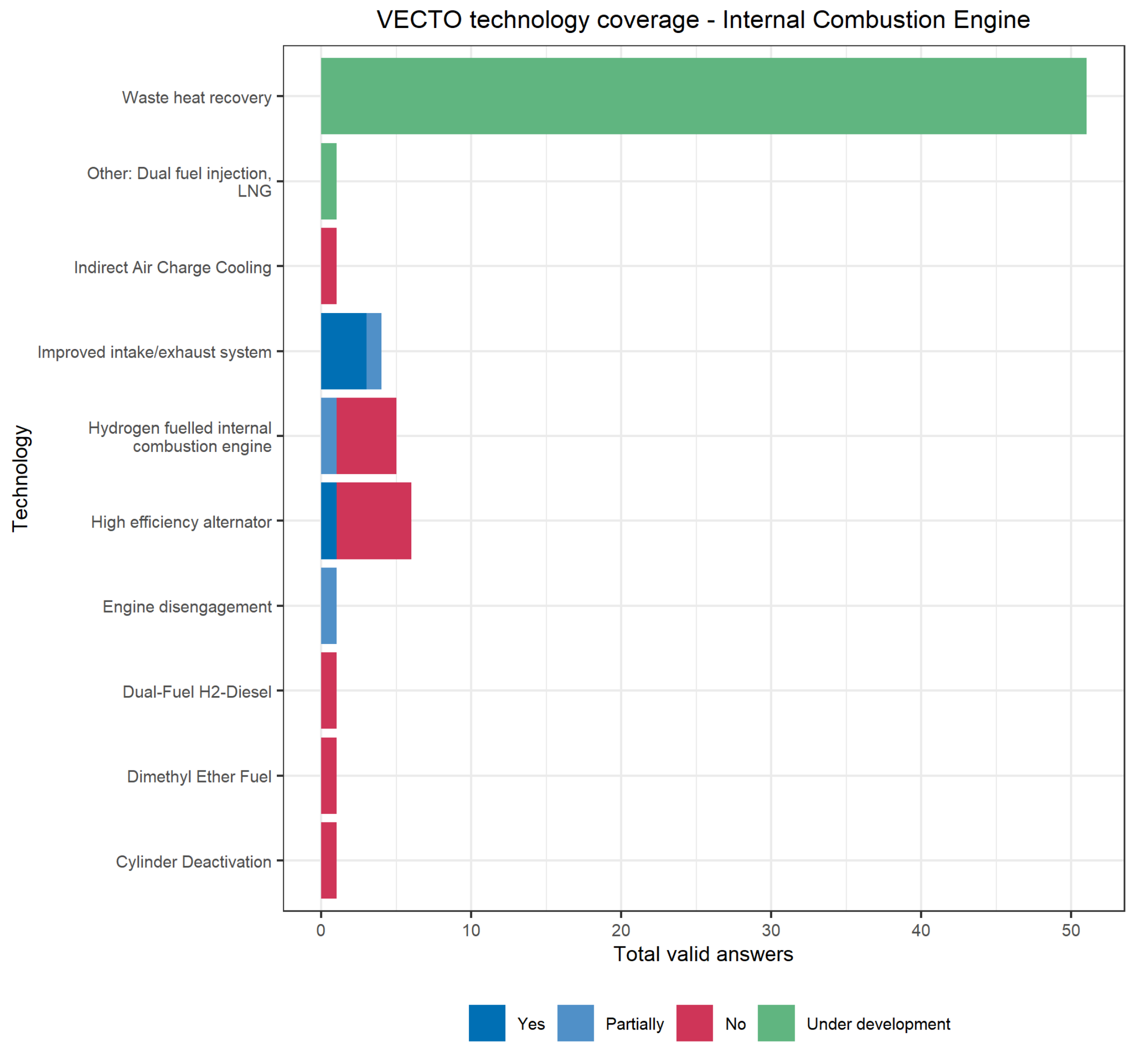
3.3 Detailed VECTO coverage

A detailed analysis of the coverage by VECTO per category is presented in the next sections.

3.3.1 Internal combustion engine

The internal combustion engine category covers several technologies such as waste heat recovery, engine improvements, cylinder deactivation, alternative carbon-based fuels but also hydrogen as a fuel for the internal combustion engine. Hydrogen for a fuel cell powertrain is investigated in the Electric powertrain section. Figure 2 presents the VECTO technology coverage of internal combustion engine technologies. Various alternative fuels were proposed that are currently not covered by VECTO. A respondent explained that electrified engine auxiliaries, such as oil pumps and water pumps can be considered that are indirectly covered by VECTO. According to the engine testing procedure that is deployed for producing the fuel maps, the electric power provided externally during the engine test is measured, converted to mechanical power with a generic efficiency and finally used to correct the engine torque measured during the engine test. Accordingly, another respondent stated the waste heat recovery could be covered by a modelling approach. It was interesting that a respondent highlighted that technologies such as engine disengagement combined with light hybridisation would change the operating point of the engine and could render the WHTC non-representative of real-world conditions.

Figure 2. VECTO coverage of internal combustion technologies



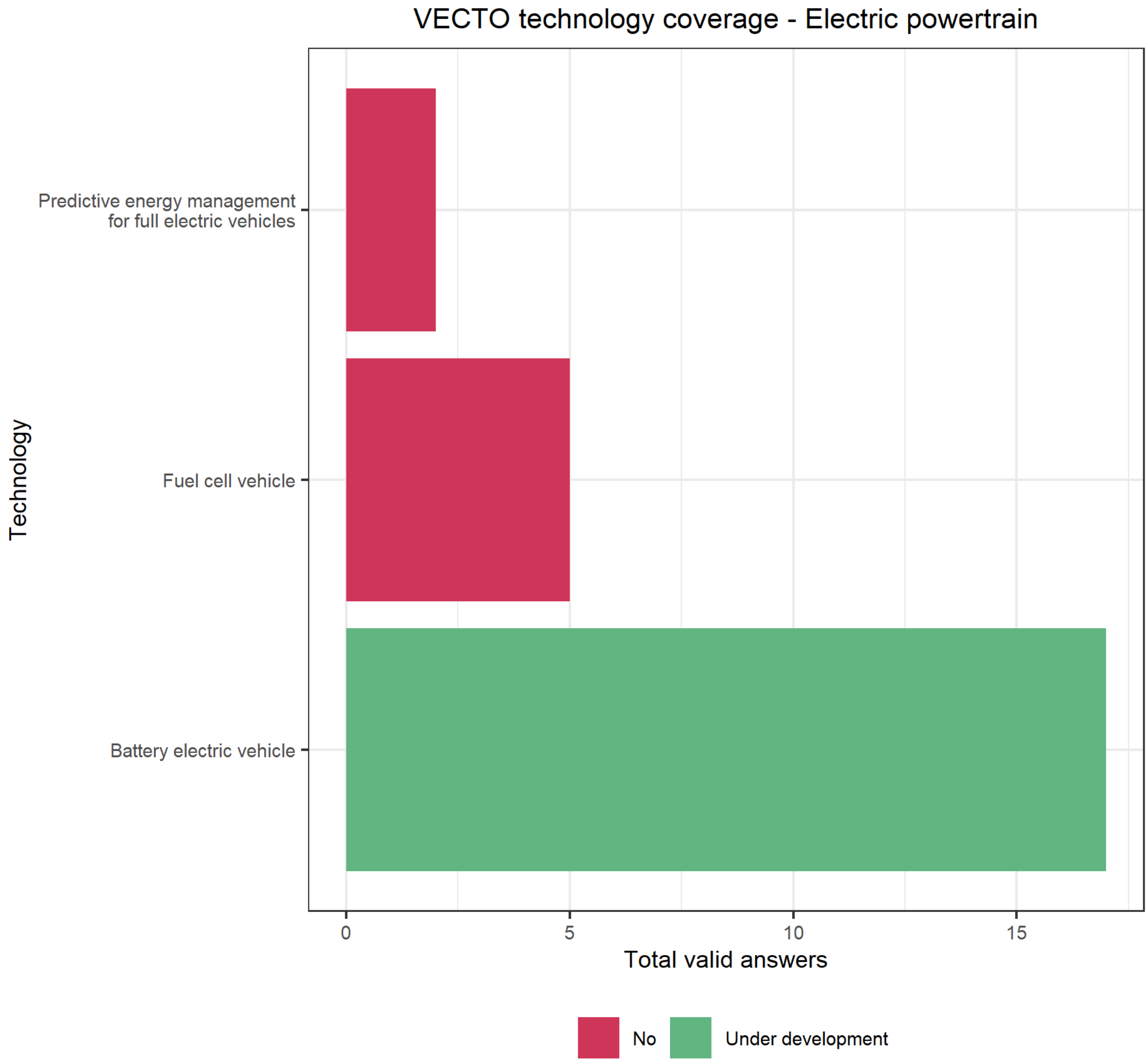
Source: JRC, 2020.

A respondent remarked a problem with the way indirect charge air cooling is handled currently in VECTO. The engine input data is based on a steady-state fuel consumption map and a series of correction factors to take into consideration the transient fuel consumption. The fuel consumption map and the transient WHTC (World Harmonized Test Cycle) are carried out on a typical engine dyno without any special equipment and usually with an indirect charge air cooler. Although it is adjusted to mimic the real direct charge air cooler's performance and pressure drop, it has a significantly different transient behaviour from the direct charge air coolers in the vehicle. The respondent proposes to modify the engine test procedure, by performing the test with the original charge air cooler hardware installed on the vehicle and not with generic engine dyno equipment. Opposing views are noted for the high efficiency alternator and hydrogen as fuel.

3.3.2 Electric powertrain

Electric powertrains offer the capability to use electricity in the vehicle propulsion, while some technologies can be used along with the internal combustion engine. The combination of the internal combustion engine and electric motor for propulsion is investigated in the hybridisation section of the current report. Figure 3 presents the VECTO coverage of electric powertrain technologies. Battery electric vehicles are currently under development, but at this stage, fuel cells vehicles are not included. A respondent stated that a component test procedure for the fuel cell is needed that correlates the H_2 flow to electrical power output in order to cover fuel cell vehicles.

Figure 3. VECTO coverage of electric powertrain technologies

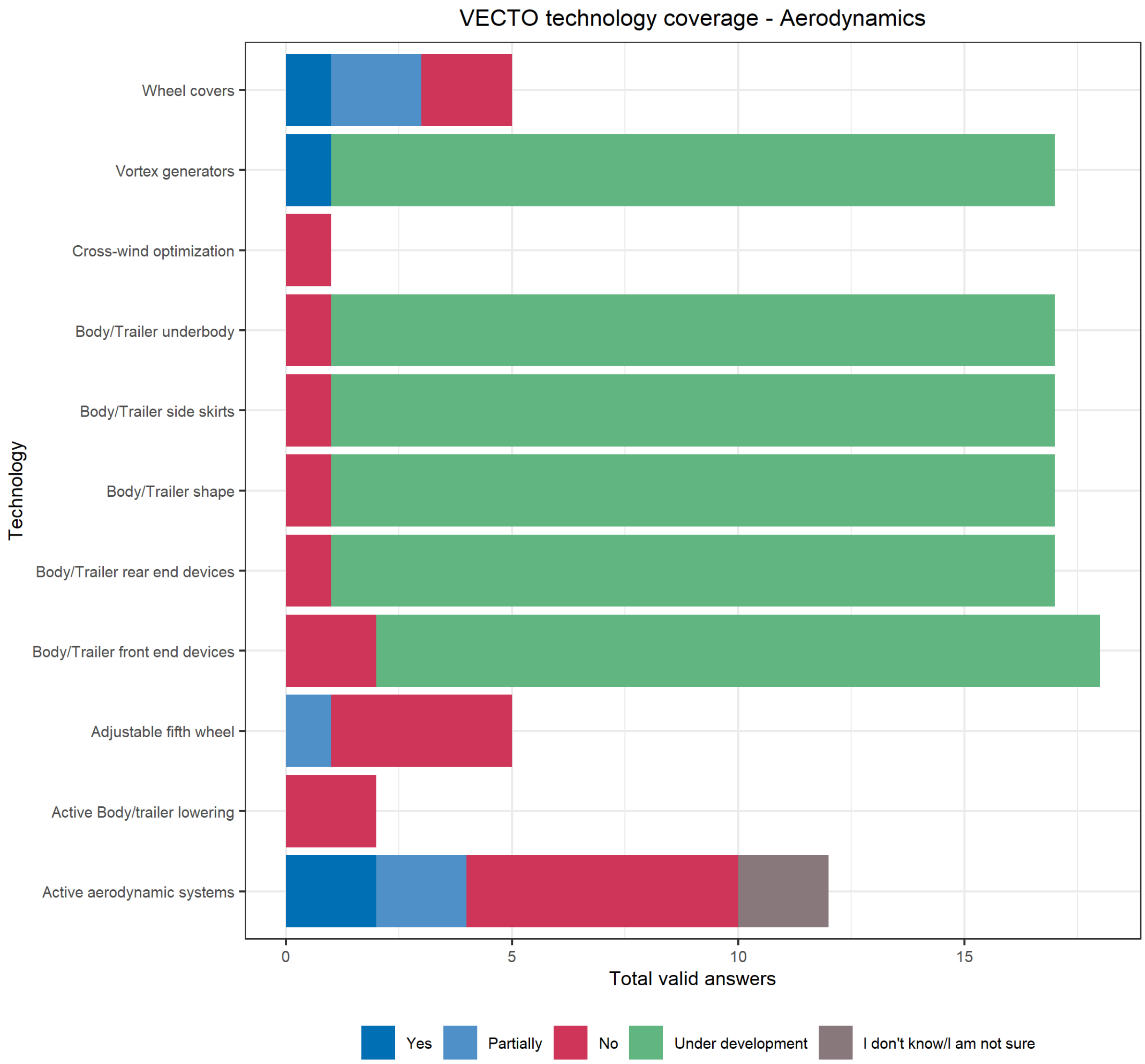


Source: JRC, 2020.

3.3.3 Aerodynamics

Aerodynamics includes several technologies that improve the aerodynamic behaviour of vehicles and reduce the air drag. These can be passive systems that focus on the vehicle design to reduce turbulence, but also active systems such as an adjustable fifth wheel and active airflow systems. The respondents provided significant information in the free text input fields. Many of the technologies are captured by VECTO if they are deployed on the vehicle's cabin, but not on the trailer. For instance, active aero devices, such as active grille shutters, are indirectly covered by VECTO, since the constant speed test used to derive the vehicle's air drag area (CdxA) allows active aero devices provided the device is always activated and effective to reduce the air drag at vehicle speed over 60 km/h. It should be highlighted, that the improvements focus on the gains of a single vehicle and do not consider platooning tactics. In this way, aerodynamic improvements are generally considered to be covered well by VECTO as shown in Figure 4. The constant speed test is performed with a standard trailer (for tractors) or body (for rigid trucks). The development is ongoing to include the actual body and trailer, to capture the effect of aerodynamic devices on the trailer and body.

Figure 4. VECTO coverage of aerodynamics technologies



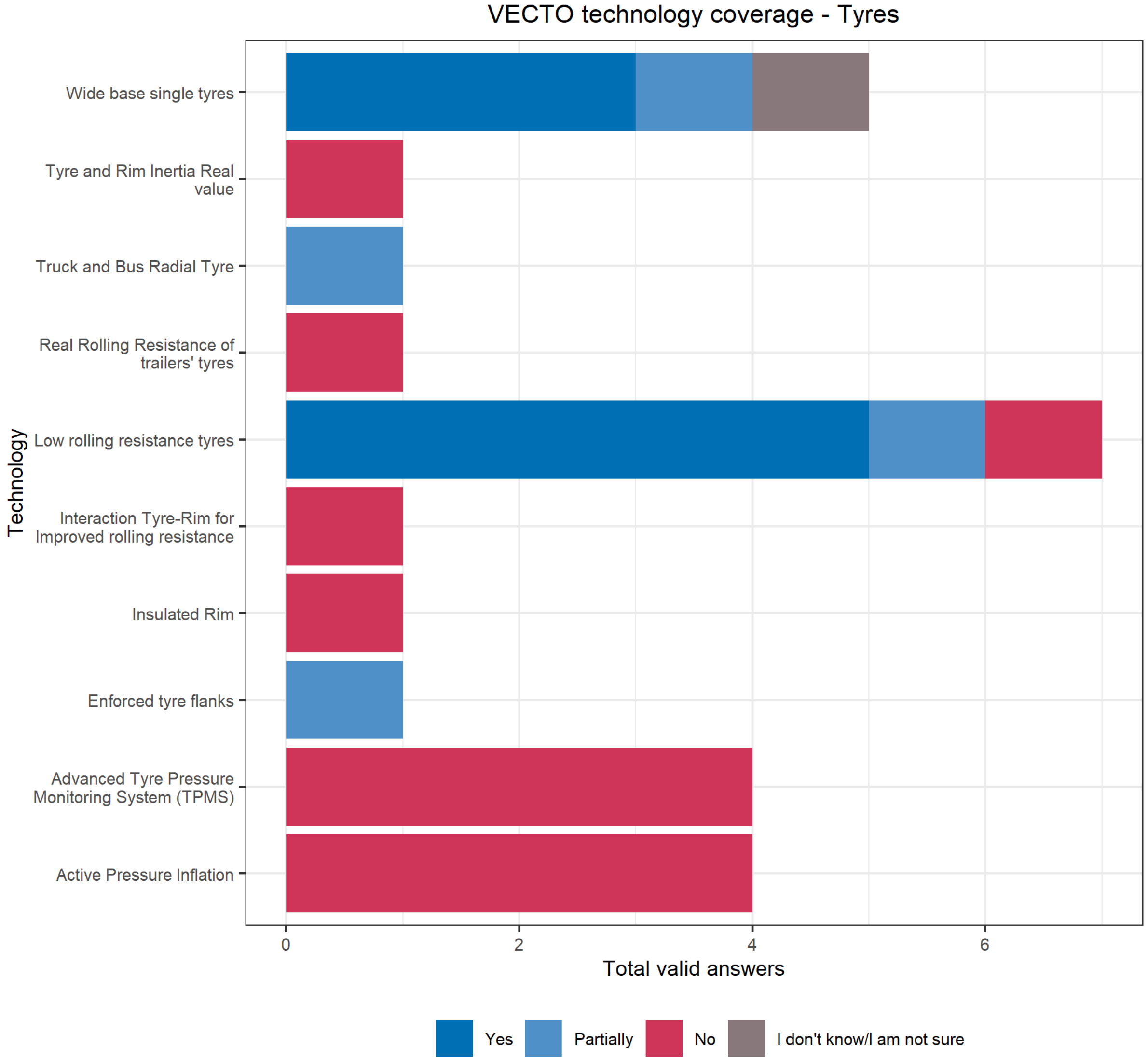
Source: JRC, 2020.

A respondent raised the issue that technologies installed after the vehicle purchase are not taken into consideration by the VECTO simulation. These after-market technologies were Body/Trailer front end devices, Body/Trailer rear-end devices, Body/Trailer shape, Body/Trailer side skirts and Body/Trailer underbody. Another respondent considers that the wheel covers lie in a grey zone as the Regulation (EU) 2017/2400 defines the wheels as part of the measurement equipment. Additionally, there were two comments concerning the VECTO air drag tool, which is used for calculating the vehicle's CdxA. It is recommended that any device that reduces air drag such as wheel covers and Body/Trailer front end devices should be included in the tool. Also, the impact of Body/Trailer side skirts would be low due to the low yaw angle. Regarding the adjustable fifth wheel, it was stated that the technology exists for a vehicle at standstill but it is not adjustable during driving. These systems exist in the market but their use in VECTO could be very limited if the vehicle's length is kept at 16.5 m. It was recommended to make an amendment to the Regulation (EU) 2017/2400 to assess the technology's effect by including it preferably in the constant speed testing or by attributing a bonus factor.

3.3.4 Tyres

The tyre technologies include a series of improvements that focus on the rolling resistance, tyre/rim architecture and systems for monitoring and adjusting tyre pressure. Figure 5 shows that most of the technologies are related to rolling resistance and tyre dimensions are largely covered. However, all the respondents agreed that systems that are monitoring and adjusting tyre pressure are not currently covered. A respondent commented that the tyre pressure monitoring system and tyre inflation system are indirectly covered by VECTO since a properly maintained vehicle with the correct tyre pressure is simulated. Regarding the rim insulation, this technology assists in keeping the temperature of the tyre.

Figure 5. VECTO coverage of tyre technologies



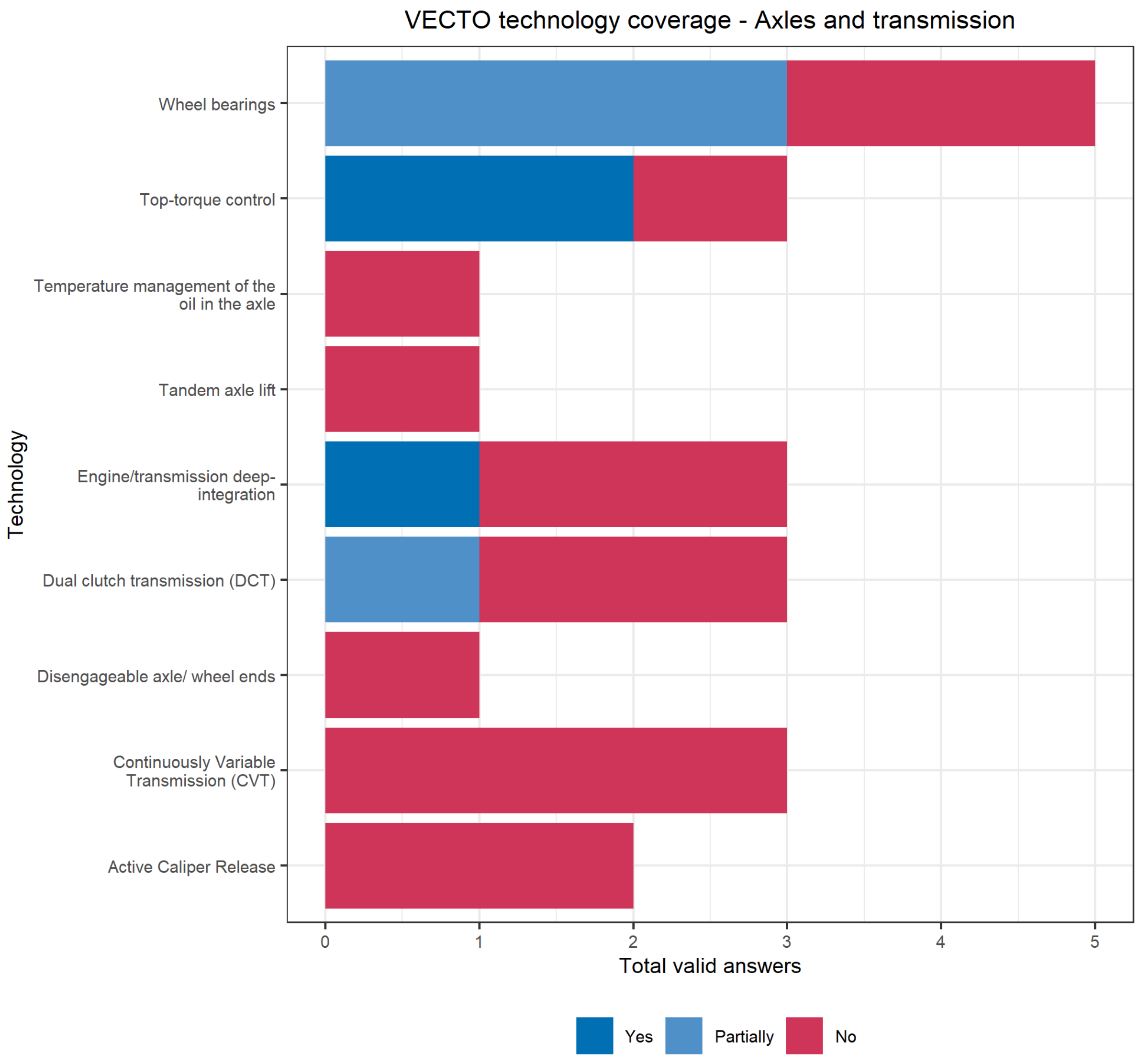
Source: JRC, 2020.

