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BRIEFING

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Overview and evaluation of eco-innovations in European passenger car CO_2 standards

BACKGROUND

In November 2017, the European Commission (EC) published a proposal for the third stage of carbon dioxide (CO_2) standards for light-duty vehicles in the European Union (EU). The proposal sets CO_2 reduction targets for new passenger cars and light commercial vehicles in the 2025–2030 timeframe, proposing to reduce distance-specific emissions by 15% from 2021 to 2025 and 30% from 2021 to 2030.[1] Previous standards for passenger cars set CO_2 targets of 130 gram per kilometer (g/km) for 2015 and 95 g/km for 2020/21, as measured over the New European Driving Cycle (NEDC).

The post-2020 CO_2 standards will continue to use the eco-innovations provision to incentivize the development and uptake of efficiency technologies. At their core, the eco-innovations mechanism rewards innovative technologies that produce real-world CO_2 savings beyond what is measured over the standardized test cycle during vehicle type approval. Technologies that yield such benefits are therefore also referred to as "off-cycle" technologies. Both vehicle manufacturers and component suppliers can apply for eco-innovations certification. Because CO_2 savings from eco-innovation technologies, or "eco-innovations" for short, count toward manufacturers' CO_2 targets, manufacturers have an incentive to develop and deploy cost-effective eco-innovations to meet CO_2 standards.

In theory, providing credits to manufacturers for technologies that reduce real-world CO_2 emissions can both reduce the cost of complying with the CO_2 standards and increase total real-world CO_2 reductions. However, if estimated eco-innovations CO_2 savings

1 Jan Dornoff et al., "The European Commission Regulatory Proposal for Post-2020 CO_2 Targets for Cars and Vans" (The International Council on Clean Transportation, January 9, 2018). https://www.theicct.org/publications/ec-proposal-post-2020-CO2-targets-briefing-20180109.

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exceed the amount of real-world CO_2 reductions, or if credits are given that double-count CO_2 reductions on the type-approval test, they can become a loophole and erode the benefits of the CO_2 standards. Thus, it is critical to properly account for the real-world benefits of eco-innovations.

Historically, the eco-innovation provision has been relegated to relative obscurity in literature on European CO_2 standards, in part due to the limited market uptake of the technologies. Because the uptake of eco-innovations is expected to accelerate as manufacturers approach 2021 CO_2 targets, the provision is now gaining more attention. This briefing summarizes the eco-innovation provision, investigates the types and market uptake of approved eco-innovations, and discusses how regulatory developments could affect eco-innovations in the future.

The CO_2 standards for both passenger cars and light commercial vehicles (or "vans") include eco-innovation provisions. Because no applications for light commercial vehicle technologies have been submitted to date, this briefing focuses on passenger cars. All CO_2 values presented in this briefing were measured over the New European Driving Cycle (NEDC).

SUMMARY OF ECO-INNOVATION REGULATIONS AND THE APPROVAL PROCESS

In an attempt to ensure that the eco-innovations provision incentivizes novel technologies, the approval procedure for eco-innovations restricts which technologies are eligible:[2]

- Technologies **may not be currently mandated or part of the European Commissions' strategy** to reduce CO_2 emissions from light-duty vehicles.[3] This restriction prevents air conditioning systems, tire pressure monitoring systems, tire rolling resistance measures, gear shift indicators, and bio fuels from qualifying as eco-innovations.
- Technologies must be **novel** to be approved as eco-innovations. In the 2015 and 2021 CO_2 standards, a technology would be considered novel if it did not exceed a market penetration of 3% in 2009.
- Technologies **must contribute to the safety or performance** of the vehicle. Non-essential comfort technologies like entertainment and air-conditioning systems are not eligible as eco-innovations.
- Technologies must produce measurable CO_2 savings during repeated tests. Measured **CO_2 savings must exceed 1 g/km in a statistically significant manner**.
- Eco-innovations can be **bundled in technology packages** in order to meet the 1 g/km CO_2 saving threshold as long as they are functionally similar, i.e., aggregate CO_2 savings can be measured using one testing methodology.
- Only CO_2 savings **outside of type-approval conditions** count toward eco-innovation emission reductions.
- In principle, **technologies that depend on driver behavior are not eligible** unless statistical evidence about average driver behavior can be provided.