The respondents commented on the use of generic values and standard bodies. The tyre and rim inertia values are covered with a standard value that depends on the tyre size, but the use of the actual value would have a significant impact on CO_2 emissions. The development is ongoing to include the actual body and trailer and to capture the effect of the trailer's tire rolling resistance. Regarding the wide base single tyres, the respondents agree that it would be an easy update to VECTO and it could be handled by adding the tyres' dimensions in the respective list. However, a respondent argued on whether it should be included as there would be no CO_2 savings.

3.3.5 Axle and transmission

Axle and transmission present a variety of technologies that can have an impact on CO_2 emissions. These include different gearbox architectures such as dual-clutch transmissions (DCT) and continuously variable transmissions (CVT), while others aim in increasing the driveline efficiency by improving the system's moving parts. In general, the respondents agree that the technologies are not covered by VECTO as shown in Figure 6. A respondent provided additional feedback on the DCT technology that it is relatively covered as vehicles with a DCT have lower gear ratios than vehicles with an Automated Manual Transmission (AMT), which is already covered in VECTO. However, DCT and AMT could have different gear shifting strategies that according to the comment is not within the current scope of VECTO. It was also specified that the DCT technology is used by at least one OEM. While the implementation has not yet started, a proposal is being elaborated to include the friction of the wheel bearings in VECTO.

Figure 6. VECTO coverage of axles and transmission technologies

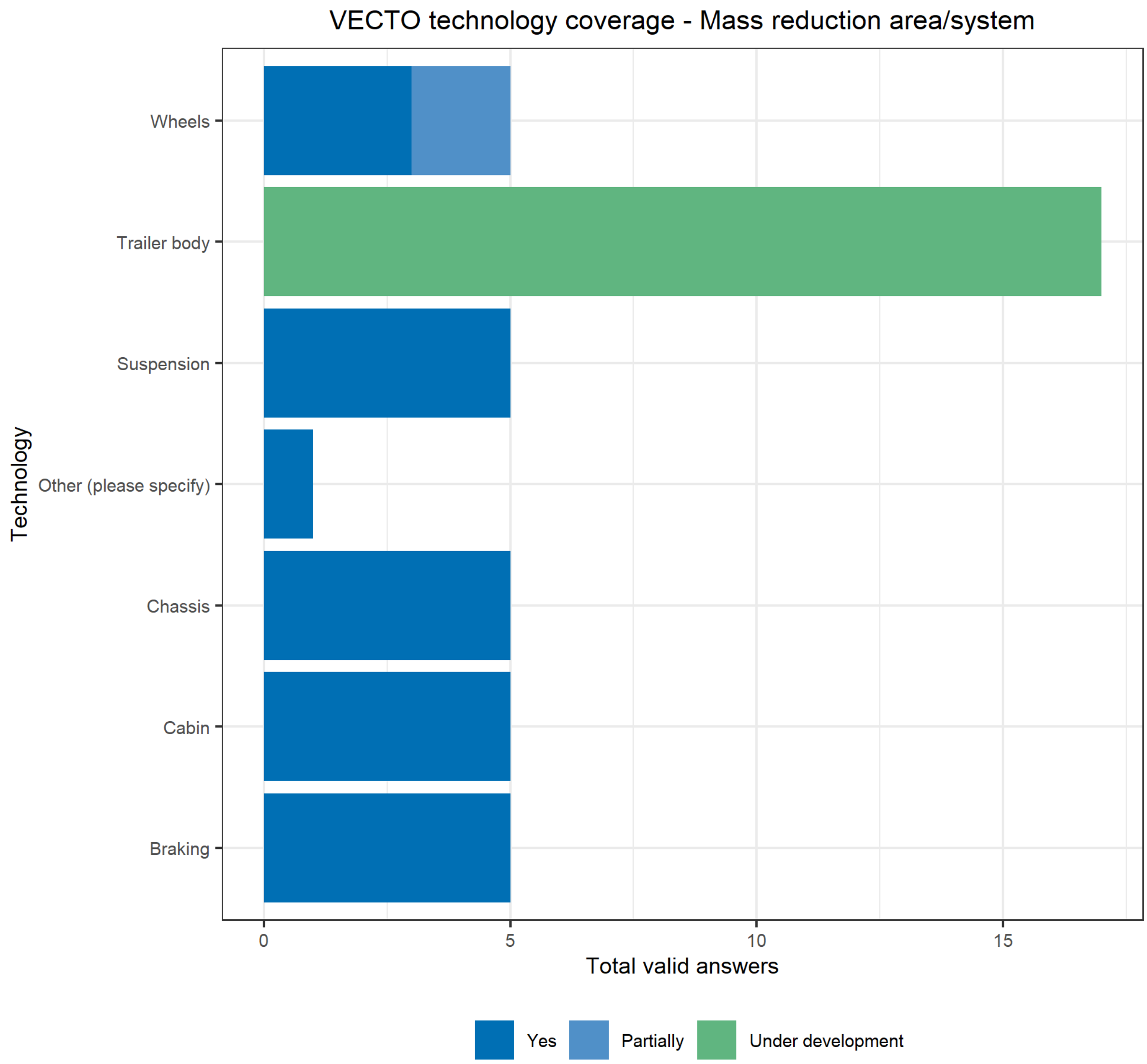


Source: JRC, 2020.

3.3.6 Mass reduction area/system

The mass reduction system received a significant number of replies (5 to 15) with the majority of the respondents considering that the effect is fully captured in almost all cases. It is agreed that modifications in the trailer are not captured by VECTO, but the work is under development to be properly implemented. The replies are presented in Figure 7. The respondents highlighted that there are continuous improvements in the cabin, chassis, wheels and braking systems. However, its significance is questioned by some respondent. A reduction in mass would leave space for safety and comfort utilities that in turn increase mass. It was also stated that significant benefits are expected with the introduction of autonomous vehicles.

Figure 7. VECTO coverage of mass reduction technologies

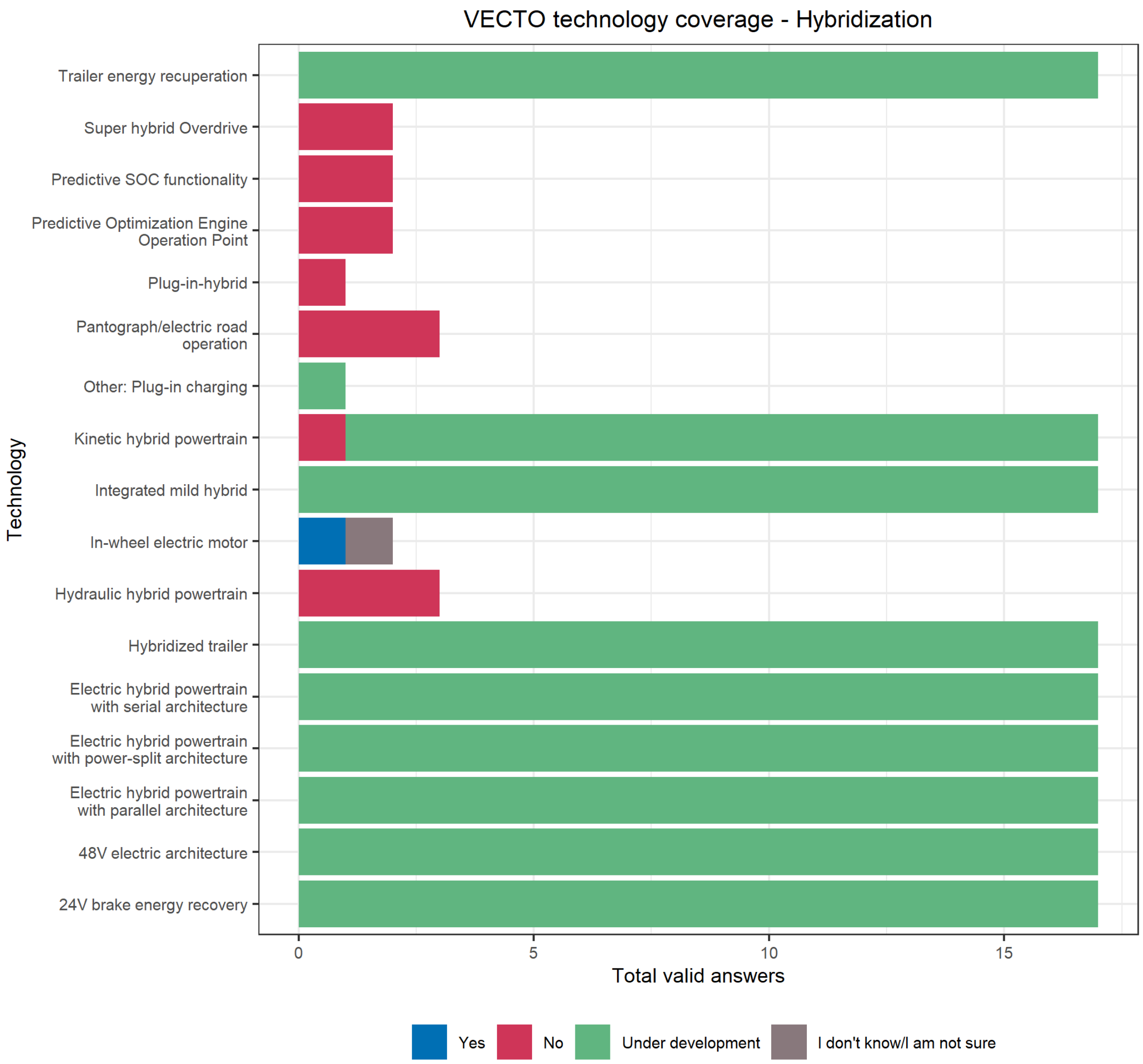


Source: JRC, 2020.

3.3.7 Hybridisation

The hybridisation received a significant number of replies where in some cases it reached 17 replies. The majority of the replies consider that most of the hybridisation technologies are under implementation in VECTO as shown in Figure 8, which is justified as the current focus on the development are the hybrid powertrains. There are some technologies such as predictive State of Charge (SOC) functionality, plug-in hybrids and pantographic functionality that are not included in the current development scheme according to the respondents. A respondent highlighted that the development of the powertrain in parallel architecture should be prioritised as the other architectures can be derived. Additionally, the implementation of 48V systems could facilitate the development of hybridised trailers.

Figure 8. VECTO coverage of hybridisation technologies

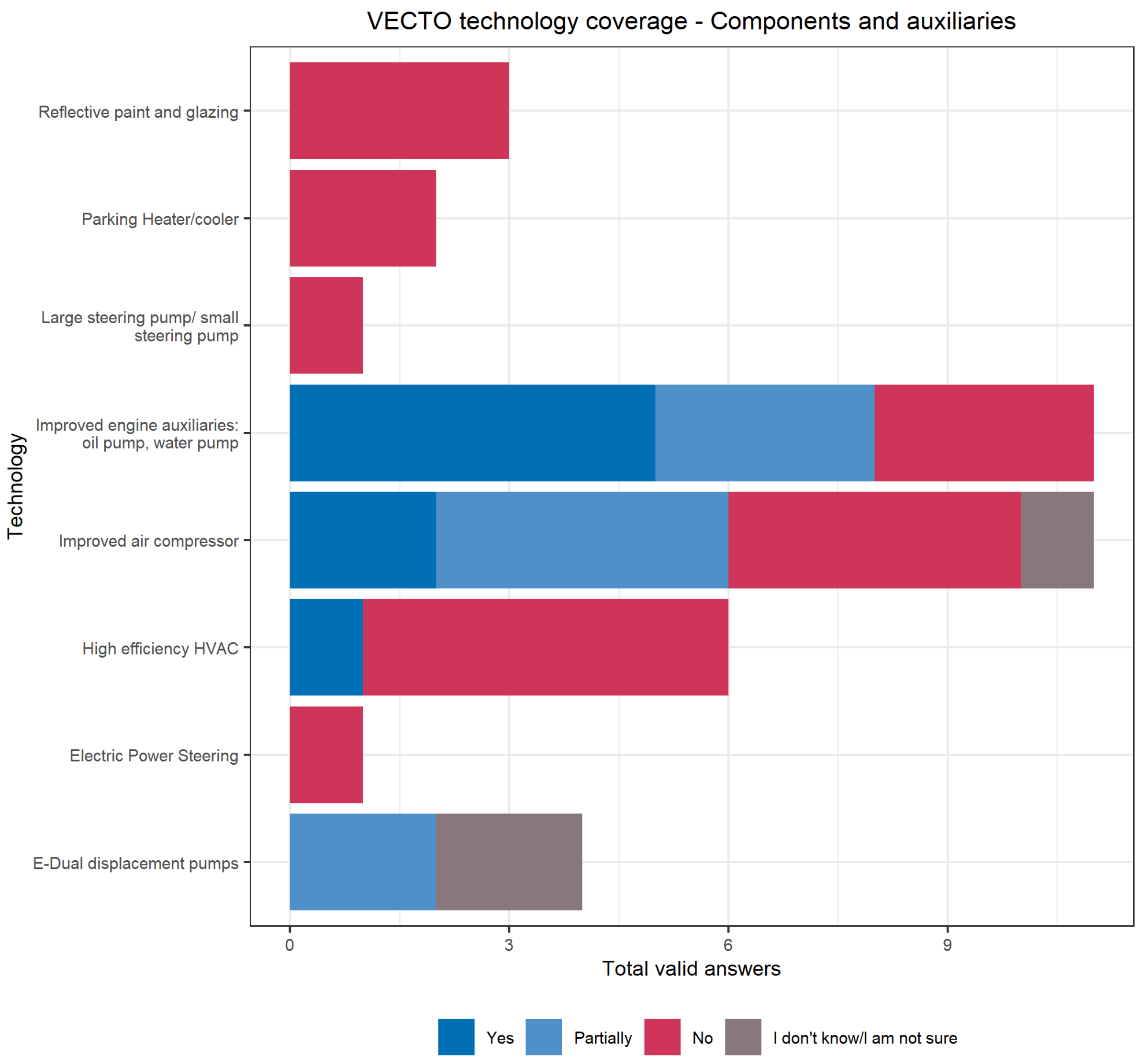


Source: JRC, 2020.

3.3.8 Components and auxiliaries

The components and auxiliaries category cover technologies that improve driving comfort such as steering assist systems and air-conditioning and vehicle operation beyond the regular on-road operation, namely parking/heating cooler. The latter would focus more on vehicles with sleeper cabs and vehicles with fridge units that require energy to maintain temperature during overnight parking. In general, as shown in Figure 9, it is considered that these technologies are not covered by VECTO. A respondent stated that the steering pump system has to be reworked for E-Dual displacement pumps.

Figure 9. VECTO coverage of components and auxiliaries technologies

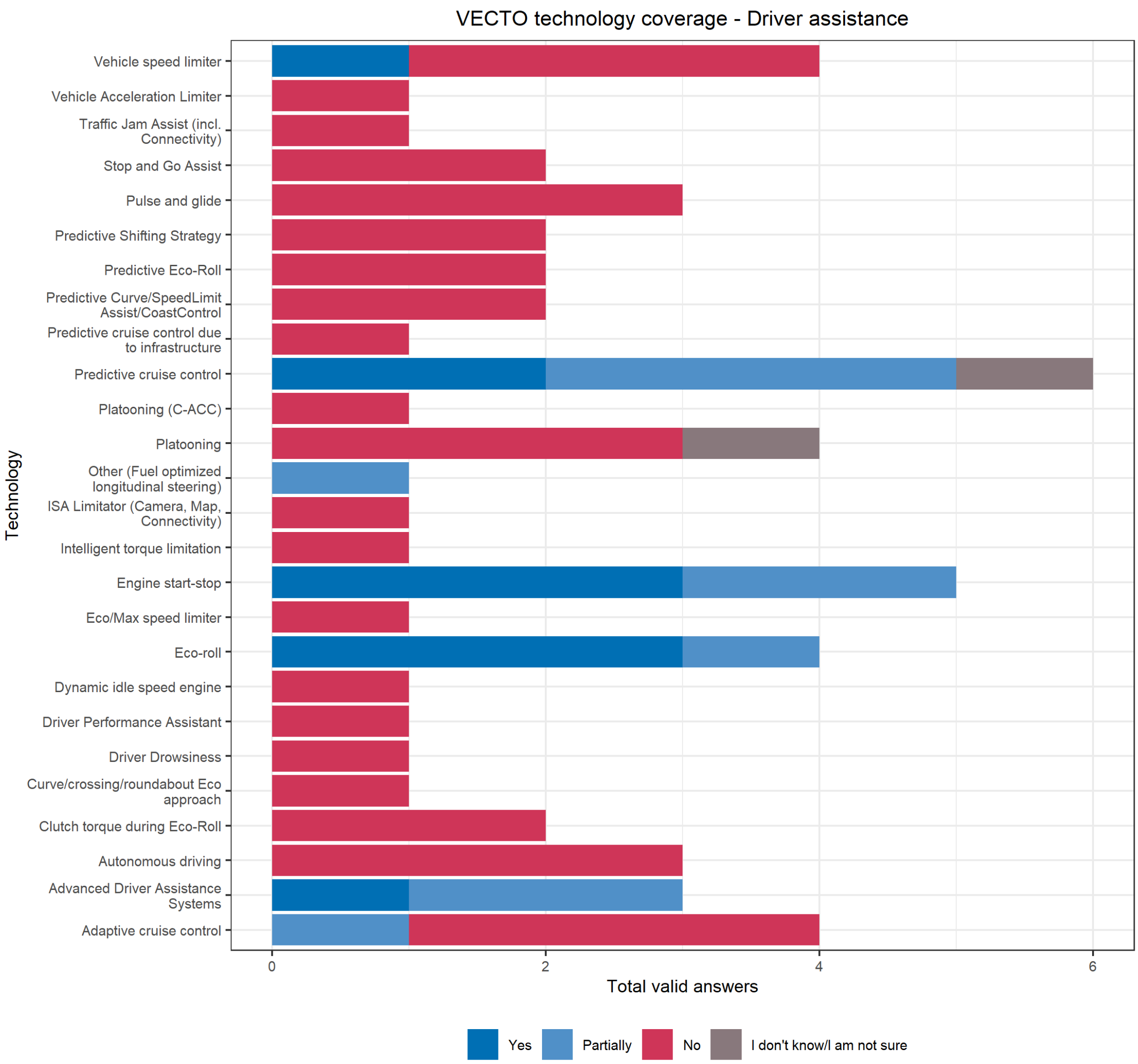


Source: JRC, 2020.

3.3.9 Driver assistance

The driver assistance category includes technologies that primarily contribute to an environmentally friendly driving style. Such technologies are various predictive control strategies, eco-roll, engine start-stop, platooning and advanced driver assistance systems. Many of these technologies are not supported by VECTO, as shown in Figure 10, but some systems are considered to be at least partially covered. The partially covered technologies, namely engine start-stop, eco-roll and advanced driver assistance systems have also been the focus of VECTO development lately. However, a respondent commented that for eco-roll, engine start-stop and predictive cruise control a new VECTO model has to be developed in order to obtain realistic values. Another comment highlighted the vehicle speed limiter that can have a significant impact on CO_2 emissions, but it should be verified that it is not tampered with on the market. A comment regarding adaptive cruise control stated that this technology focuses on safety and not on CO_2 reduction so it is irrelevant for the scope of the regulation.

Figure 10. VECTO coverage of driver assistance technologies

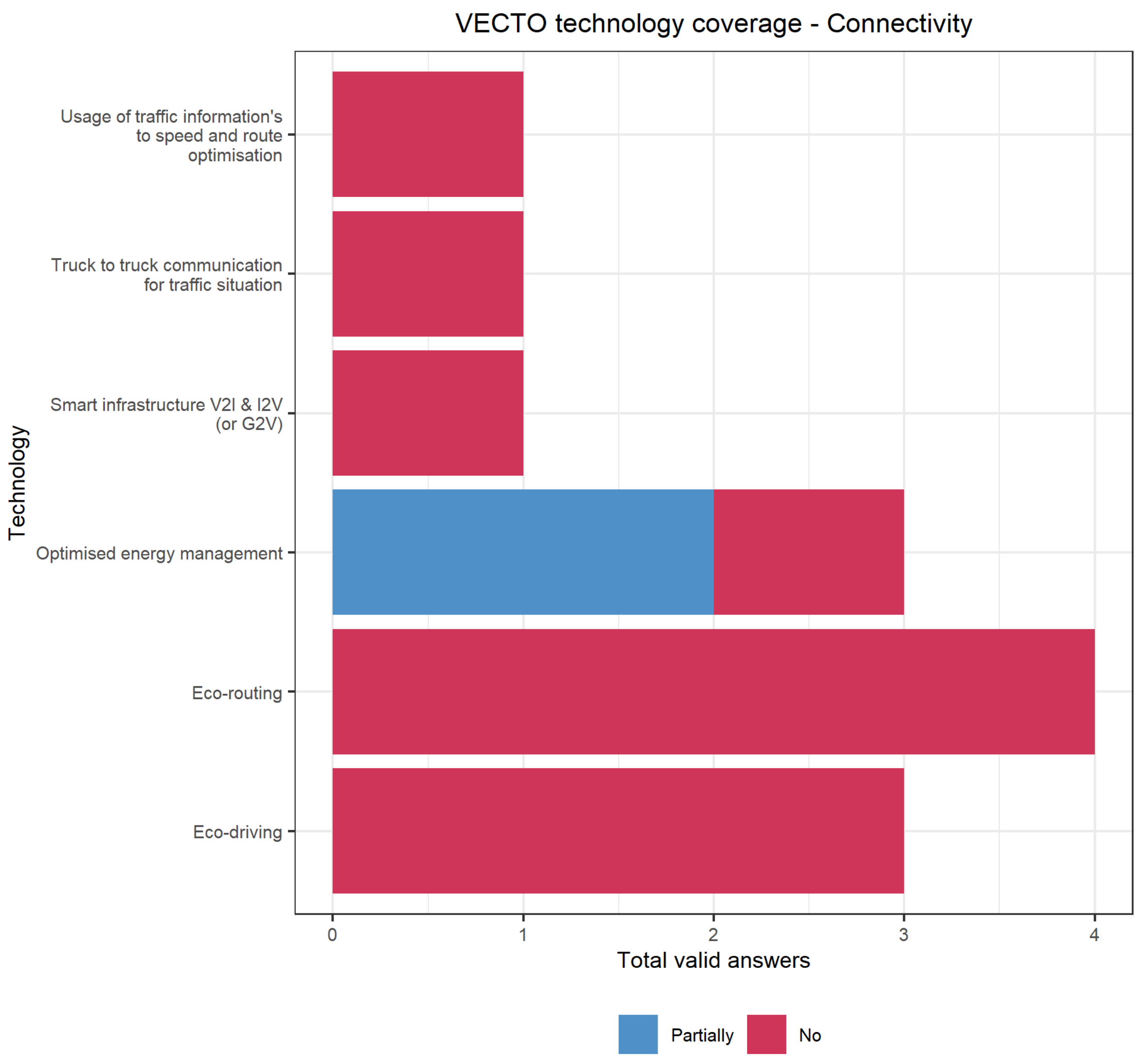


Source: JRC, 2020.

3.3.10 Connectivity

The connectivity category includes technologies that connect the vehicle with other vehicles and the infrastructure in order to exchange information on the upcoming driving conditions. Regarding this category, all the respondents agreed that technologies are not covered. Only the optimised energy management is considered to be partially covered by some respondents that have clarified that the auxiliary control options capture indirectly some aspects of the energy management. Eco-routing technology is expected to be initially implemented in BEVs. Figure 11 presents the replies for each technology with the most answers focusing on optimised energy management, eco-routing and eco-driving.

Figure 11. VECTO coverage of connectivity technologies



Source: JRC, 2020.

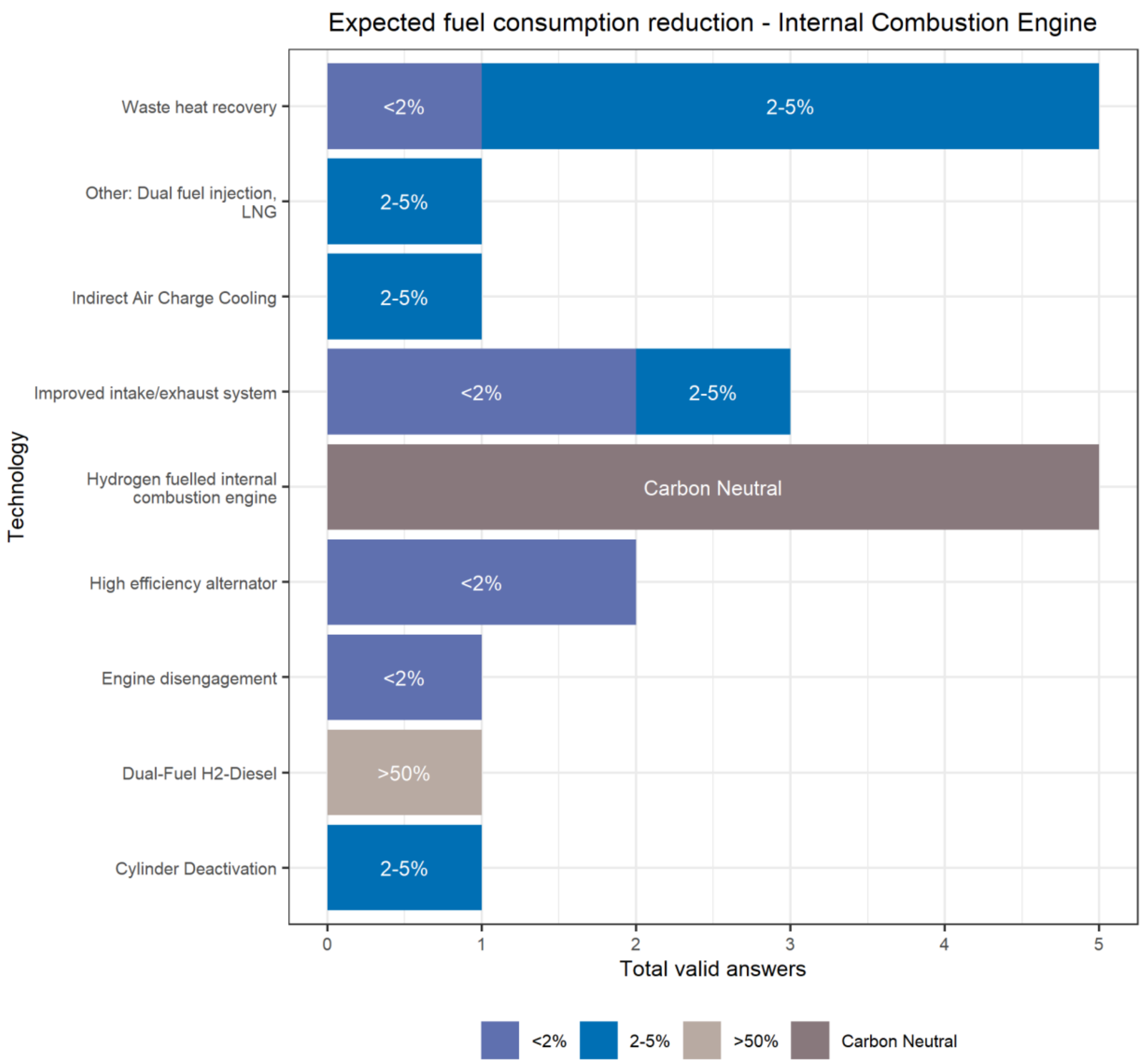
4 Future CO_2 reducing technologies

This section investigates in detail the new technologies, which are separated by category due to their large number. For each technology, the estimated reduction in CO_2 emissions, the introduction year and the expected market penetration in 2025 and 2030 are presented.

4.1.1 Internal combustion engine

The majority of the new technologies related to the internal combustion engine can potentially yield CO_2 savings by up to 5% as shown in Figure 12. Within this frame, it is important to highlight hydrogen technologies that deliver savings of more than 50% and can even be carbon neutral. The deployment of such technologies in the future could be a potential way of reaching carbon neutral emission from a tank-to-wheel (TTW) perspective. A respondent commented that a high-efficiency alternator would result in a reduction of about 1% and would have a limited effect on trucks.

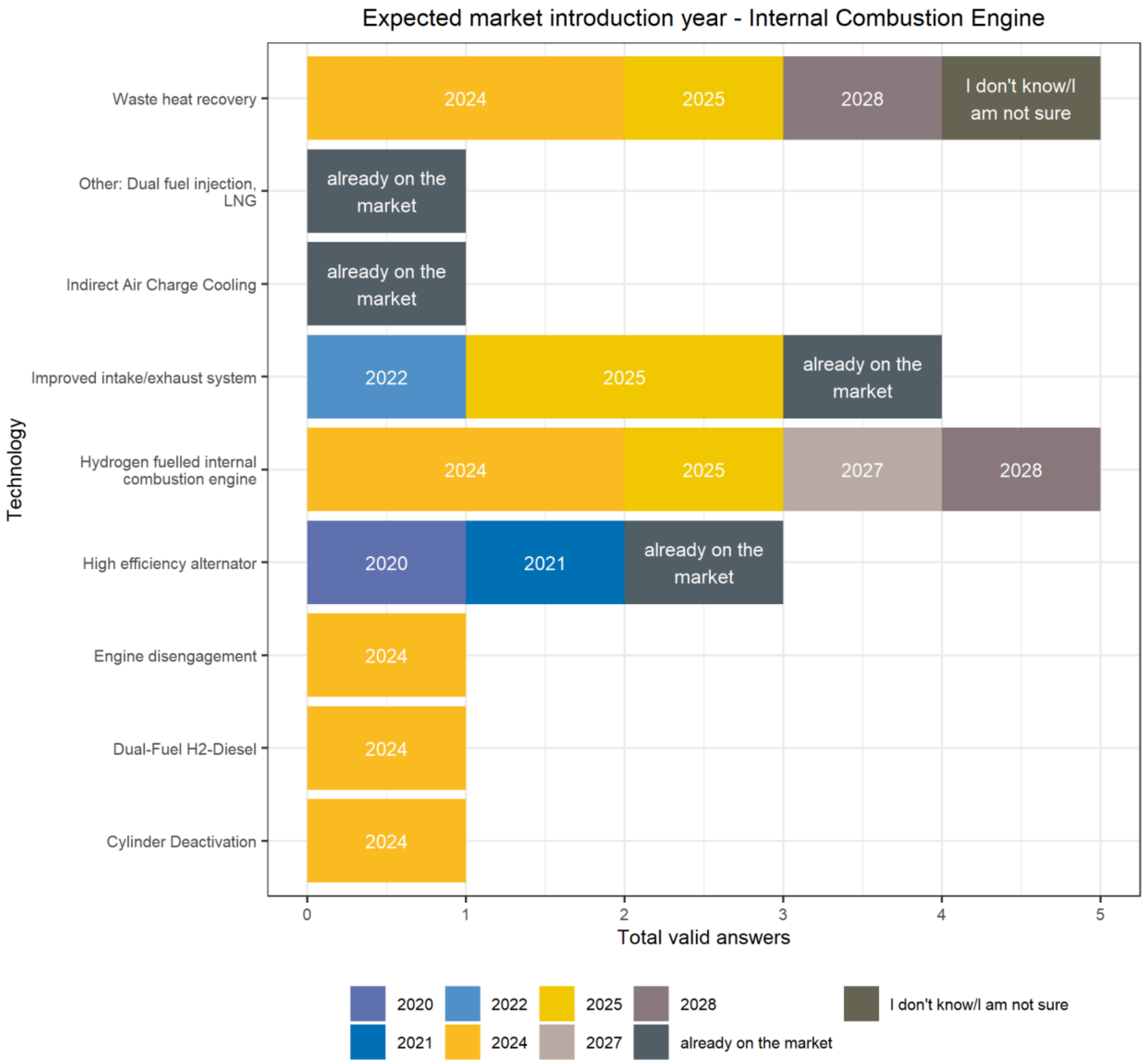
Figure 12. Expected CO_2 emissions reduction for internal combustion engine technologies



Source: JRC, 2020.

Many technologies have already been implemented in the current vehicle fleet or they will be introduced shortly in the market. Despite many of the technologies receiving only one reply, it seems that technologies that are dealing with engine improvement (e.g. cylinder deactivation) are easier and faster to deploy along with energy recuperation technologies such as waste heat recovery. On the other hand, hydrogen technologies are expected to be introduced after 2024 at the earliest. However, a respondent stated that a hydrogen-fuelled internal combustion engine could be implemented relatively easy by adding an "H_2 positive ignition" engine fuel type and correction factors would relate to H_2 mass flow for a generic net calorific value. Figure 13 presents the expected introduction year by technology.

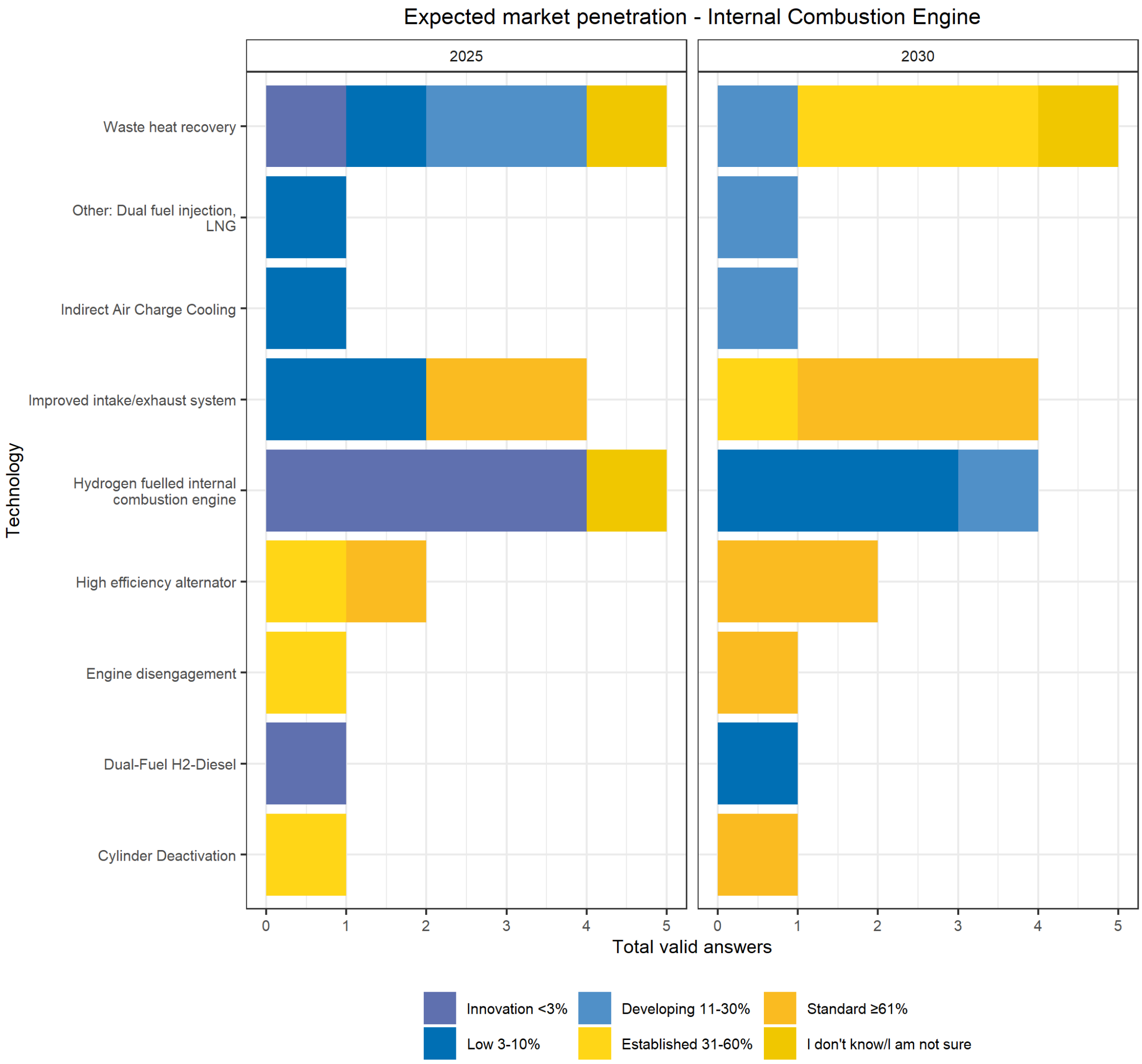
Figure 13. Expected market introduction year for internal combustion engine technologies



Source: JRC, 2020.

According to the respondents' replies, several of the technologies will have a relatively low market penetration by 2025, with some exceptions such as cylinder deactivation, improved air compressor and auxiliaries. They present a higher penetration in 2030, where many of them are estimated to achieve established and standard status. On the other hand, hydrogen technologies have a relatively low penetration rate in 2025, which slightly increases in 2030. Figure 14 presents the expected technology penetration for the years 2025 and 2030.

Figure 14. Expected market penetration of internal combustion engine technologies

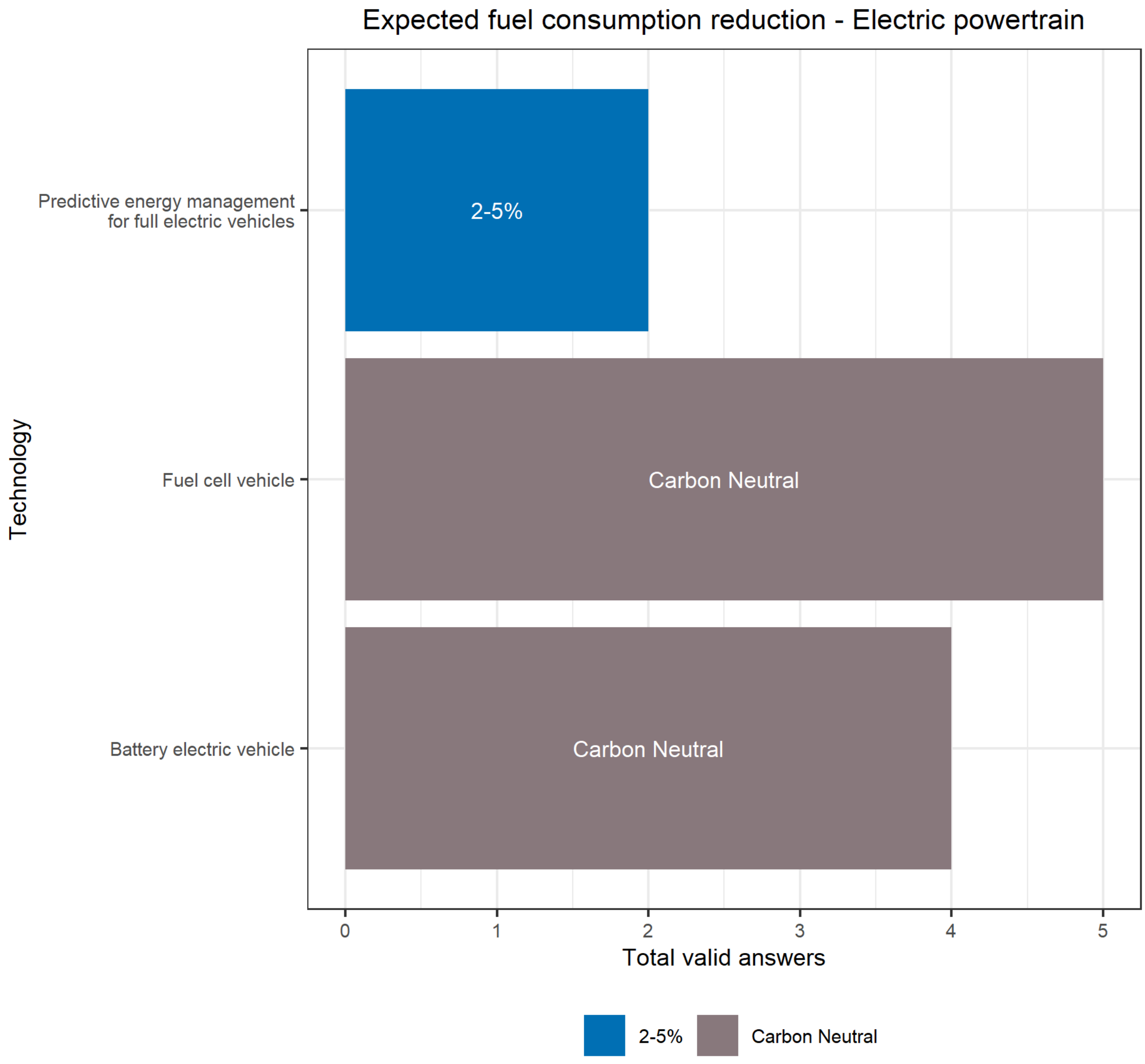


Source: JRC, 2020.

4.1.2 Electric powertrain

The electric powertrains do not have tailpipe emissions in a tank-to-wheel approach and for this reason they are considered to be carbon neutral. Predictive energy management in this powertrain type can yield a potential energy reduction of 2-5%.Figure 15 presents the effect of electric powertrain technologies on CO_2 emissions.

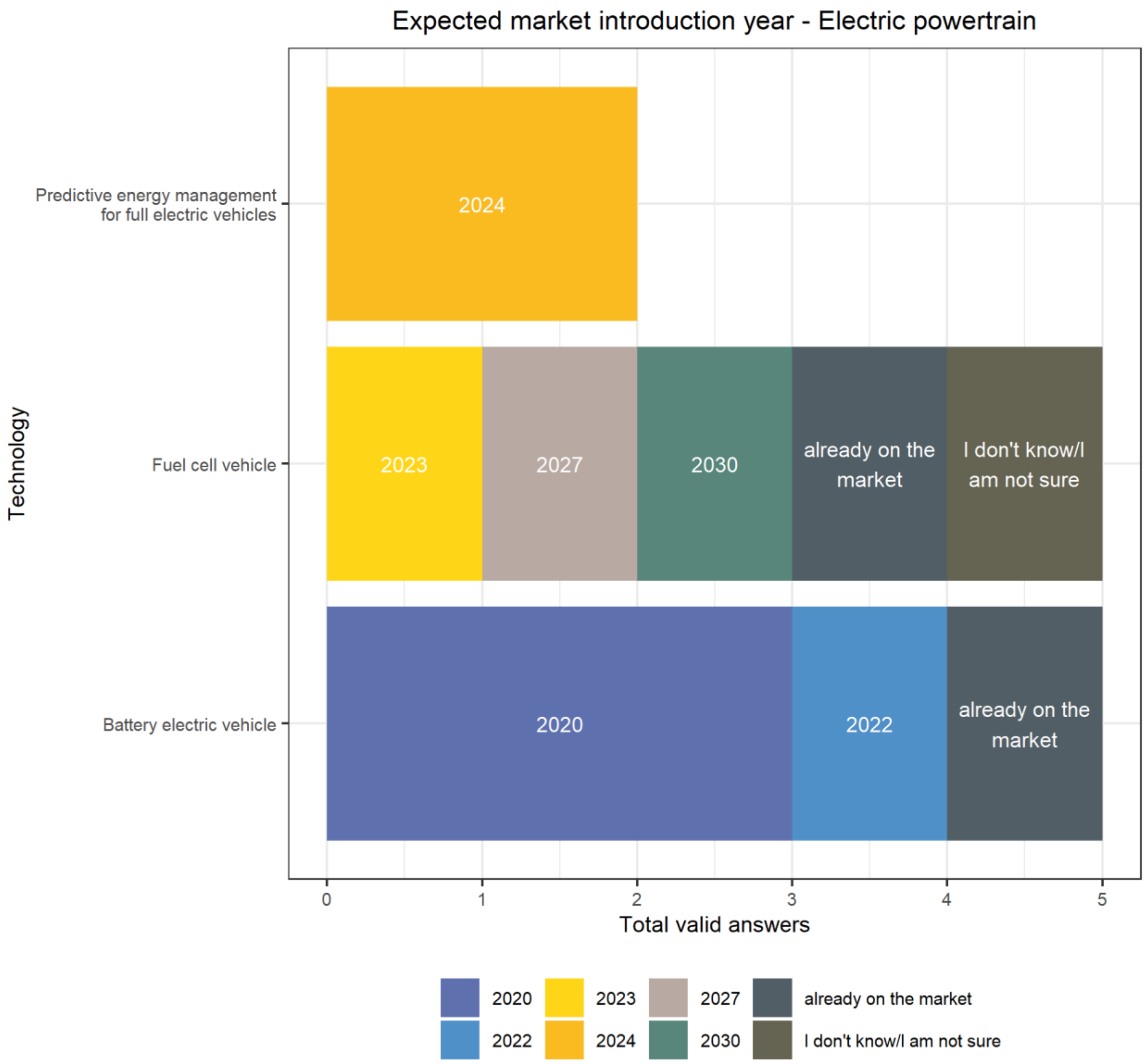
Figure 15. Expected CO_2 emissions reduction for electric powertrain technologies



Source: JRC, 2020.