2 European Commission, "Commission Implementing Regulation (EU) No 725/2011 of 25 July 2011 Establishing a Procedure for the Approval and Certification of Innovative Technologies for Reducing CO_2 Emissions from Passenger Cars Pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council," 725/2011/EU § (2011). http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R0725&from=EN.

3 European Commission, "Communication from the Commission to the Council and the European Parliament—Results of the Review of the Community Strategy to Reduce CO_2 Emission from Passenger Cars and Light-Commerical Vehicles," February 7, 2007. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52007DC0019.

In addition to these requirements, CO_2 standards limit the impact of eco-innovations on manufacturers' CO_2 performance. Both 2015 and 2021 CO_2 standards restrict the total contribution of eco-innovations toward reaching each manufacturer's emissions target to 7 g/km.

The CO_2 savings from eco-innovations are calculated according to methodologies proposed by the applicants following the technical guidelines provided by the European Commission.[4] In essence, the testing methodology must demonstrate that the technology reduces CO_2 emissions outside of type-approval conditions based on verifiable, repeatable, and comparable measurements. Figure 1 provides a graphical representation of the basic process. The savings are quantified by measuring the difference in CO_2 emissions between identical vehicles with and without the eco-innovation technology installed. The tests are first conducted under modified type-approval conditions, which alter select parameters in the type-approval procedure such that the eco-innovation technology is triggered. The tests are then repeated under standard type-approval conditions. Any CO_2 savings during standard type-approval conditions are subtracted from savings under modified conditions to avoid double counting. Lastly, the result is multiplied by the so-called usage factor, which represents how often the technology is active during real-world driving.

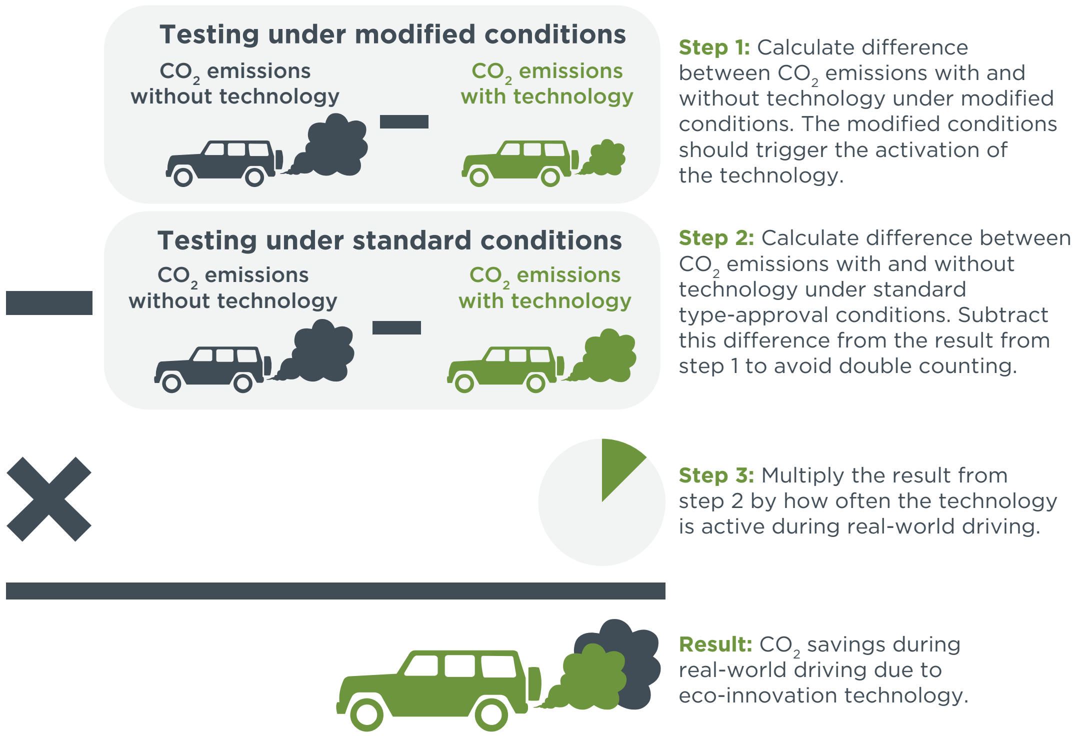

Figure 1. Simplified representation of measuring CO_2 savings from eco-innovations.

Previously, usage factors and other inputs used in the calculation of CO_2 savings were proposed by applicants, and the European Commission would evaluate the plausibility of each value on a case-by-case basis. The technical guidelines for the approval of eco-innovations now include a number of reference values for the calculation of CO_2 savings, including utility factors for types of lighting, shading of solar panels, usage of windscreen wipers, and a range of estimates for other vehicle usage, ambient conditions, and technical parameters. In some cases, data sources for reference values

4 European Commission, "Technical Guidelines for the Preparation of Applications for the Approval of Innovative Technologies Pursuant to Regulation (EC) No 443/2009 and Regulation (EU) No 510/2011," November 2017. https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp.

include peer-reviewed articles, European Commission publications, and technical standards.[5] For other reference values, such as usage factors for lighting, the data source is unclear. Regardless of data source, the determination of these values is fraught with uncertainty given the wide range of driving conditions and scant data on real-world operation of vehicles.

In practice, CO_2 savings from eco-innovations can be measured using variations of the process described above. For instance, if it is obvious that a technology does not affect CO_2 emissions during type-approval testing, step 2 in Figure 1 can be omitted. Modeling methods or on-road measurements can also be used in place of laboratory tests, but these approaches are still conceptually similar to the methodology presented in Figure 1.

The technical guidelines for eco-innovation applications provide detailed instructions and additional requirements for the application procedure. The guidelines also cover a range of other topics, including methods for calculating the uncertainty in CO_2 measurements, certification requirements, and provisions for vehicle deterioration. In the interest of brevity, these topics are not discussed in detail.

The CO_2 savings from eco-innovations are certified as part of the vehicle type-approval and recorded on the certificate of conformity. Once approved, each eco-innovation receives a unique identification number. This number is used in CO_2 monitoring data to track eco-innovations and CO_2 savings in each new vehicle. Summary reports of approved eco-innovations and test methods are available to the public.[6]

EVALUATION OF CURRENT ECO-INNOVATIONS

A wide variety of efficiency technologies can be approved as eco-innovations. Examples range from efficient lighting and alternators to roof solar panels. Table 1 lists all passenger car eco-innovations that have been approved by the European Commission to date. The table also includes a column specifying the technology type, which is used throughout this briefing to categorize eco-innovations based on how each technology reduces CO_2 emissions.[7] Out of the 25 approved eco-innovations, 16 were awarded to component suppliers and 9 to automakers.

5 For example, see S. Malfettani et al., "Latest Developments on the European Eco-Innovation Scheme for Reducing CO_2 Emissions from Vehicles: Average Input Data for Simplified Calculations," *Transportation Research Procedia* 14 (2016): 4113–21, https://doi.org/10.1016/j.trpro.2016.05.382.

6 European Commission, "Reducing CO_2 Emissions from Passenger Cars," European Commission, 2016. http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm.

7 The technical guidelines define 9 classes of eco-innovations. The types presented here correspond to those classes, but use short, descriptive names instead of the class numbering.

Table 1. List of approved eco-innovations.