The introduction of electrical powertrains is expected to take place in the mid-2020s. For the battery-electric and fuel-cell vehicles, the replies were spanning from "already on the market" to "2030" as shown in Figure 16. This could be explained by initiatives from some fleet owners that deploy such vehicles in short distance and mostly in urban delivery. However, a respondent provided an additional comment that the market penetration of such technology would be after 2025.

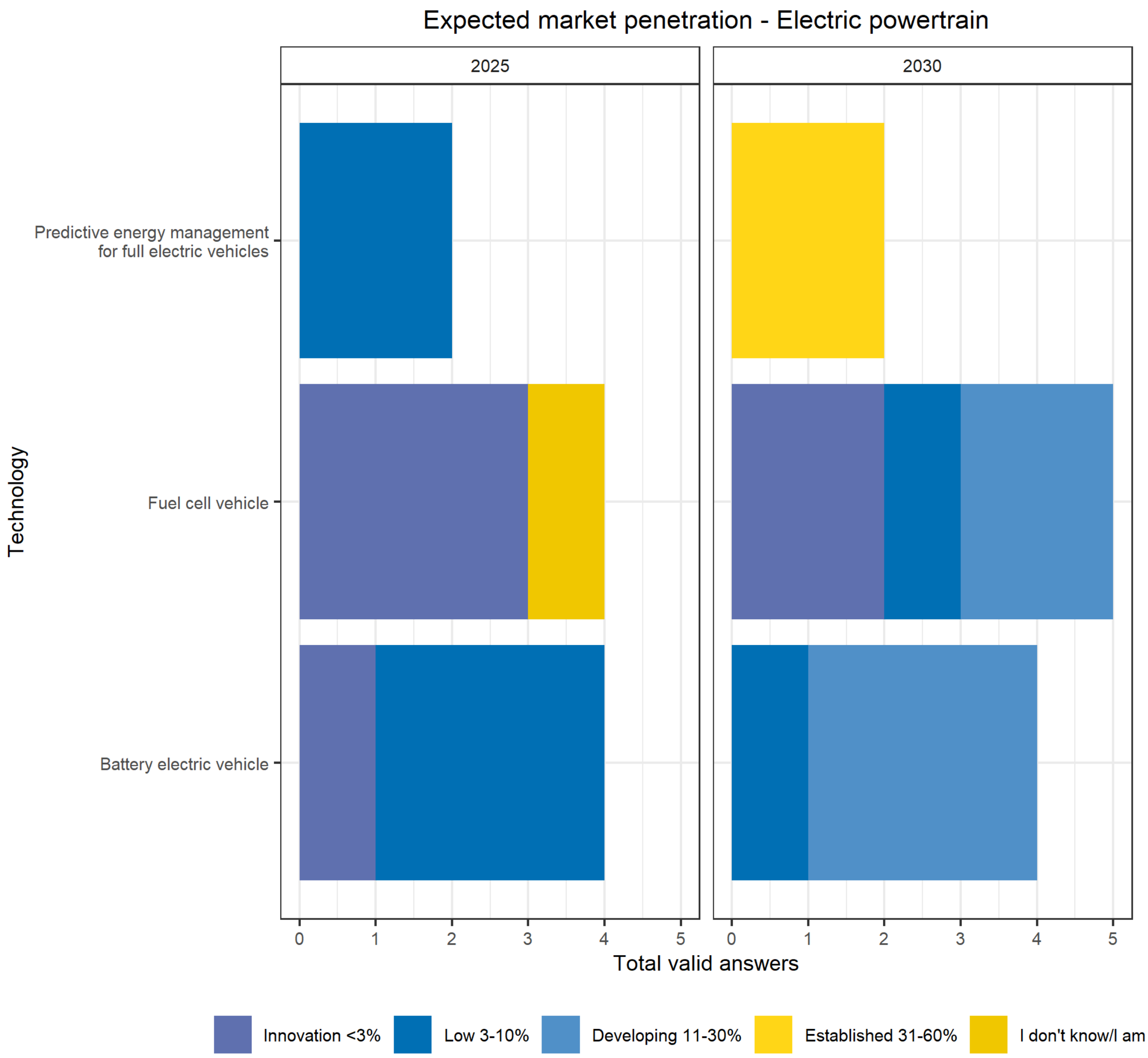
Figure 16. Expected market introduction year for electric powertrain technologies



Source: JRC, 2020.

Electric powertrains are expected to have a low market share by 2025 which is expected to rise by 2030. However, according to the respondents, they will be up to 30% in the best-case scenario as shown in Figure 17.

Figure 17. Expected market penetration of electric powertrain technologies

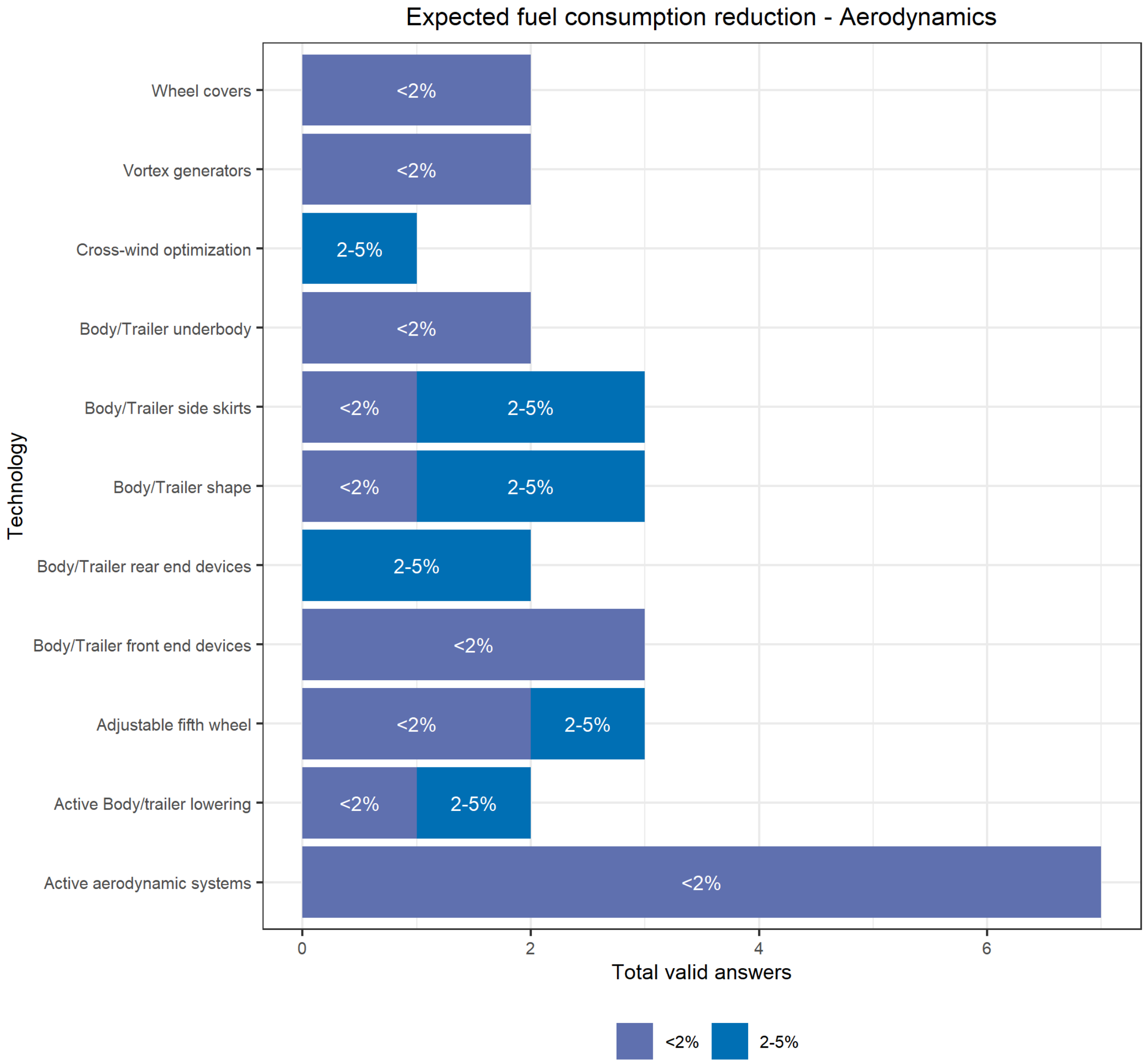


Source: JRC, 2020.

4.1.3 Aerodynamics

According to the respondents, the aerodynamic technologies can yield a reduction in CO_2 by up to 5%. It should be highlighted however that these gains are also dependent on the typical route that the vehicle travels as the effect of the aerodynamic resistance is highly dependent on the vehicle speed. Routes with a significant share of urban driving where the vehicle does not reach high speeds will present lower benefits from such technologies. These technologies are better suited for regional delivery and long-haul cycles where they can present their full potential. Figure 18 presents the expected reduction in CO_2 emissions by technology.

Figure 18. Expected CO_2 emissions reduction for aerodynamics technologies

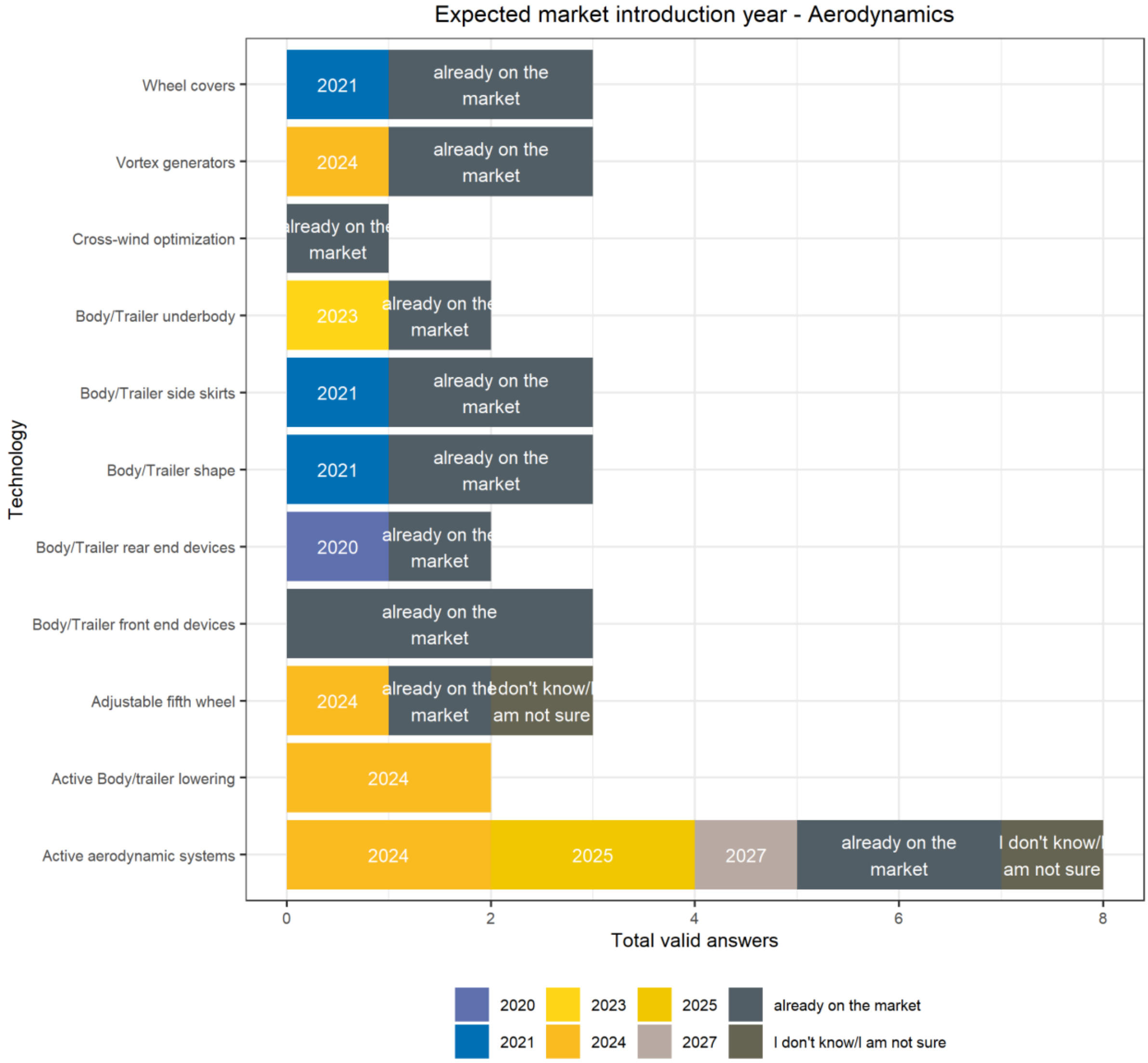


Source: JRC, 2020.

A respondent specified that the effect on CO_2 emissions would be below 1% for active aerodynamic systems, active body/trailer lowering, adjustable fifth wheel and vortex generators. Another respondent considers that there is little to no impact on CO_2 emissions for Active aerodynamic systems and vortex generators.

The replies regarding the introduction of these technologies show that most of them are already in the market or they can be implemented shortly to provide most of the benefits. According to the previous JRC survey from 2016 [5], the respondents had justified aerodynamics as "the low hanging fruit" in reducing CO_2 emissions. This trend is also reflected in Figure 19 that presents the market introduction year.

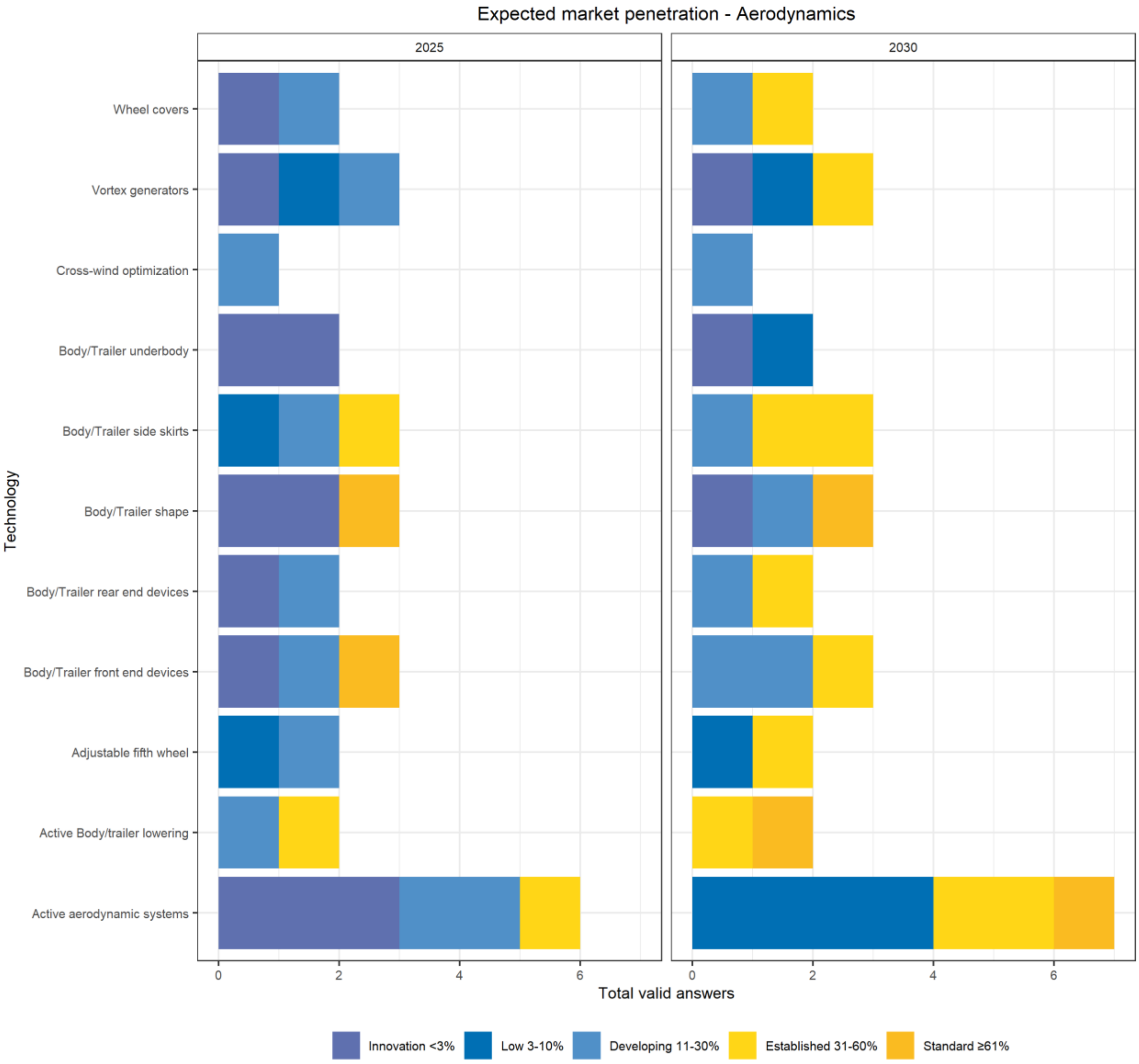
Figure 19. Expected market introduction year for aerodynamics technologies



Source: JRC, 2020.

The opinion that aerodynamic improvements are a way to significantly reduce CO_2 emissions is also supported by the expected market penetration, where many technologies will achieve "Established" and "Standard" status. Figure 20 shows that this penetration status will be achieved by a significant number of technologies by 2025 and 2030. A respondent stated that the vortex generator will not gain high market penetration due to its low impact on CO_2 emissions.

Figure 20. Expected market penetration of aerodynamics technologies

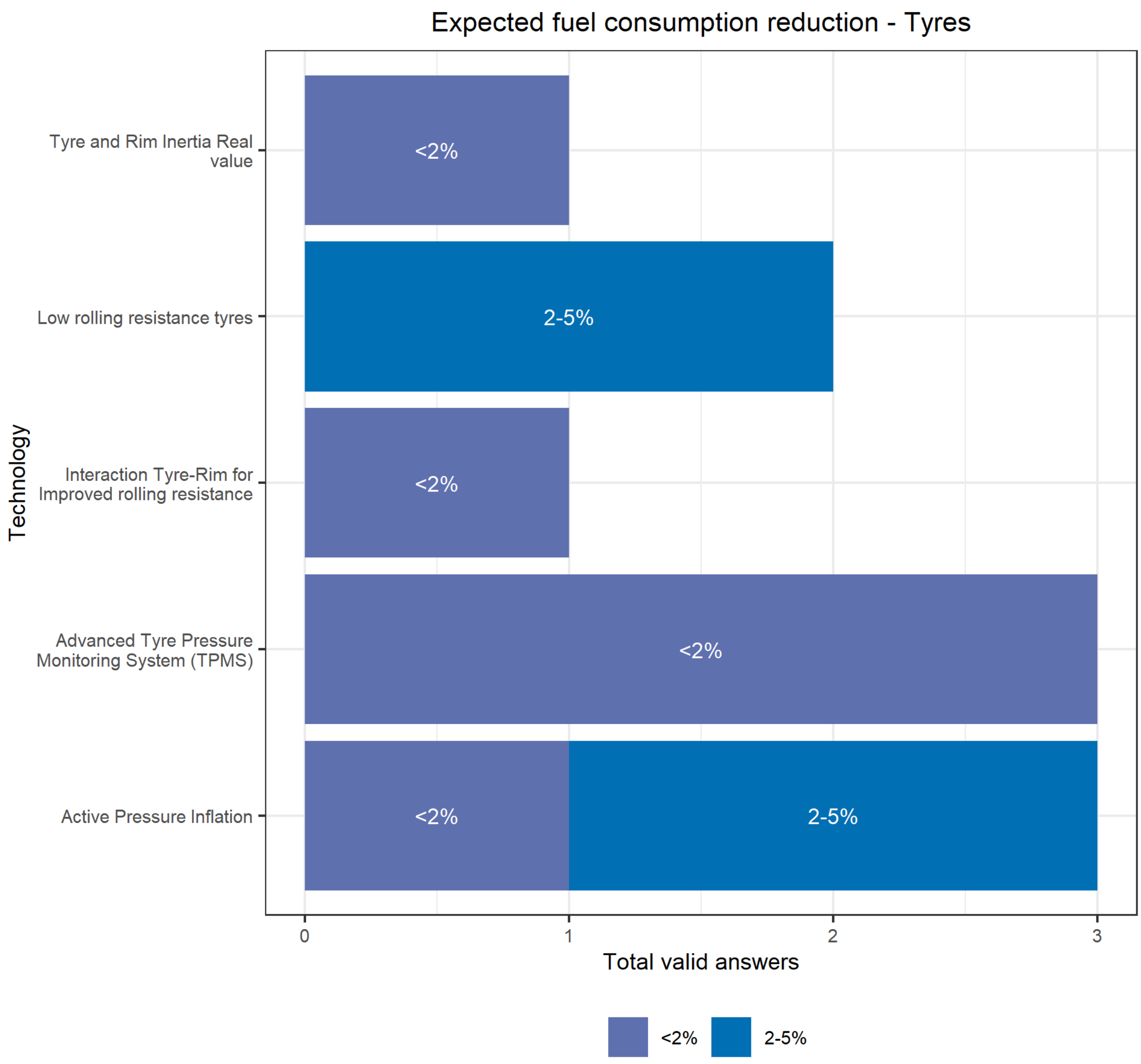


Source: JRC, 2020.

4.1.4 Tyres

The implementation of various tyre technologies is expected to yield a reduction in CO_2 emissions by up to 2% in each case and by up to 5% for low rolling resistance tyres as shown in Figure 21. However, the number of respondents that quantified the effect was quite low with only one or two answers in each category. It should be highlighted that monitoring/adjusting tyre pressure systems are considered to yield improvements of up to 5%. There was however a contradicting opinion as a respondent commented that these technologies would deliver around ~1% improvement. Another responded argued that these systems do not provide any CO_2 improvements in their current state, as their main purpose is to ensure safety. This view was supported by another comment that also quantified the benefit to be below 0.5% for a well-maintained vehicle.