ID	Company	Description	Type
01	Audi	LED lights	Lights
02	Valeo	Efficient alternator	Alternator
03	Daimler	Engine compartment encapsulation system	Thermal
04	Bosch	Adaptive state of charge control in hybrids	Kinetic
05	Automotive Lighting Reutlingen	LED lights	Lights
06	DENSO	Efficient alternator	Alternator
07	Webasto Roof & Components	Solar roof	Solar
08	Bosch	Efficient alternator	Alternator
09	Bosch	Efficient alternator	Alternator
10	Daimler	LED lights	Lights
11	Asola Technologies	Solar roof	Solar
12	Mitsubishi Electric Corporation	Efficient alternator	Alternator
13	Porsche	Coasting function	Kinetic
14	DENSO	Efficient alternator	Alternator
15	Toyota	LED lights	Lights
16	Mitsubishi Electric Corporation	Efficient alternator	Alternator
17	Bosch	Efficient alternator	Alternator
18	Valeo	Efficient alternator	Alternator
19	MAHLE Behr	Enthalpy storage tank	Thermal
20	Honda	LED lights	Lights
21	Mazda	LED lights	Lights
22	Toyota	LED lights	Lights
23	a2solar	Solar roof	Solar
24	Valeo	Efficient alternator	Alternator
25	BMW	Coasting function	Kinetic

Figure 2 shows that fleet-average CO_2 savings from eco-innovations were negligible in the past—less than 0.04 g/km in 2017—but that their impact grew over time. The figure also reveals that efficient alternators were the most impactful type of eco-innovation. Some vehicles were type-approved with multiple eco-innovations (labeled "multiple") and a significant share of eco-innovations cannot be classified due to missing or erroneous entries in the monitoring data.

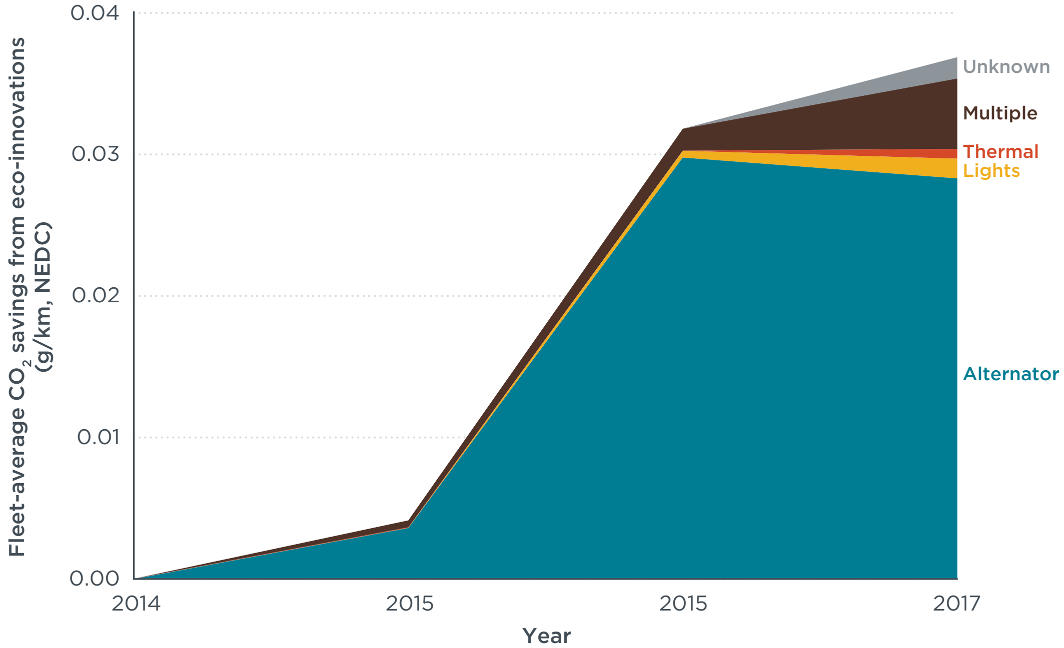

Figure 2. New passenger car fleet-average CO_2 savings by type of eco-innovation over time.[8]

Table 2 groups eco-innovations by type and provides summary statistics. Out of the 25 approved eco-innovations, only 9 were installed in passenger cars in 2017, and less than 3% of new cars were equipped with eco-innovation technologies. While average CO_2 savings in cars with eco-innovations were significant at 1.5 g/km, fleet-average CO_2 savings were orders of magnitude lower because of the low market penetration of the technologies.