Figure 21. Expected CO_2 emissions reduction for tyre technologies

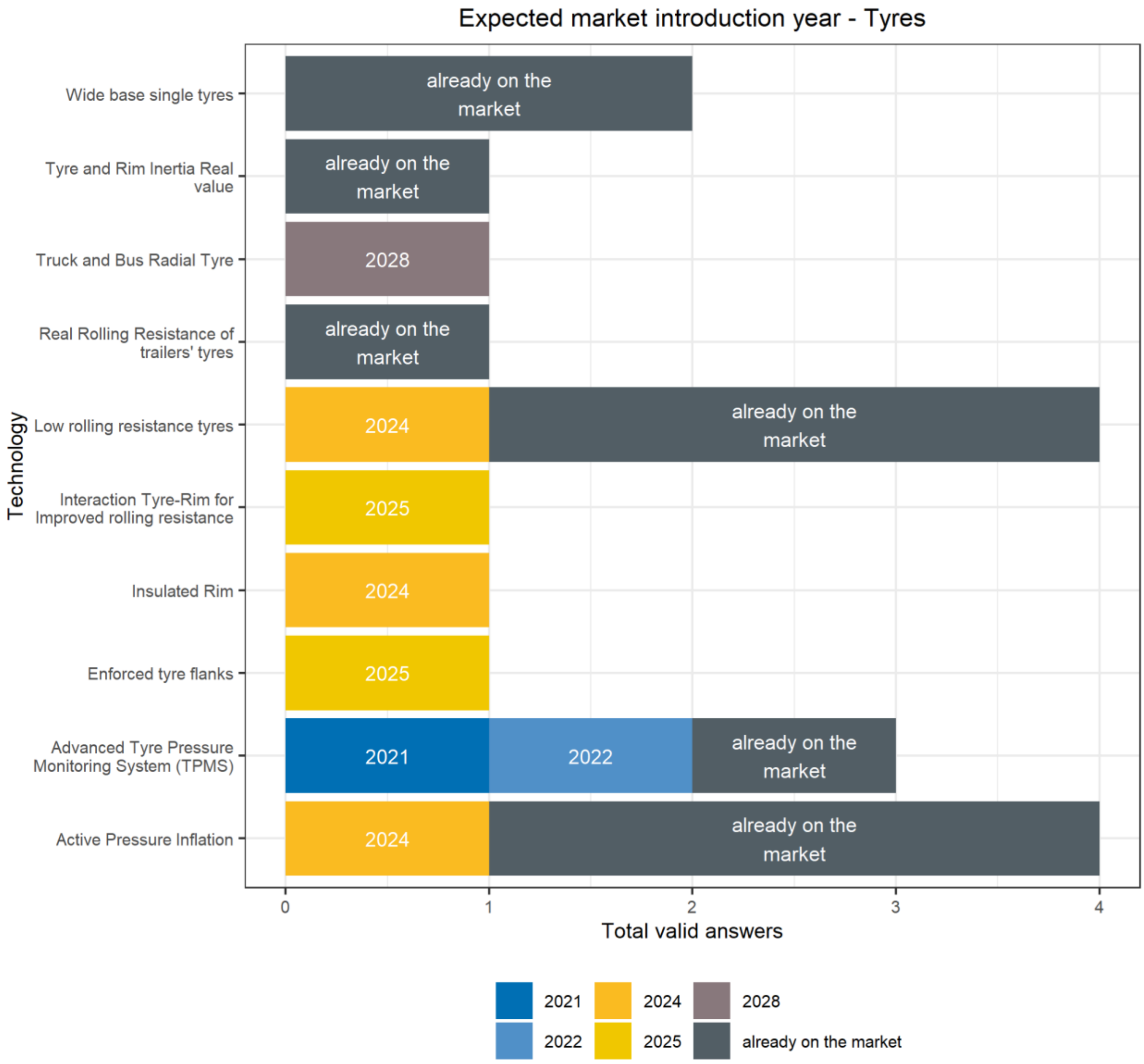


Source: JRC, 2020.

The respondents agreed that there are constant improvements in the tyre rolling resistance, especially since higher efficiency class tyre labels become available for more purposes. This trend is expected to provide an annual reduction of 1% in the vehicle's rolling resistance by 2030. In addition, it was highlighted that the extension of VECTO to non-standard trailer configurations would include more representative values.

The expected market introduction presented an interesting finding, as many of the technologies are considered to be already on the market, as shown in Figure 22. A respondent commented that the market penetration of the active pressure inflation systems depends on the technology integration with the trailer systems, while another respondent linked the adoption rate of such systems to incentives that are provided by the legislator.

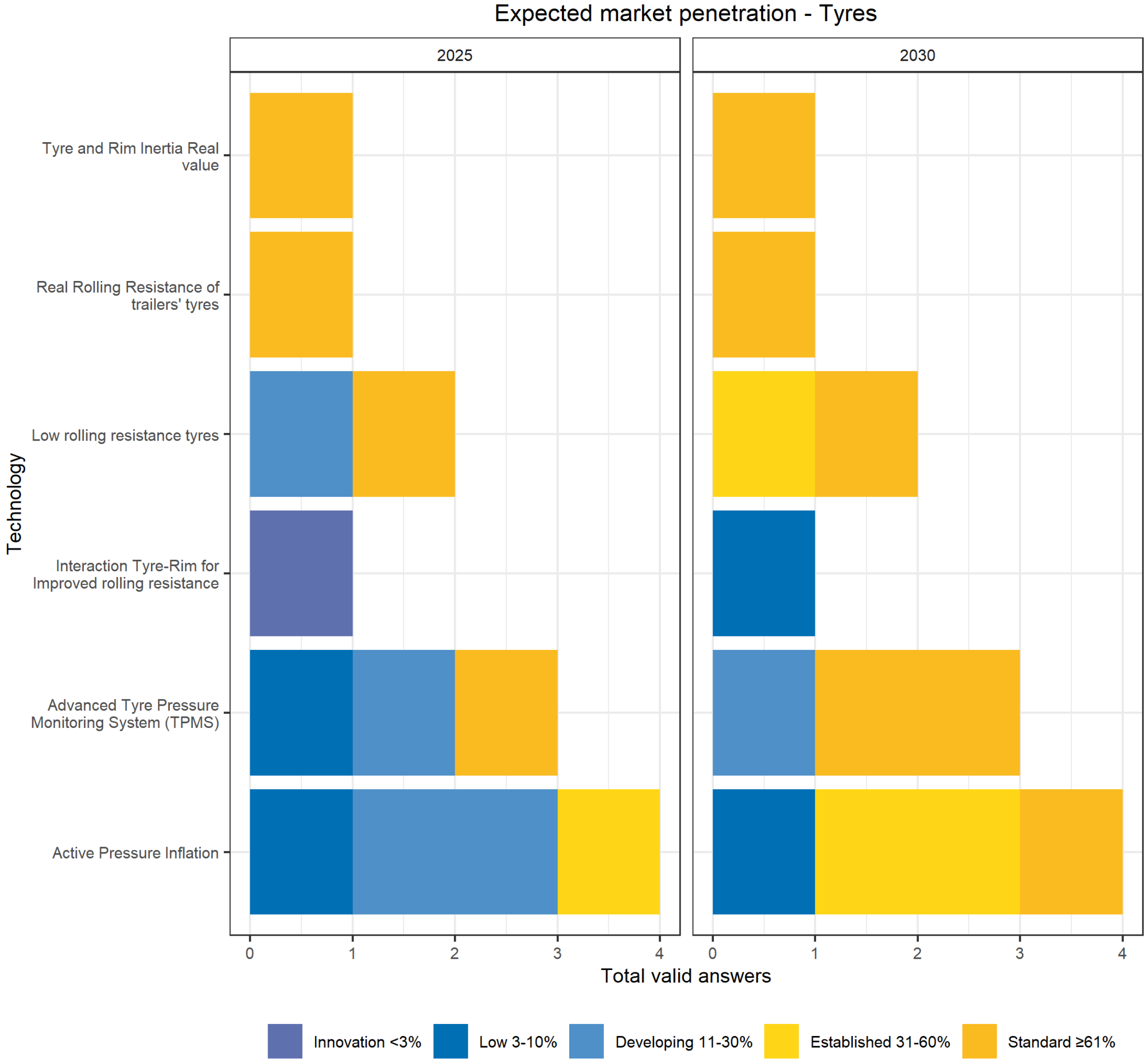
Figure 22. Expected market introduction year for tyre technologies



Source: JRC, 2020.

The results regarding the expected market penetration present a quick technology uptake with many technologies achieving "Standard" status by 2025 and almost all of them by 2030. Figure 23 presents the expected development of market penetration. A respondent linked the wide base single tyres penetration to the demand of the OEMs.

Figure 23. Expected market penetration of tyre technologies

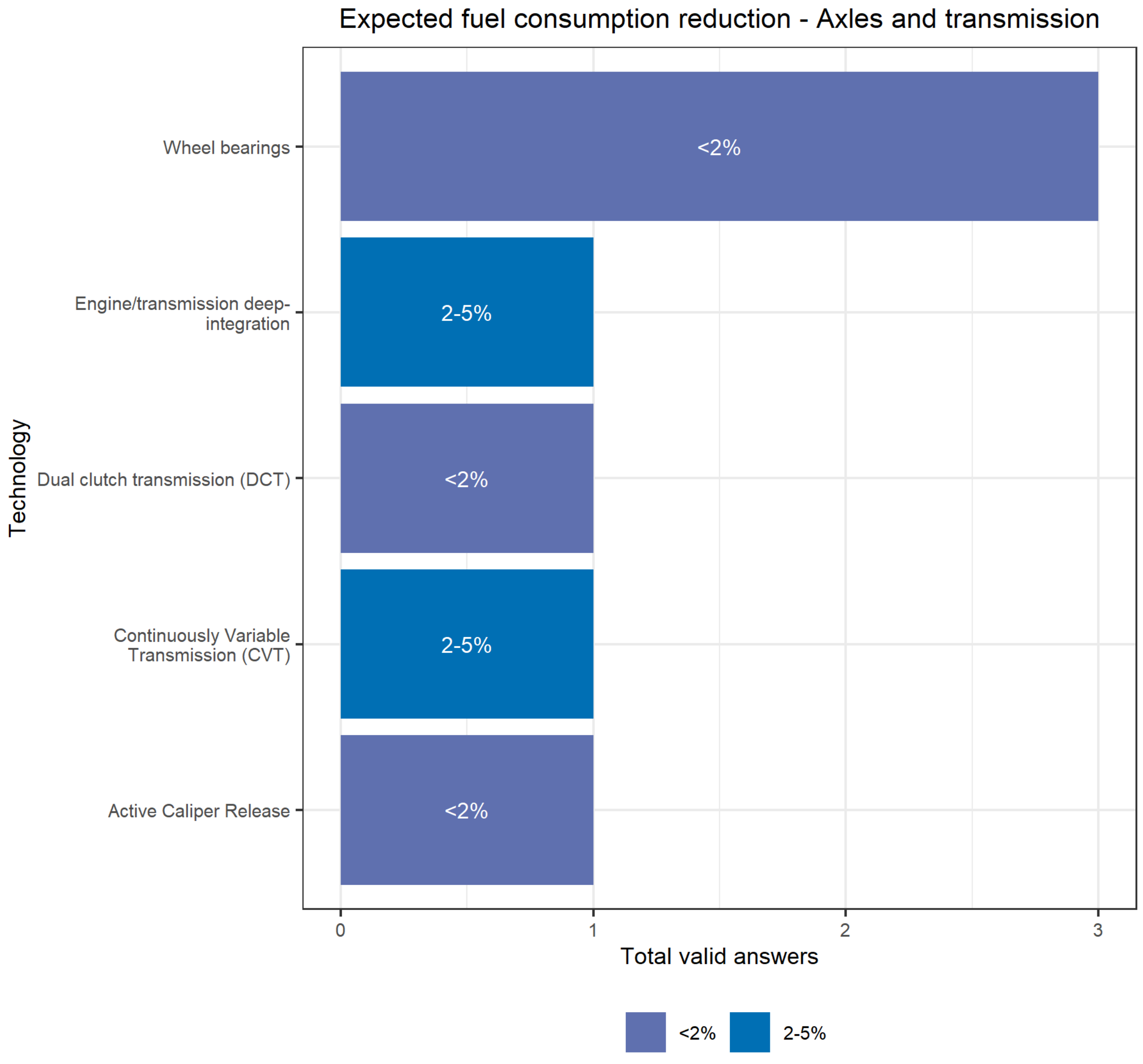


Source: JRC, 2020.

4.1.5 Axle and transmission

Improvements in the axle-transmissions system could deliver savings in CO_2 by up to 5% and it is interesting to highlight that CVT could present a reduction of up to 5% in combination with a hybrid powertrain. CVT is a popular gearbox type for light-duty hybrid vehicles, but so far it has a limited market share for HDVs. A gearbox manufacturer indicated in the 2016 JRC survey [5] that they do not aim to develop such a solution for HDVs. A respondent commented that the active calliper release would deliver improvements of about ~1%. Figure 24 presents the expected CO_2 emissions reduction by technology.

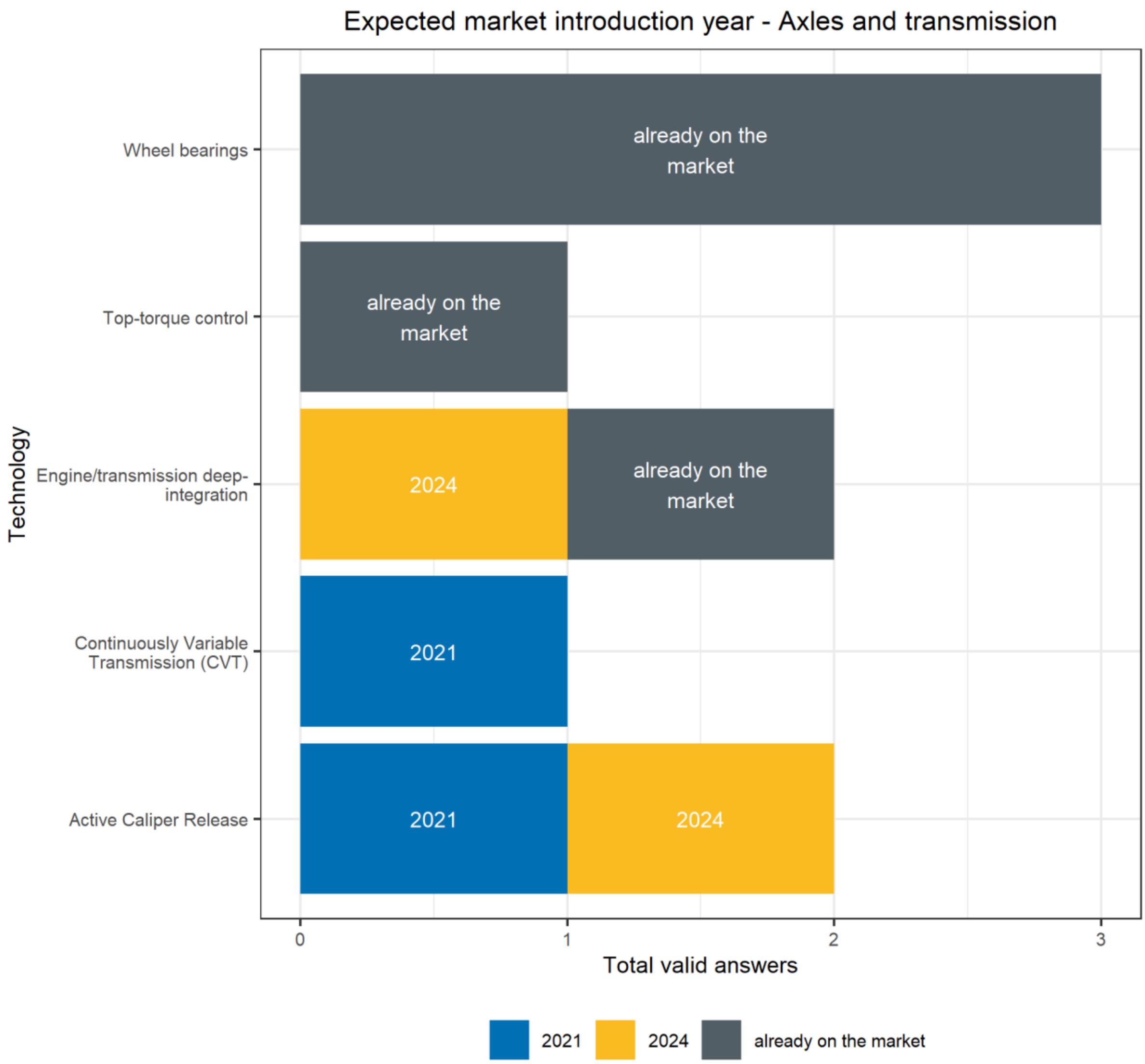
Figure 24. Expected CO_2 emissions reduction for axle and transmission technologies



Source: JRC, 2020.

According to the replies regarding the market introduction, most of the technologies are already present in the market as shown in Figure 25. Regarding the active calliper release, the respondents reported to be implemented in 2021 and 2024, while there is a conflicting opinion regarding engine/transmission integration. One respondent replied that it is already presented on the market, while the other that it is expected to enter the market in 2024.

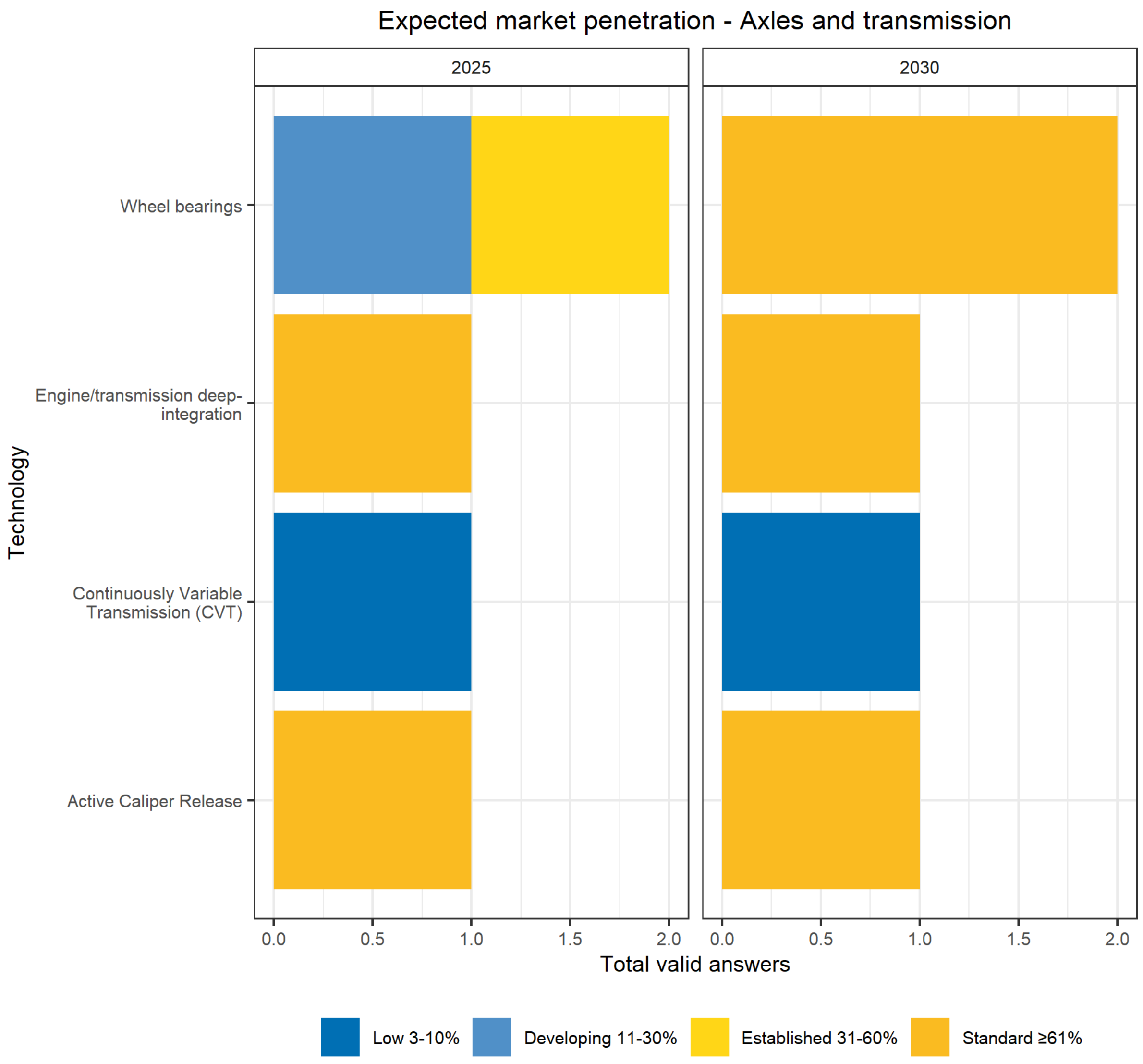
Figure 25. Expected market introduction year for axle and transmission technologies



Source: JRC, 2020.

Active caliper release and Engine/transmission deep integration are expected to be "Standard" technologies by 2025, although only one respondent provided feedback on this. If the latter technology is already present in the market, achieving this target is possible, but if it is to enter the market in 2024, such quick technology uptake is unlikely. Wheel bearings are expected to reach this status by 2030 as it is proposed by two respondents. The CVT is not expected to achieve higher penetration than 10%. Figure 26 presents the expected market penetration by 2025 and 2030.