Table 2. Summary of approved eco-innovations by type: number of approved eco-innovations to date; number of eco-innovations installed in cars in 2017; number of vehicles with eco-innovations registered in 2017; average CO_2 savings in vehicles with eco-innovations in 2017; fleet-average CO_2 savings in 2017.

Type	Approved eco-innovations	Installed eco-innovations	Vehicle registrations	Average CO_2 savings (g/km)	Fleet-average CO_2 savings (g/km)
Alternator	10	5	304,986	1.4	0.028
Kinetic	3	1	1	4.1	<0.001
Lights	7	1	20,109	1.0	0.001
Solar	3	0	0	—	0
Thermal	2	2	8,540	1.2	0.001
Multiple	—	—	28,140	2.7	0.005
Unknown	—	—	17,711	1.3	0.002
Total	**25**	**9**	**379,487**	**1.5**	**0.040**

Figure 3 plots each eco-innovation used in the 2017 new passenger car market in terms of average emission reduction and the number of cars equipped with it. Because some vehicles were sold with multiple eco-innovations, several markers represent combined eco-innovations. The figure shows that five eco-innovation technology packages accounted for the vast majority of emission reductions. An efficient alternator by Bosch (eco-innovation 08), is by far the most impactful eco-innovation. Although it had a relatively minor impact on CO_2 emissions in each vehicle it was installed in, with CO_2 savings of approximately 1.3 g/km, it was installed in more than 200,000 new cars in 2017. The Bosch alternator and three other eco-innovations—a Valeo alternator (eco-innovation 02), another Bosch

8 "Monitoring of CO_2 Emissions from Passenger Cars – Regulation (EC) No 443/2009," Data, European Environment Agency, April 24, 2018. https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-14.

alternator (eco-innovation 09), and Daimler lighting (eco-innovation 10)—accounted for more than 90% of fleet-average CO_2 savings through eco-innovations.

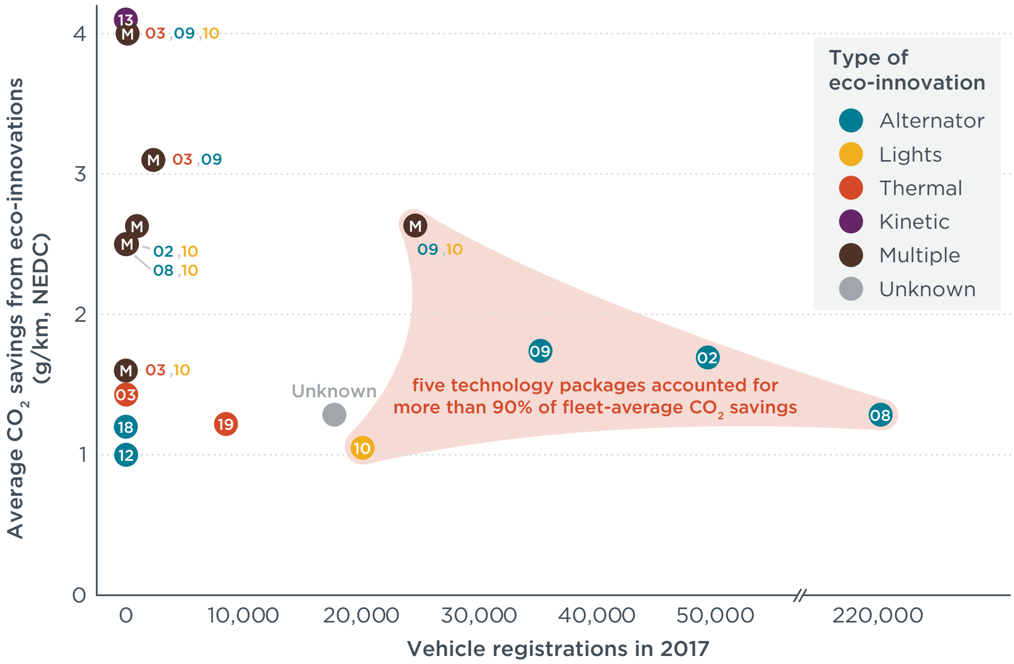

Figure 3. Average CO_2 savings and number of vehicles registered with each eco-innovation technology. The marker color denotes the type of eco-innovation and numbers refer to the eco-innovation ID in Table 1.