Figure 26. Expected market penetration of axle and transmission technologies

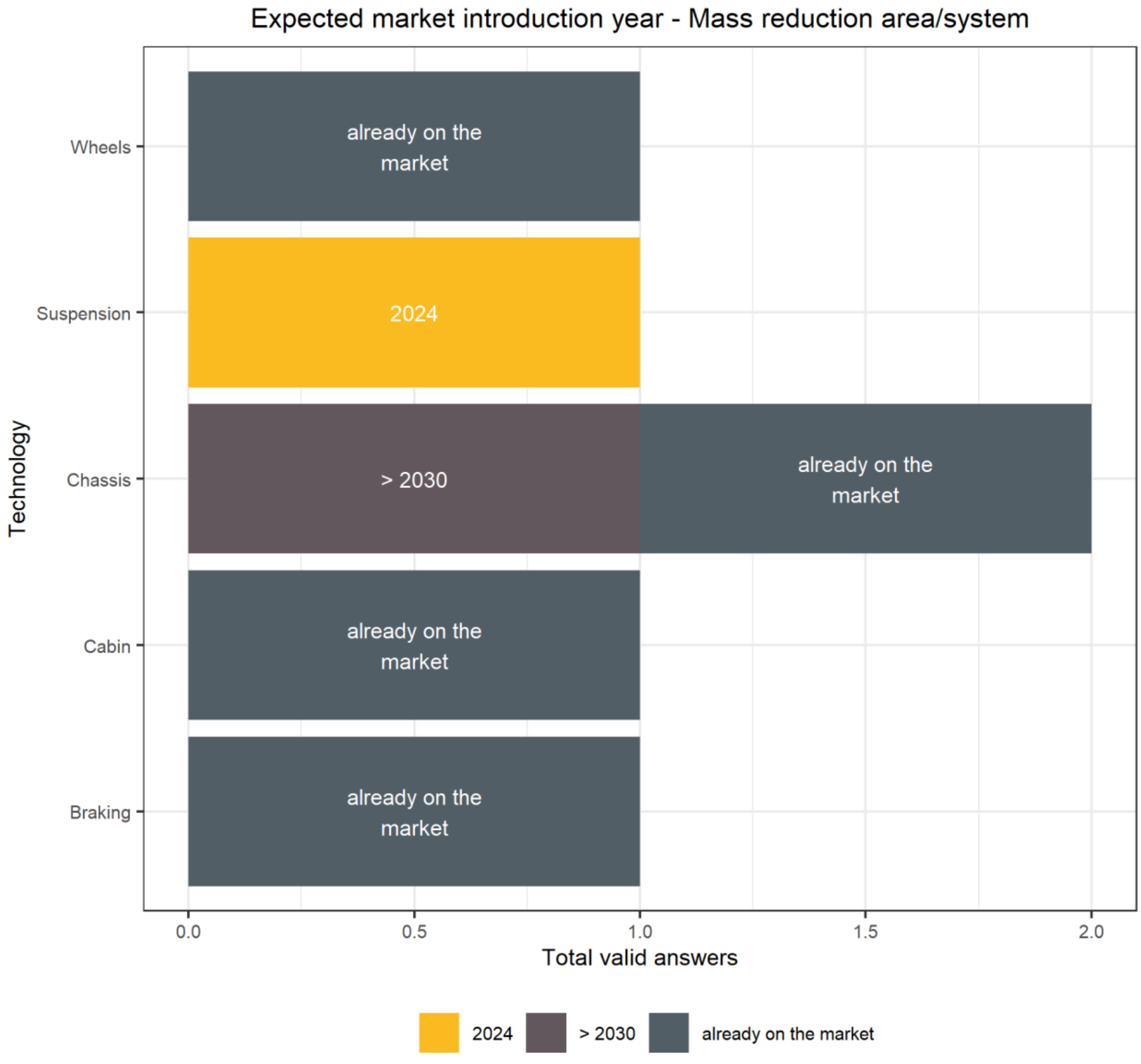


Source: JRC, 2020.

4.1.6 Mass reduction area/system

Only one answer was received for the effect on CO_2 emissions and it claimed an expected decrease of 2% by reducing the chassis mass. Nonetheless, the respondents reported there are constant improvements in the field of braking, cabin and chassis. Interestingly, the respondent commented that mass reduction would be limited as safety, comfort and utility accessories increase the weight. Subsequently, a significant mass reduction should be expected with the introduction of autonomous vehicles. Regarding the introduction year of most technologies, it is mainly agreed that they are already present in the market as shown in Figure 27.

Figure 27. Expected market introduction year for mass reduction technologies



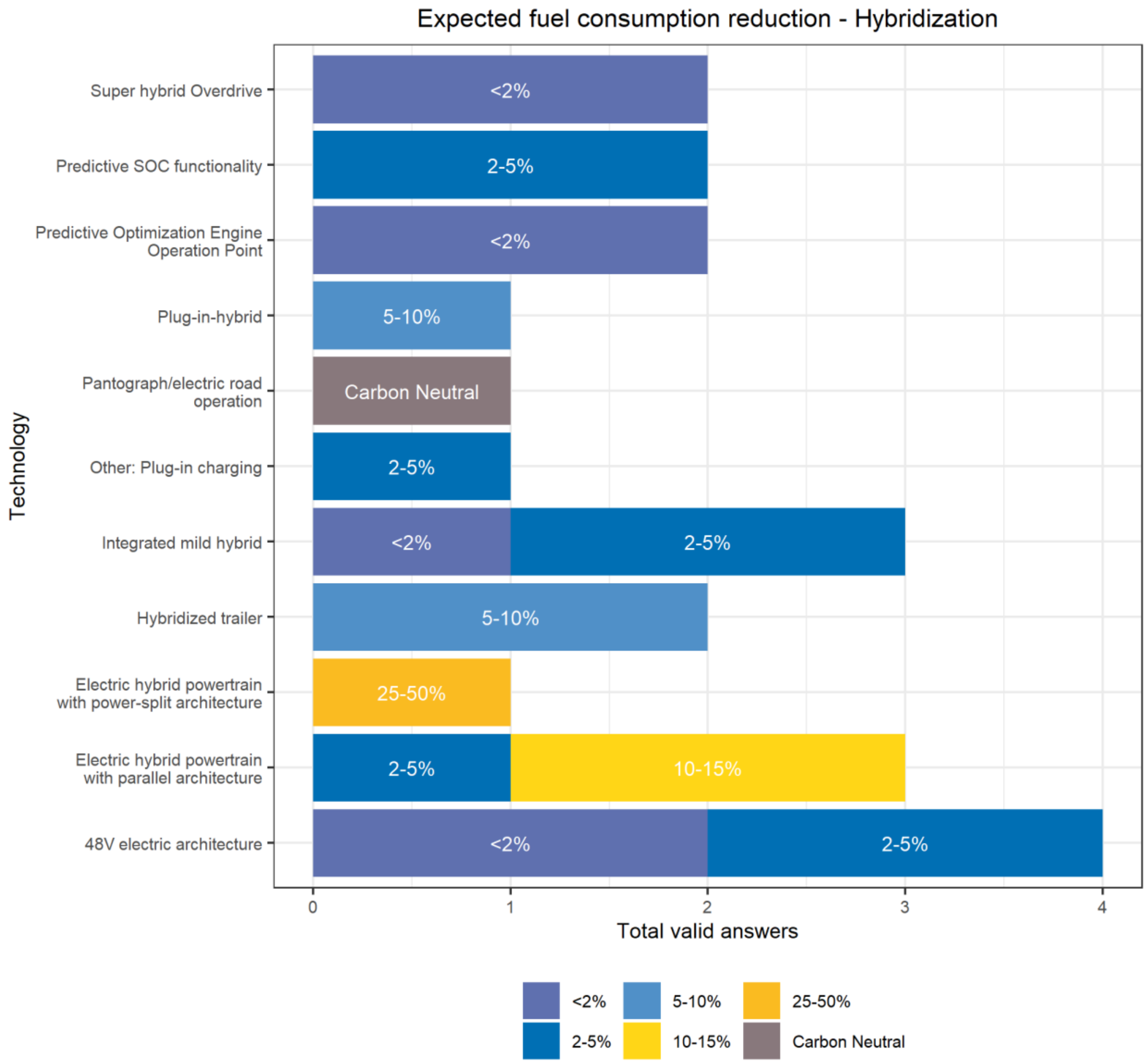
Source: JRC, 2020.

4.1.7 Hybridisation

The hybridisation can significantly reduce CO_2 emissions with an electric hybrid powertrain with power-split architecture that achieves reductions by up to 50%, while an electric hybrid powertrain with parallel architecture can reach a 15% reduction. It was stated that an in-wheel electric motor would have no additional benefit. It is interesting to highlight the pantograph functionality, which has the potential to be a carbon-neutral technology.

The respondents provided significant comment in their comments for various technologies. Several technologies such as 48V and an electric hybrid powertrain with power-split architecture could have a higher impact in the regional delivery than the long-haul cycle. For the 48V technology, it was indicated that this technology is needed for the integration of mild hybrids and electrified components. Mild hybrids could potentially produce up to 40 kW and a higher impact could be achieved in combination with WHR and an electric oil pump. However, a respondent argued that the benefits would be below 1%. Figure 28 presents the expected CO_2 emissions reductions for hybridisation technologies.

Figure 28. Expected CO_2 emissions reduction for hybridisation technologies

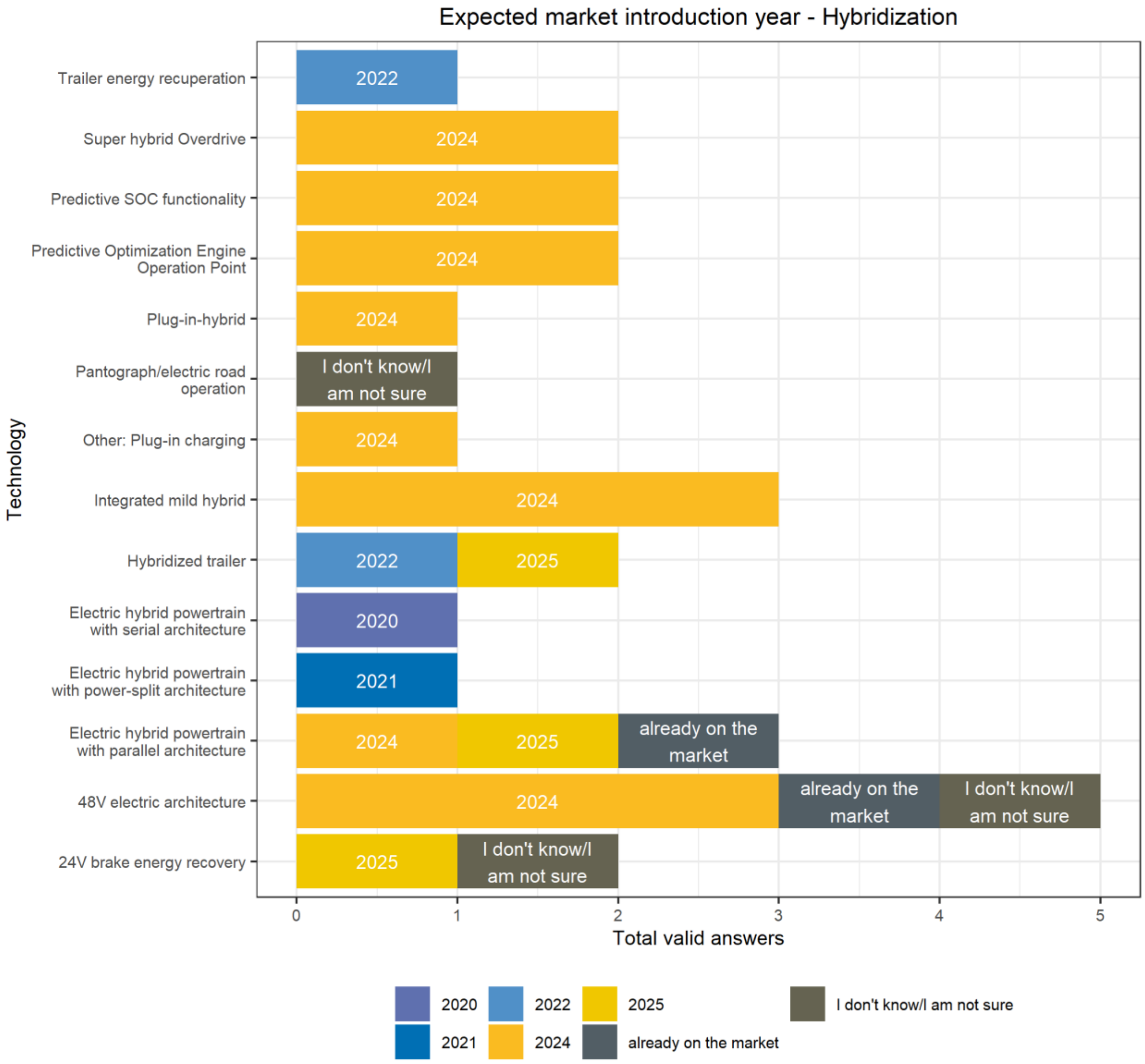


Source: JRC, 2020.

A respondent provided some detailed feedback regarding the hybridized trailer. The technology should be integrated with the brake management system for optimized recuperation and in combination with traction control for higher benefits. In this case, the gains were quantified to 15.5% for a 40 t and 10.5% for a 28 t vehicle in the regional delivery and 6.6% and 5.9% in the long-haul for a 40 t and 34 t vehicle respectively.

The majority of the answers agree that hybridisation will be introduced in the market in the mid-2020s with some respondents indicating that some technologies (48V battery, hybrid parallel architecture, etc.) are already available in the market as shown in Figure 29. It is unknown whether pantograph functionality will be introduced in the market as it requires a significant investment in infrastructure and a respondent commented that this is a rather political decision on whether such an investment would proceed.

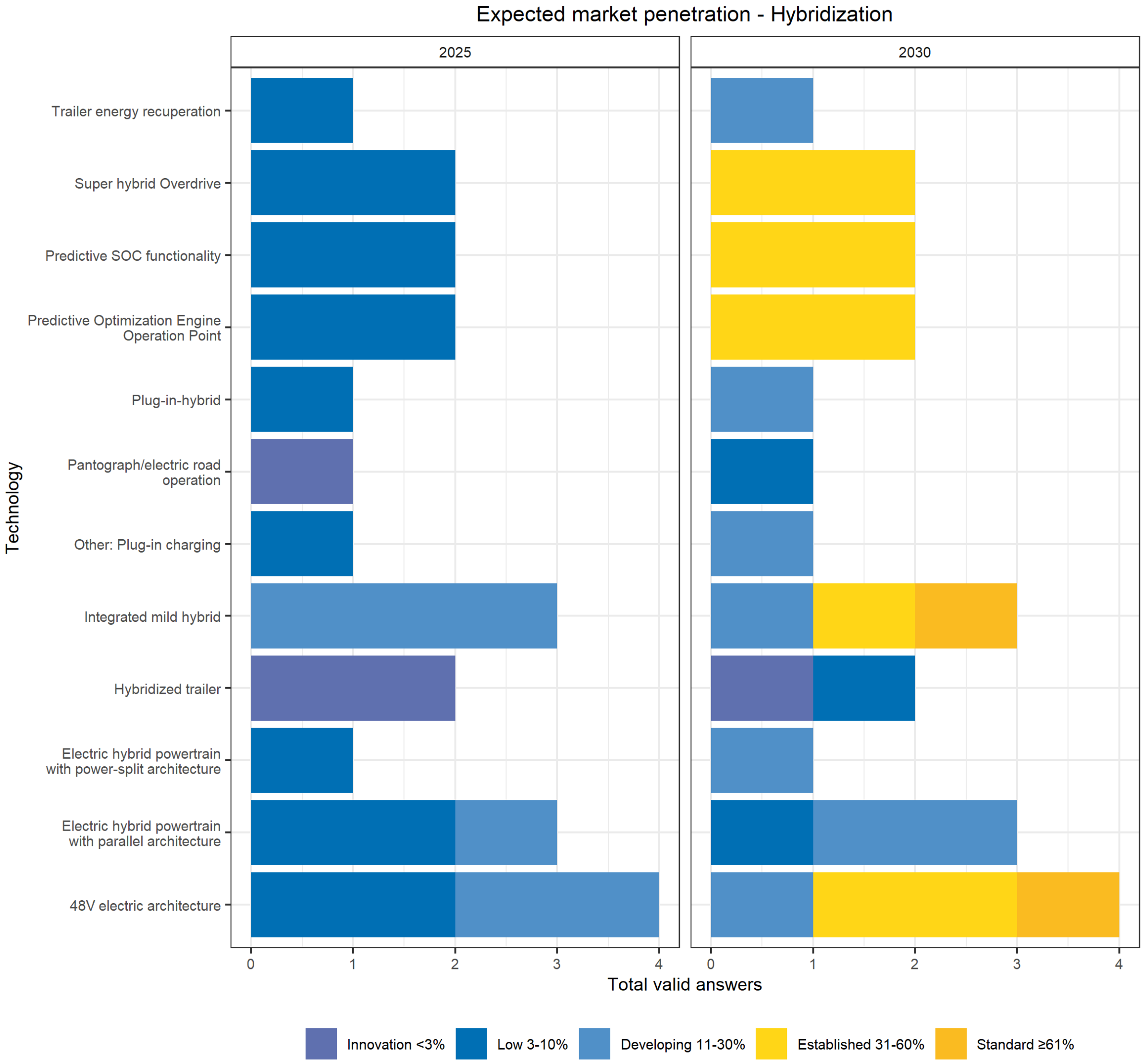
Figure 29. Expected market introduction year for hybridisation technologies



Source: JRC, 2020.

In terms of market penetration, it is expected that the technology uptake will be in general low by 2025, but it seems to accelerate and gain a higher market share by 2030. Figure 30 presents this trend as most of the technologies are considered to have low penetration by 2025 while achieving developing and established status by 2030.

Figure 30. Expected market penetration of hybridisation technologies

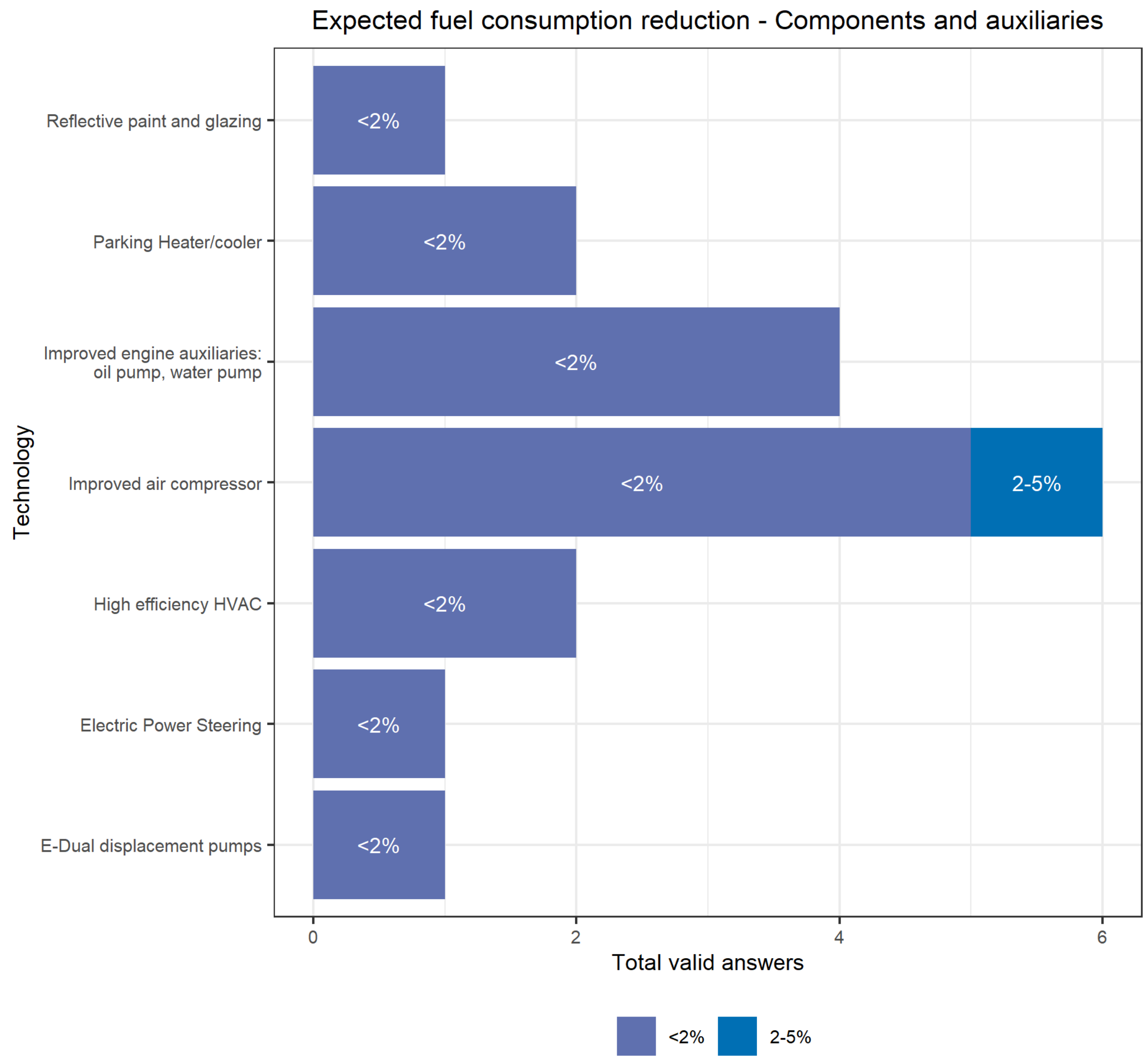


Source: JRC, 2020.

4.1.8 Components and auxiliaries

The expected reduction for auxiliary technologies is estimated to be up to 2%. Although it should be noted that few respondents provided an answer in most cases. For the electric power steering, high-efficiency HVAC, improved air compressor and improved engine auxiliaries: oil pump, water pump it was claimed that their effect would be below 1%. Regarding the HVAC and the reflective paint and glazing, a respondent commented that trucks' power demand is significantly underestimated in VECTO due to the method of aligning measurement data to European average climate data. According to the feedback, there are continuous improvements in the HVAC technologies that should be taken into consideration. A respondent stated that an electric air compressor is a standard component for battery electric vehicles that can provide a reduction of more than 2% on a conventional vehicle compared to an engine-driven compressor. Another respondent stated that generic values for the air compressor are already available for a range of technologies. There seems to be high interest in this technology as there are continuous improvements and it is significant for electric vehicles, where a disengageable compressor is needed. It was also stated that a large steering pump offers an advantage compared to two small steering pumps. Regarding the electrified oil and water pumps (included within improved engine auxiliaries) a respondent commented that their effect is overestimated in VECTO. It was clarified that their effect could be reflected in an engine test but the electric load increase is not necessarily accounted for. Figure 31 presents the expected CO_2 emissions by technology.

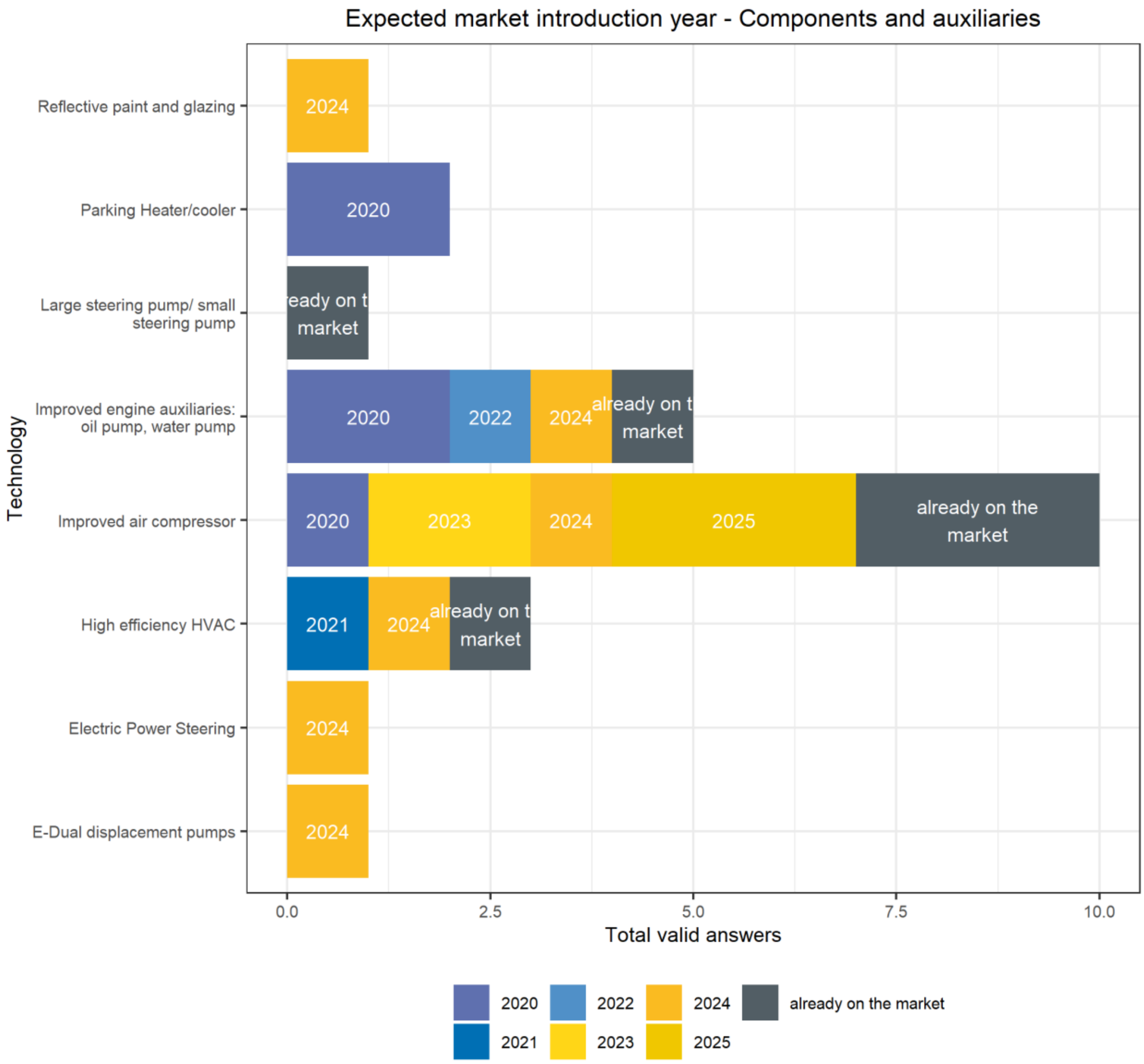
Figure 31. Expected CO_2 emissions reduction for components and auxiliaries technologies



Source: JRC, 2020.

The responses regarding the technology introduction indicate that most technologies will be introduced in the early 2020s. However, there was only one respondent indicated in most cases. In the case of HVAC, there were two or three replies that contradicted each other, as shown in Figure 32.

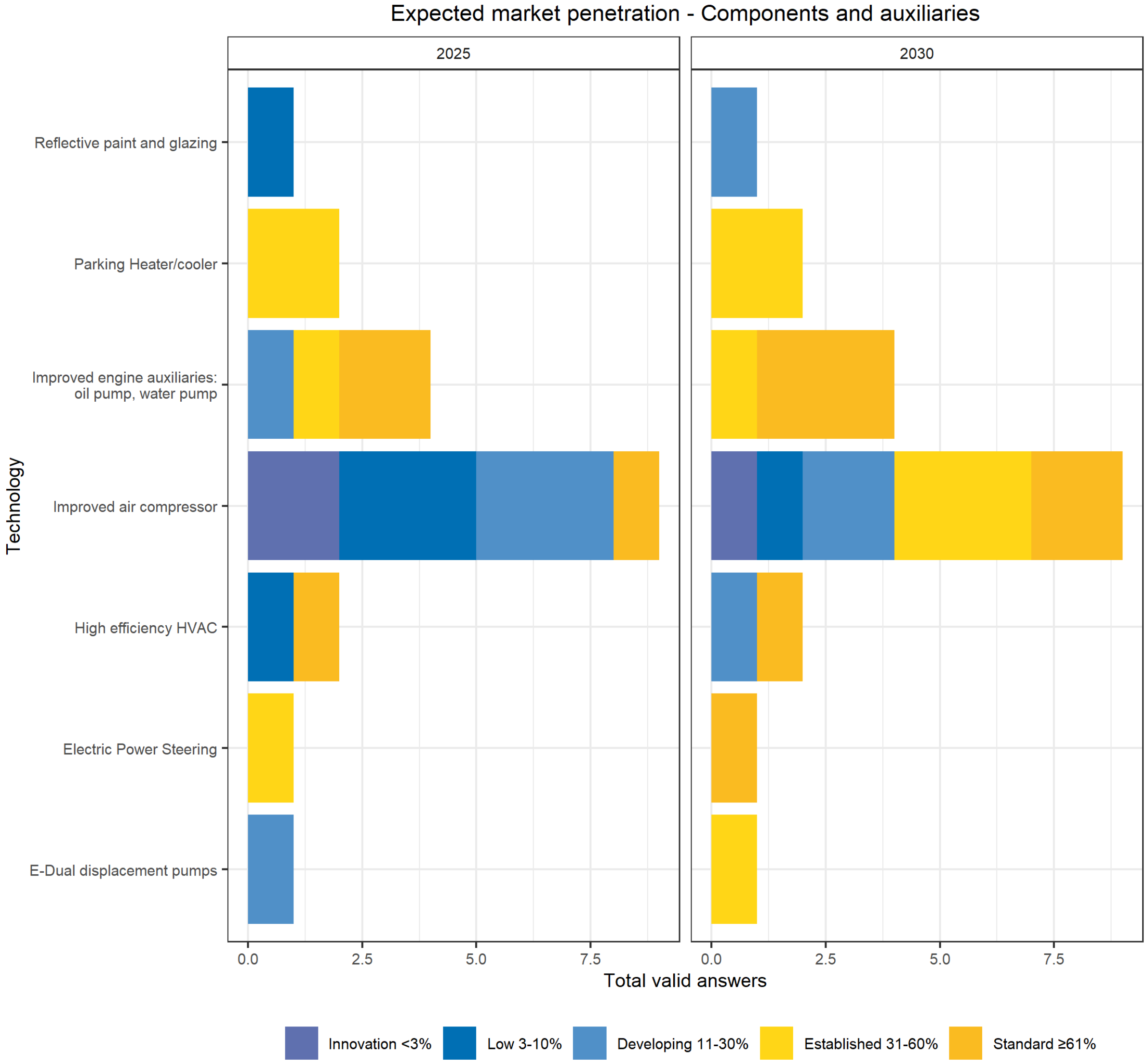
Figure 32. Expected market introduction year for components and auxiliaries technologies



Source: JRC, 2020.

Significant market penetration for most technologies is expected to achieve "Established" status by 2025 and develop to "Standard" by 2030. Figure 33 presents the replies regarding market penetration for 2025 and 2030 by category.

Figure 33. Expected market penetration of components and auxiliaries technologies

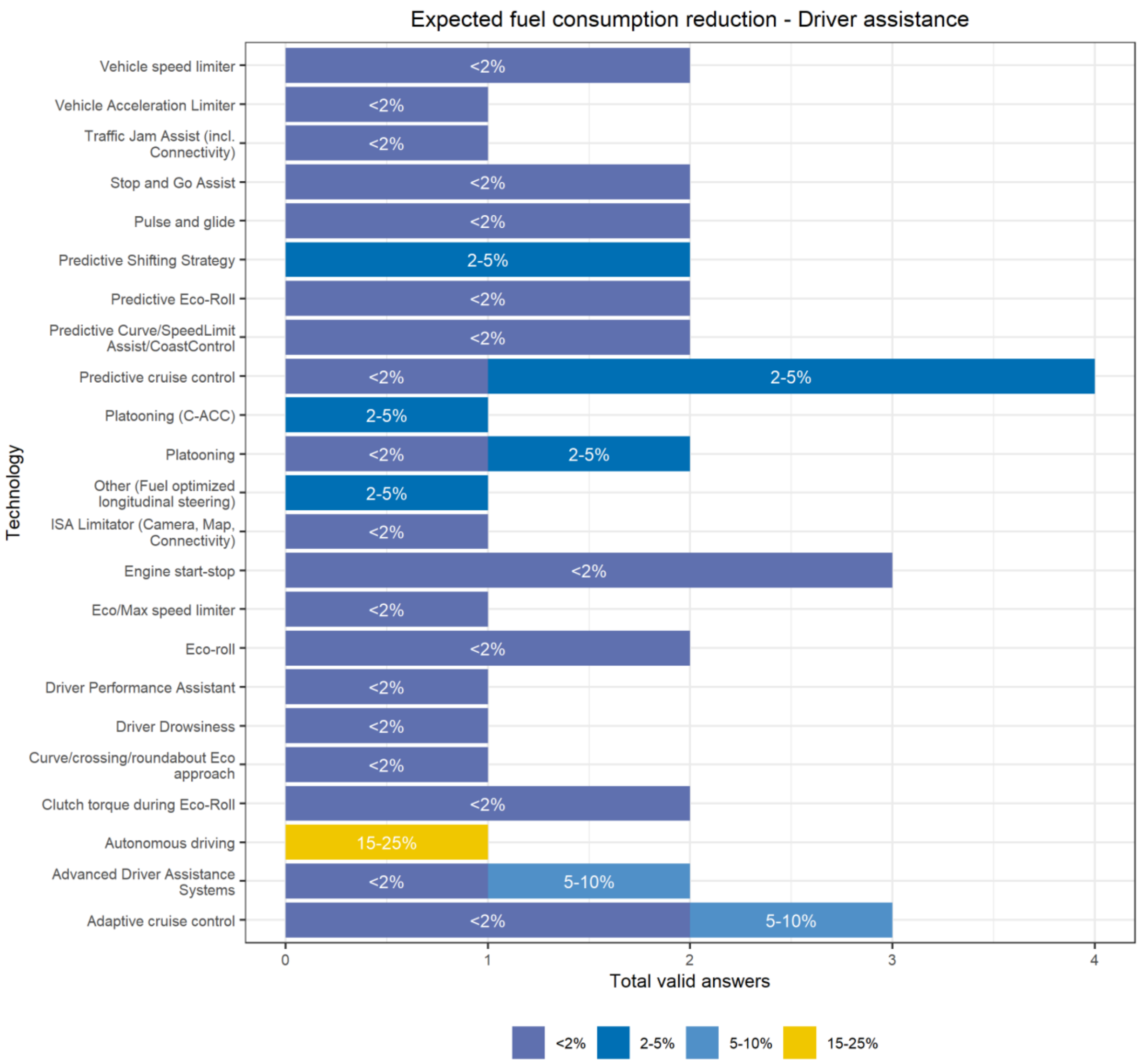


Source: JRC, 2020.

4.1.9 Driver assistance

Most driver-assistance technologies present a potential CO_2 reduction of up to 2% with some exhibiting reductions up to 5%. The technologies that provide the highest potential have generally been included somehow in the VECTO development except for Autonomous Driving. According to one respondent, this technology has the potential to reduce emissions by up to 25%, but VECTO does not cover it. The respondent clarified that this reduction could be achieved by driving at lower speed and during off-peak hours but it could require investment in infrastructure and is rather a political decision. On the other hand, it should be highlighted that the effect of platooning could be significant in long-haul operation, but the vehicle in-between distance should be taken into consideration. The results are presented in detail in Figure 34. Advanced Driver Assistance Systems that can also "read" speed signs and traffic information could be an important area to improve and achieve significant savings. Demonstrating the technology's capabilities could promote both innovation and market penetration. Regarding predictive cruise control, its effect could vary on the road conditions with the highest benefits in hilly routes, while it could also be used to adjust speed based on the speed limits.

Figure 34. Expected CO_2 emissions reduction for driver assistance technologies

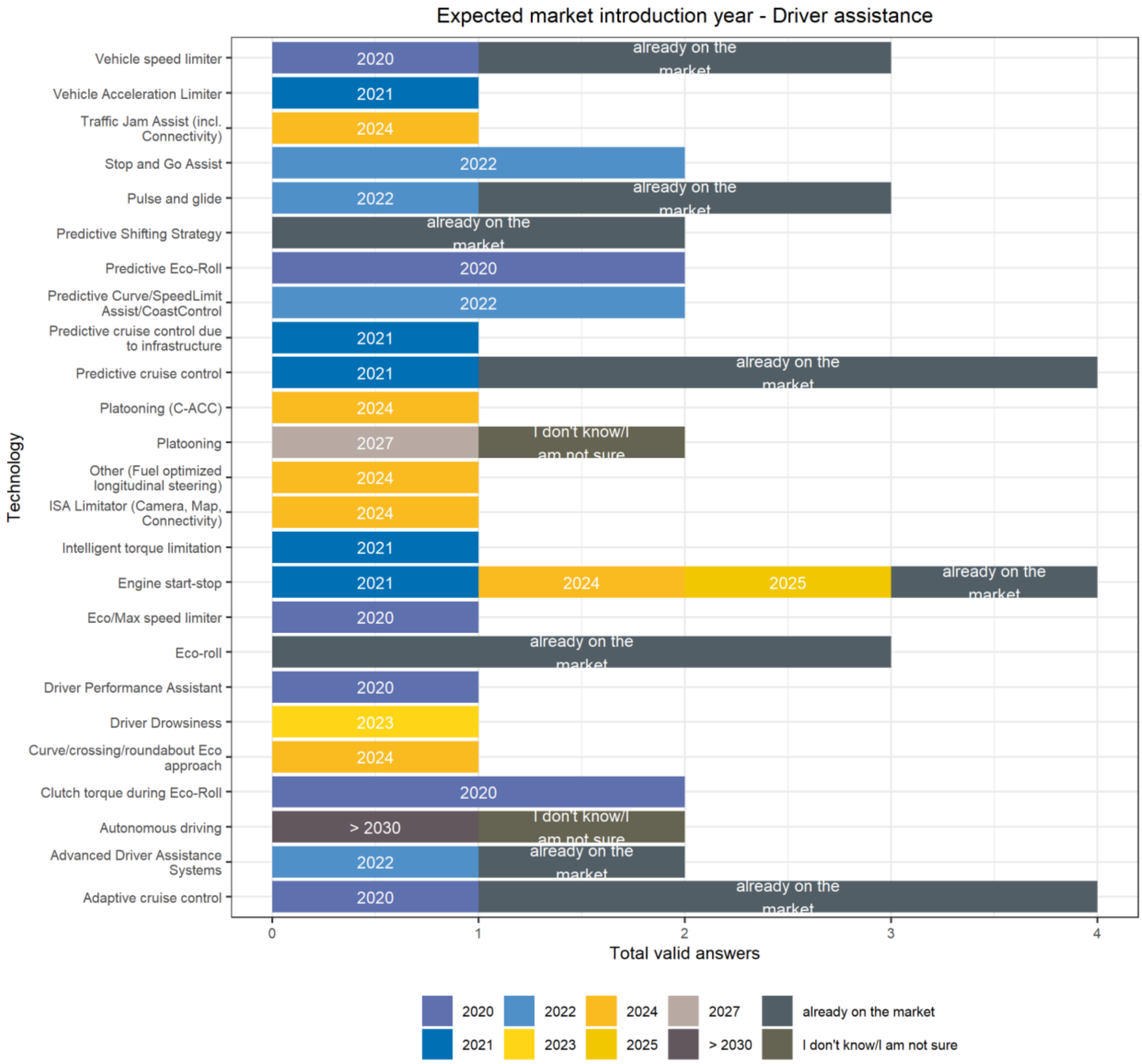


Source: JRC, 2020.

A respondent clarified that the effect would be below 1% for each of the following technologies: curve/crossing/roundabout eco approach, driver drowsiness, driver performance assistant, engine start-stop, eco/max speed limiter, engine start-stop, ISA limitator, predictive cruise control, traffic jam assist, vehicle acceleration limiter and vehicle speed limiter.

The responses regarding market introduction indicate that many of the already existing technologies are already included at least partially or are under development for implementation in VECTO. The exceptions are the vehicle speed limiter and pulse and glide, which are not considered covered or under development. The autonomous driving technology, which claimed to have a high potential in reducing CO_2 emissions, is indicated that will probably enter the market after 2030. Figure 35 presents the expected introduction year for driver assistance technologies.

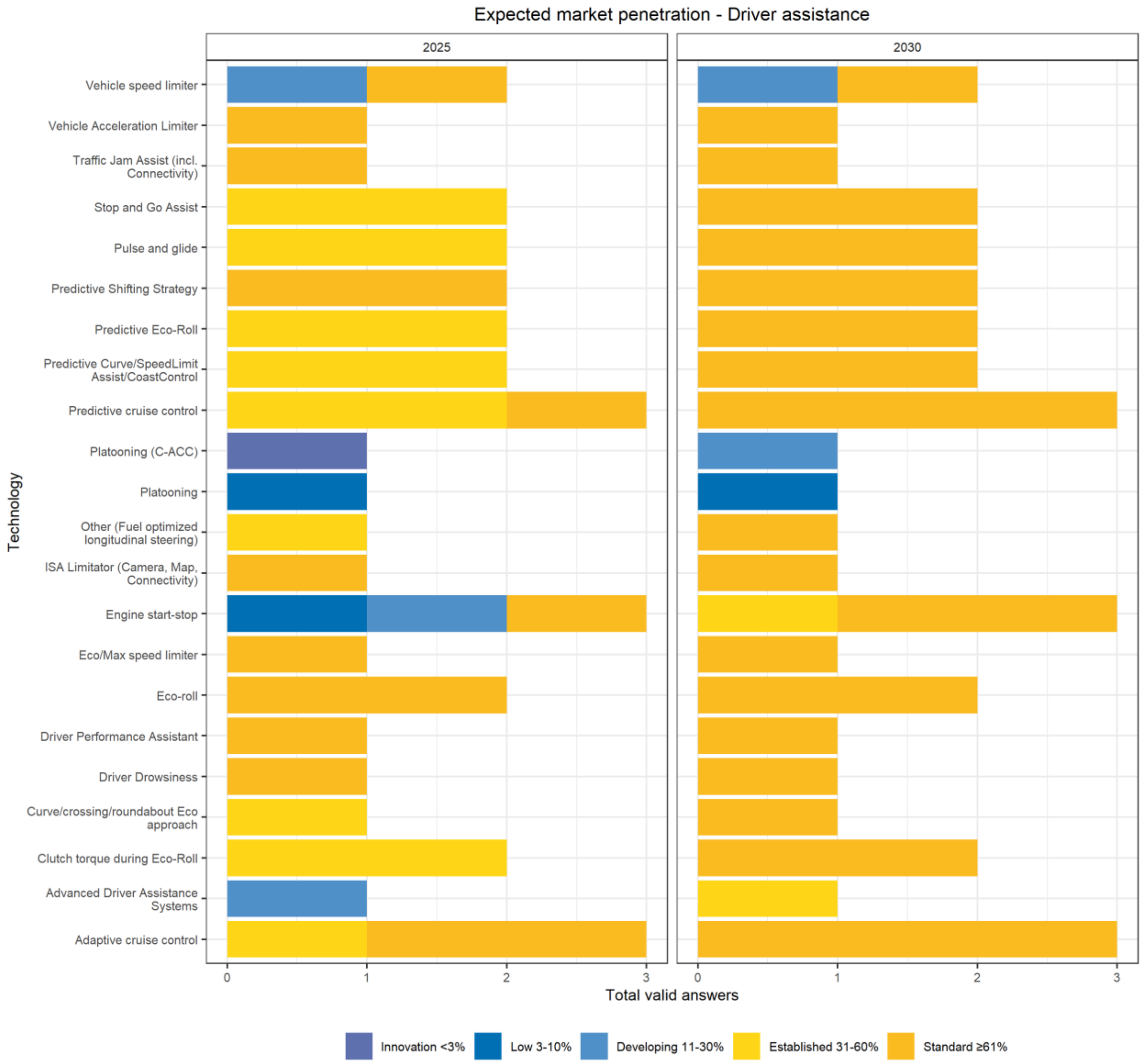
Figure 35. Expected market introduction year for driver assistance technologies



Source: JRC, 2020.

A really interesting finding is that the respondents agree more or less that the technology uptake will be relatively fast, as is presented in Figure 36. By 2025 most of the technologies will have achieved at least "Established" status and they will be "Standard" by 2030.

Figure 36. Expected market penetration of driver assistance technologies

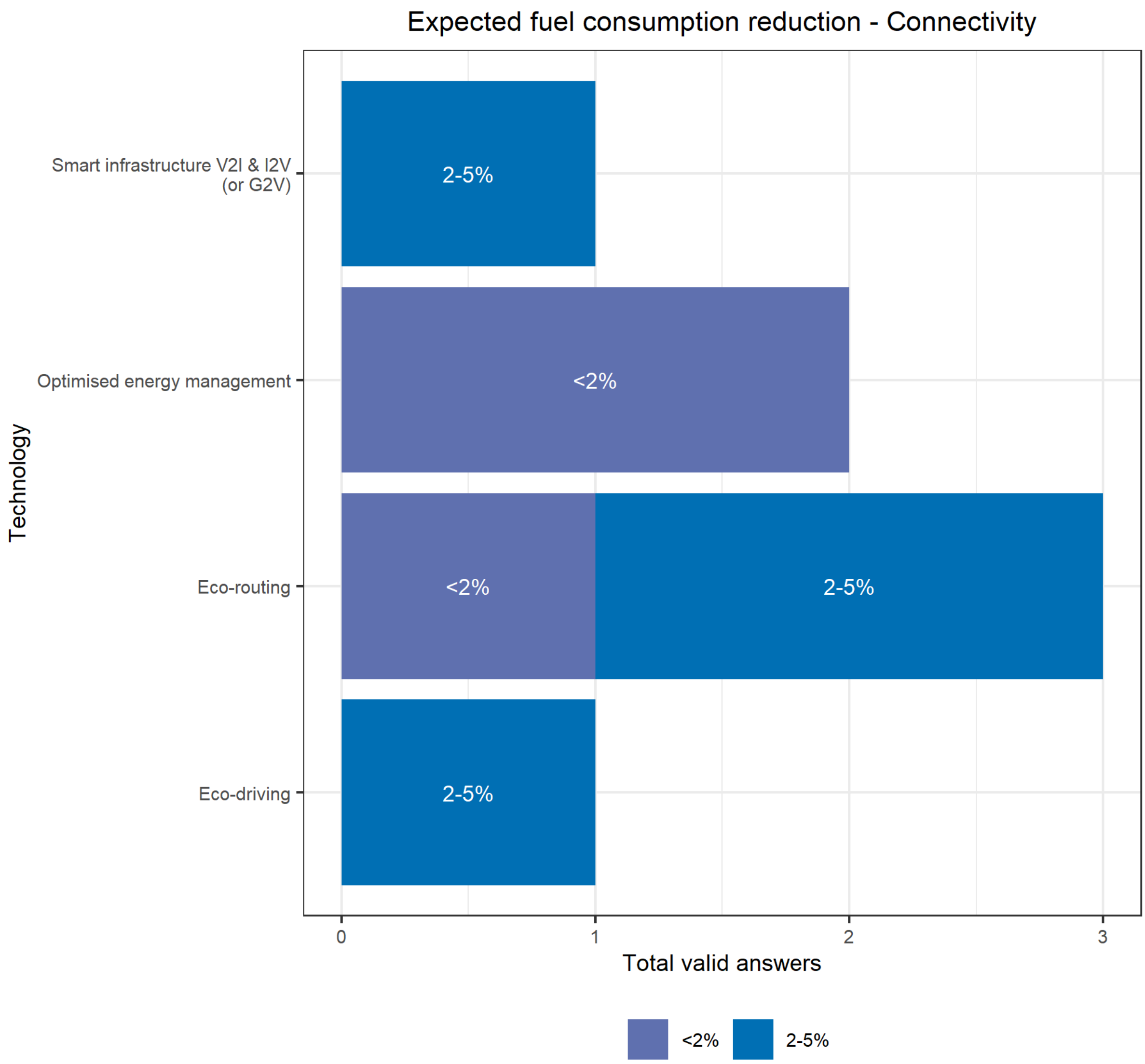


Source: JRC, 2020.

4.1.10 Connectivity

The expected reduction in CO_2 emissions is estimated by up to 5% for most technologies, but only a few answers were quantifying the effect. Figure 37 presents the replies by technology and highlight the potential of reducing CO_2 emissions.

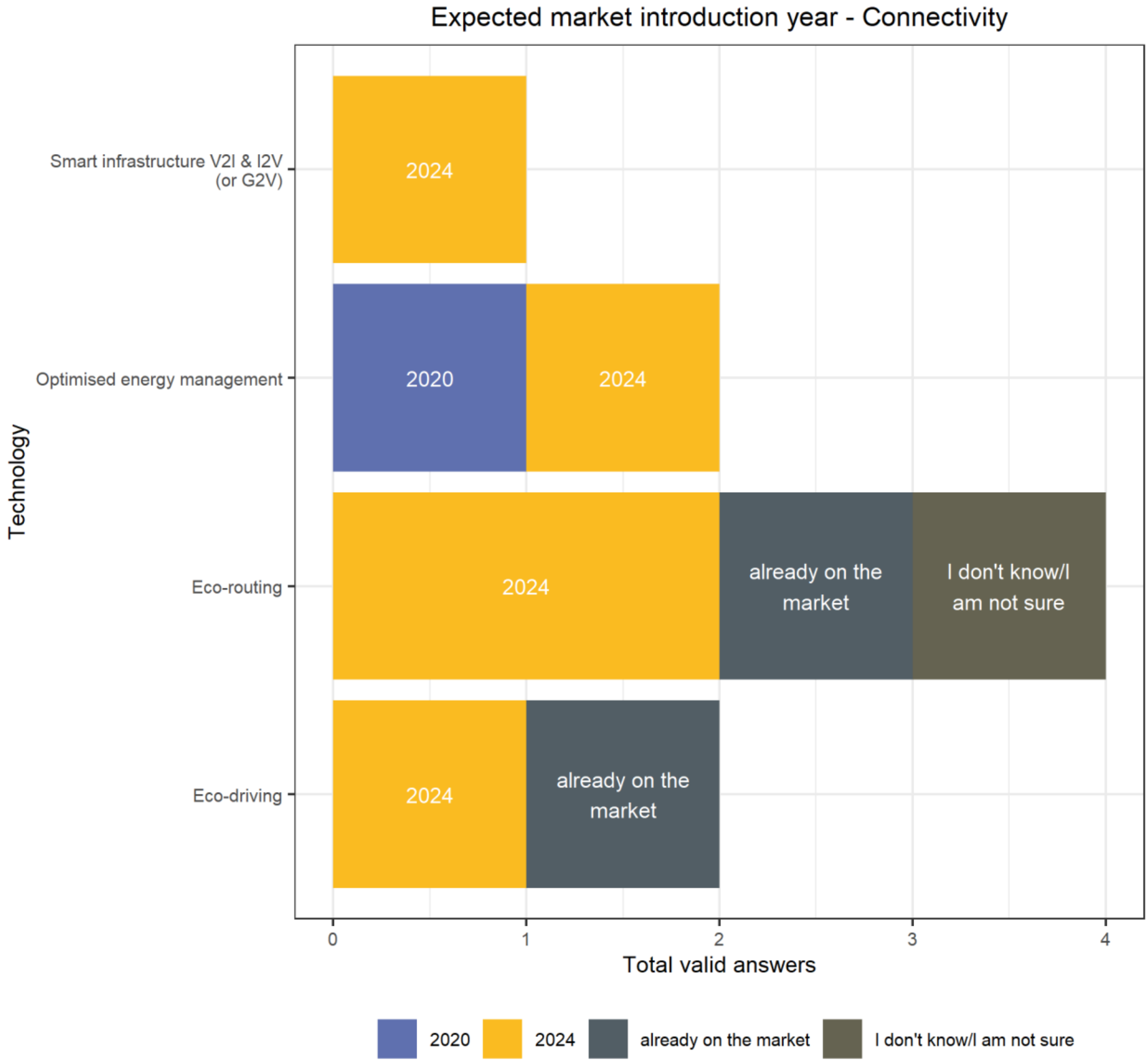
Figure 37. Expected CO_2 emissions reduction for connectivity technologies



Source: JRC, 2020.

The expected market introduction is mostly taking place by 2024, but for Eco-routing and Eco-driving there are conflicting opinions as some respondents stated that it will be available by 2024, whereas others that it is already available. Figure 38 presents the market introduction year by technology.

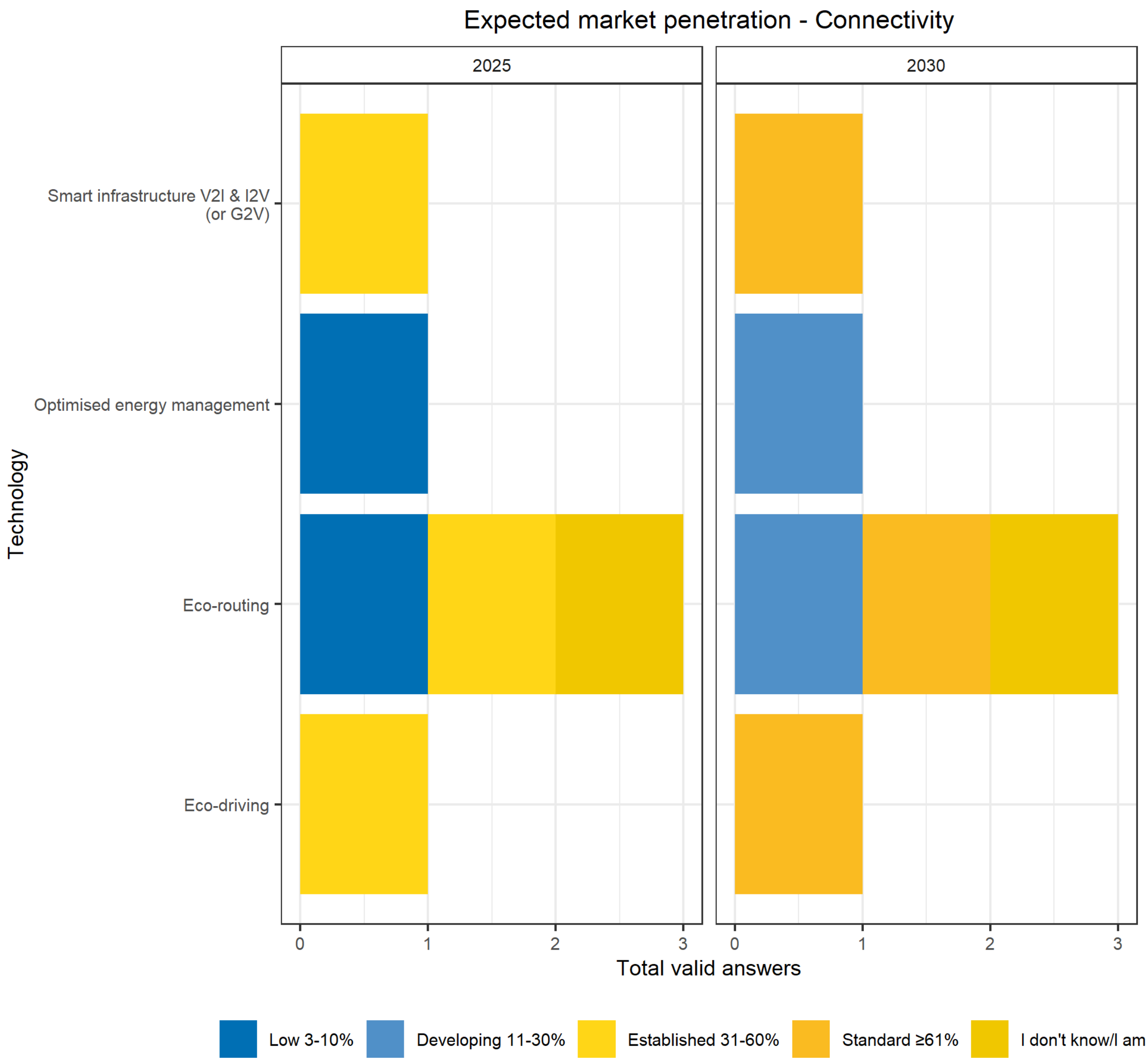
Figure 38. Expected market introduction year for connectivity technologies



Source: JRC, 2020.

The technologies are expected to reach an "Established" status by 2025 and "Standard" status by 2030, according to one respondent. There have not been many replies regarding the penetration with only Eco-routing collecting three replies as shown in Figure 39. The latter technology present also a somehow contradicting view as one respondent indicated a "Low" penetration rate for 2025 and "Developing" for 2030, whereas the other one replied respectively "Established" and "Standard".

Figure 39. Expected market penetration of connectivity technologies



Source: JRC, 2020.

5 Conclusions

The survey results presented an overview of the current VECTO capabilities to simulate a series of technologies that are expected to be implemented in the future to reduce the fuel consumption and CO_2 emissions of heavy-duty vehicles. Many of the technologies with the highest potential in reducing CO_2 and the highest market uptake in the near future are currently under development for implementation in VECTO.

Based on the replies that we received, the inclusion of the hybrid vehicles in VECTO should move forward first as they are already under development, they present a significant CO_2 emissions reduction potential and have also collected one of the highest response rates. Also, aerodynamic improvements should be included in the development as many of these technologies are already on the market and present an easy to implement a solution to reduce emissions. Tyres with wide-based singles and low rolling resistance technologies and mass reduction could also be considered to be prioritised. Many respondents highlighted the need to include technologies that improve the trailers and are not included in VECTO, as VECTO includes only standard trailers and bodies. Several technologies can be implemented easily and help drivers reduce the vehicle's CO_2 emissions compared to more sophisticated driving systems. There is a trend in this direction as some of these technologies have already been implemented. Battery electric vehicles offer higher reduction potential but are expected to gain lower market penetration in the coming years.

Many technologies about to be brought to market are already covered by VECTO or are part of the **current development process**. These include:

- Hybrid-electric powertrains
- Battery-electric powertrains
- Waste heat recovery with an Organic Rankine Cycle
- Body and trailer aerodynamics

It would be reasonable to focus the **short-term VECTO development** efforts on technologies that can either be easily implemented in the tool or technologies with a significant CO_2 reduction potential that will be brought to the market in the short to medium term. Examples of such technologies are:

- Fuel Cell powertrain
- Hydrogen fuelled internal combustion engine
- High-efficiency auxiliaries
- Engine/cylinder deactivation

In the **longer term**, other relevant technologies that will be brought to the market later should be considered, such as:

- Catenary vehicles
- Optimised and predictive energy management
- Continuously variable transmission
- Electrified trailers
- Driver assistance
- Connected and automated vehicles

References

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4. Fontaras G., Grigoratos T., Savvidis D., Anagnostopoulos K., Luz R., Rexeis M. and Hausberger S., 'An experimental evaluation of the methodology proposed for the monitoring and certification of CO_2 emissions from heavy-duty vehicles in Europe', Energy Vol. 102, 2016, pp. 354-364.

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List of abbreviations and definitions

CO_2	Carbon Dioxide
CVT	Continuously Variable Transmission
DCT	Dual Clutch Transmission
DME	Dimethyl Ether
EPS	Electric Power Steering
ICAC	Indirect Charge Air Cooling
JRC	Joint Research Centre
LNG	Liquefied Natural Gas
OEM	Original Equipment Manufacturer
SOC	State Of Charge
TBR	Truck and Bus Radial Tyre
TPMS	Tyre Pressure Monitoring System
VECTO	Vehicle Energy Consumption Calculation TOol

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Annexes

Annex 1. Survey

Table A1. List of technologies included in the survey

Category	Technology
Internal Combustion Engine	Improved air compressor
Internal Combustion Engine	Improved intake/exhaust system
Internal Combustion Engine	Waste heat recovery
Internal Combustion Engine	Hydrogen fueled internal combustion engine
Internal Combustion Engine	High-efficiency alternator
Internal Combustion Engine	Engine disengagement
Internal Combustion Engine	Dimethyl Ether Fuel
Internal Combustion Engine	Other: Dual fuel injection, LNG
Internal Combustion Engine	Dual-Fuel H2-Diesel
Internal Combustion Engine	Indirect Air Charge Cooling
Internal Combustion Engine	Cylinder Deactivation
Electric powertrain	Battery electric vehicle
Electric powertrain	Fuel cell vehicle
Electric powertrain	Predictive Energy Management
Aerodynamics	Active aerodynamic systems
Aerodynamics	Adjustable fifth wheel
Aerodynamics	Body/Trailer front end devices
Aerodynamics	Body/Trailer rear end devices
Aerodynamics	Body/Trailer side skirts
Aerodynamics	Body/Trailer shape
Aerodynamics	Body/Trailer underbody
Aerodynamics	Vortex generators
Aerodynamics	Wheel covers
Aerodynamics	Active Body/trailer lowering
Aerodynamics	Other (please specify)

Aerodynamics	Cross-wind optimisation
Aerodynamics	Aero devices, e.g. Sunvisor
Tyres	Wide base single tyres
Tyres	Low rolling resistance tyres
Tyres	Advanced Tyre Pressure Monitoring System (TPMS)
Tyres	Active Pressure Inflation
Tyres	Insulated Rim
Tyres	Enforced tyre flanks
Tyres	Truck and Bus Radial Tyre
Tyres	Real Rolling Resistance of trailers' tyres
Tyres	Tyre and Rim Inertia Real value
Tyres	Interaction Tyre-Rim for Improved rolling resistance
Axles and transmission	Dual clutch transmission (DCT)
Axles and transmission	Continuously Variable Transmission (CVT)
Axles and transmission	Top-torque control
Axles and transmission	Engine/transmission deep-integration
Axles and transmission	Wheel bearings
Axles and transmission	Active Caliper Release
Axles and transmission	Disengageable axle/ wheel ends
Axles and transmission	Temperature management of the oil in the axle
Axles and transmission	Tandem axle lift
Mass reduction area/system	Braking
Mass reduction area/system	Cabin
Mass reduction area/system	Chassis
Mass reduction area/system	Suspension
Mass reduction area/system	Trailer body
Mass reduction area/system	Wheels
Mass reduction area/system	Other (please specify)

Hybridization	48V electric architecture
Hybridisation	24V brake energy recovery
Hybridisation	Integrated mild hybrid
Hybridisation	Electric hybrid powertrain with serial architecture
Hybridisation	Electric hybrid powertrain with parallel architecture
Hybridisation	Electric hybrid powertrain with power-split architecture
Hybridisation	Hydraulic hybrid powertrain
Hybridisation	Kinetic hybrid powertrain
Hybridisation	In-wheel electric motor
Hybridisation	Hybridised trailer
Hybridisation	Trailer energy recuperation
Hybridisation	Pantograph/electric road operation
Hybridisation	Plug-in-hybrid
Hybridisation	Other: Plug-in charging
Hybridisation	Reflective paint and glazing
Hybridisation	Predictive SOC functionality
Hybridisation	Predictive Optimization Engine Operation Point
Hybridisation	Super hybrid Overdrive
Components and auxiliaries	Reflective paint and glazing
Components and auxiliaries	High efficiency HVAC
Components and auxiliaries	Electric Power Steering
Components and auxiliaries	Large steering pump/ small steering pump
Components and auxiliaries	Parking Heater/cooler
Components and auxiliaries	E-Dual displacement pumps
Components and auxiliaries	Improved engine auxiliaries: oil pump, water pump
Driver assistance	Advanced Driver Assistance Systems
Driver assistance	Eco-roll
Driver assistance	Engine start-stop

Driver assistance	Predictive cruise control
Driver assistance	Vehicle speed limiter
Driver assistance	Adaptive cruise control
Driver assistance	Autonomous driving
Driver assistance	Platooning (C-ACC)
Driver assistance	Vehicle Acceleration Limiter
Driver assistance	ISA Limitator (Camera, Map, Connectivity)
Driver assistance	Eco/Max speed limiter
Driver assistance	Curve/crossing/roundabout Eco approach
Driver assistance	Traffic Jam Assist (incl. Connectivity)
Driver assistance	Driver Performance Assistant
Driver assistance	Driver Drowsiness
Driver assistance	Platooning
Driver assistance	Pulse and glide
Driver assistance	Intelligent torque limitation
Driver assistance	Predictive cruise control due to infrastructure
Driver assistance	Dynamic idle speed engine
Driver assistance	Other (Fuel optimised longitudinal steering)
Driver assistance	Eco-driving
Driver assistance	Eco-routing
Driver assistance	Predictive Shifting Strategy
Driver assistance	Predictive Eco-Roll
Driver assistance	Clutch torque during Eco-Roll
Driver assistance	Predictive Curve/SpeedLimit Assist/CoastControl
Driver assistance	Stop and Go Assist
Connectivity	Eco-driving
Connectivity	Eco-routing
Connectivity	Optimised energy management

Connectivity	Smart infrastructure V2I & I2V (or G2V)
Connectivity	Truck to truck communication for traffic situation
Connectivity	Usage of traffic information's to speed and route optimisation

Source: JRC, 2020.

Annex 2. Survey results

Table A2. Technologies grouped together

Technology group	Technology
Advanced Tyre Pressure Monitoring System (TPMS)	TPMS
	Tyre pressure monitoring system
	Active Pressure Monitoring
Active Pressure Inflation	Tire pressure regulation
	Central tyre inflation system
Body/Trailer front end devices	Aero devices, e.g. Sunvisor
Electric hybrid powertrain with power-split architecture	Electric hybrid powertrain with powersplit architecture
	Electric hybrid powertrain with power split architecture
Improved air compressor	Electrically driven compressor
	Improved air compressor/Compressed air use reduction
	Air compressor clutch - disconnecting of air compressor
Waste heat recovery	Waste heat recovery with electrical turbo-compounding
	Waste heat recovery with organic rankine cycle
	Waste heat recovery with thermoelectric generator
Parking Heater/cooler	Battery for hotel mode, Parking Heat/cooling
Improved engine auxiliaries: oil pump, water pump	Electrified engine auxiliaries: oil pump, water pump
	Electrified/Clutched engine auxiliaries: oil pump, water pump
Active aerodynamic systems	Active flow systems
	Active grille shutters
	Active roof spoiler height adjustment
Active Body/trailer lowering	Active systems (Active ride height, self-adjusted air deflectors, active boat tail)

Source: JRC, 2020.

Table A3. Technologies not covered by VECTO

Category	Technology	Category	Technology
Internal Combustion Engine	Cylinder Deactivation	Hybridisation	Super hybrid Overdrive
Internal Combustion Engine	Dual-Fuel H2-Diesel	Components and auxiliaries	E-Dual displacement pumps
Internal Combustion Engine	High efficiency alternator	Components and auxiliaries	Electric Power Steering
Internal Combustion Engine	Hydrogen fuelled internal combustion engine	Components and auxiliaries	High efficiency HVAC
Internal Combustion Engine	Improved air compressor	Components and auxiliaries	Large steering pump/ small steering pump
Internal Combustion Engine	Indirect Air Charge Cooling	Components and auxiliaries	Parking Heater/cooler
Internal Combustion Engine	Engine disengagement	Components and auxiliaries	Reflective paint and glazing
Internal Combustion Engine	Other: DME Fuel	Driver assistance	Adaptive cruise control
Electric powertrain	Fuel cell vehicle	Driver assistance	Advanced Driver Assistance Systems
Electric powertrain	Predictive Energy Management	Driver assistance	Autonomous driving
Aerodynamics	Active aerodynamic systems	Driver assistance	Clutch torque during Eco-Roll
Aerodynamics	Active Body/trailer lowering	Driver assistance	Curve/crossing/roundabout Eco approach
Aerodynamics	Adjustable fifth wheel	Driver assistance	Driver Drowsiness
Aerodynamics	Aero devices, e.g. Sunvisor	Driver assistance	Driver Performance Assistant
Aerodynamics	Cross-wind optimisation	Driver assistance	Dynamic idle speed engine
Aerodynamics	Wheel covers	Driver assistance	Eco/Max speed limiter
Tyres	Active Pressure Inflation	Driver assistance	Intelligent torque limitation
Tyres	Advanced Tyre Pressure Monitoring System (TPMS)	Driver assistance	ISA Limitator (Camera, Map, Connectivity)
Tyres	Enforced tyre flanks	Driver assistance	Other (Fuel optimised longitudinal steering)
Tyres	Insulated Rim	Driver assistance	Platooning
Tyres	Interaction Tyre-Rim for Improved rolling resistance	Driver assistance	Platooning (C-ACC)
Tyres	Real Rolling Resistance of trailers' tyres	Driver assistance	Predictive cruise control
Tyres	Truck and Bus Radial Tyre	Driver assistance	Predictive cruise control due to infrastructure
Tyres	Tyre and Rim Inertia Real value	Driver assistance	Predictive Curve/SpeedLimit Assist/CoastControl
Axles and transmission	Active Caliper Release	Driver assistance	Predictive Eco-Roll
Axles and transmission	Continuously Variable Transmission (CVT)	Driver assistance	Predictive Shifting Strategy

Category	Technology	Category	Technology
Axles and transmission	Disengageable axle/ wheel ends	Driver assistance	Pulse and glide
Axles and transmission	Dual clutch transmission (DCT)	Driver assistance	Stop and Go Assist
Axles and transmission	Engine/transmission deep-integration	Driver assistance	Traffic Jam Assist (incl. Connectivity)
Axles and transmission	Tandem axle lift	Driver assistance	Vehicle Acceleration Limiter
Axles and transmission	Temperature management of the oil in the axle	Driver assistance	Vehicle speed limiter
Axles and transmission	Wheel bearings	Connectivity	Eco-driving
Hybridisation	Hydraulic hybrid powertrain	Connectivity	Eco-routing
Hybridisation	Pantograph/electric road operation	Connectivity	Optimised energy management
Hybridisation	Plug-in-hybrid	Connectivity	Smart infrastructure V2I & I2V (or G2V)
Hybridisation	Predictive Optimization Engine Operation Point	Connectivity	Truck to truck communication for traffic situation
Hybridisation	Predictive SOC functionality	Connectivity	Usage of traffic information's to speed and route optimisation

Source: JRC, 2020.

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