Although CO_2 savings from eco-innovations should be reported by EU member states to the European Environment Agency, approximately half of the member states seem to underreport these data. Figure 2 plots the share of new passenger cars equipped with eco-innovations in 2017 by member state. While variations between different markets are common, the range in market penetration, from 0% in eight markets to more than 40% in ten markets, is unlikely to be explained by market modalities alone. Figures presented in this briefing should therefore be seen as a conservative estimate of eco-innovations uptake, but the fleet-average impact would still be negligible—well below 1 g/km.

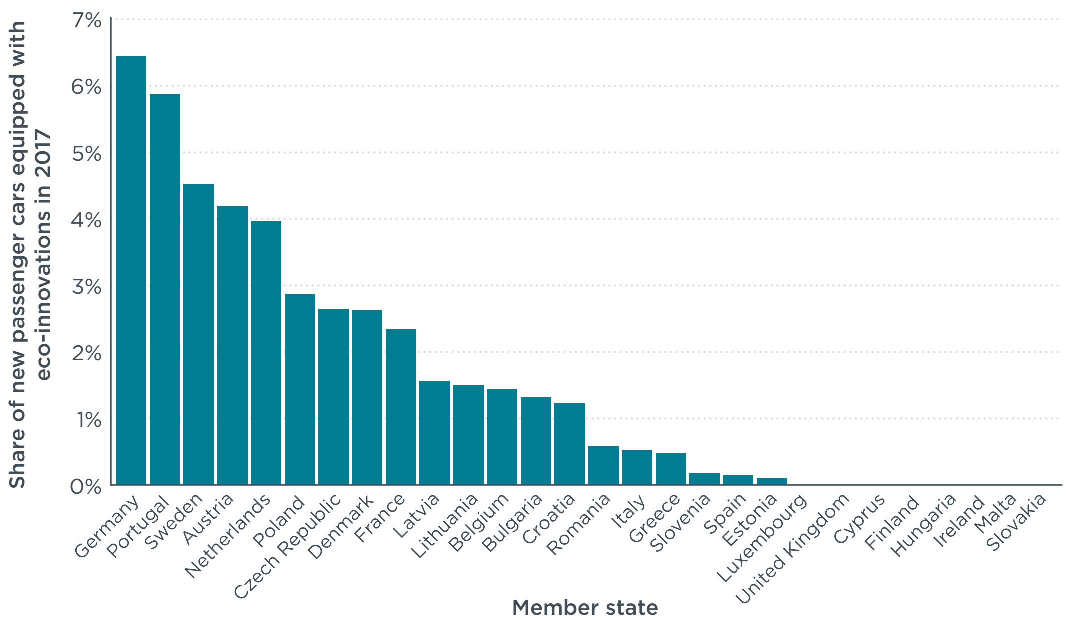

Figure 4. Reported share of new passenger cars equipped with eco-innovations in 2017, by EU member state.

THE FUTURE OF ECO-INNOVATIONS

While eco-innovations had a negligible impact on fleet-average CO_2 emission values up until 2017, Figure 5 shows that select vehicles achieve significant CO_2 savings. The graph plots CO_2 savings from eco-innovations by vehicle brand in 2017. Their impact on brand-average CO_2 emissions was negligible—less than 0.1 g/km in most cases—but the average generally increases by orders of magnitude when filtering for vehicles that have eco-innovation technologies installed. Some individual vehicles exceed 4 g/km of CO_2 savings. The graph also shows that German premium brands are leading the market in eco-innovations: Mercedes-Benz and BMW saw the highest brand-average CO_2 savings, while Porsche saw the highest vehicle-level CO_2 savings. The fact that select brands and vehicles already achieved notable CO_2 savings indicates that eco-innovations could significantly contribute to manufacturers' efforts to meet 2020–2030 CO_2 targets if they are installed in more vehicles in the future.

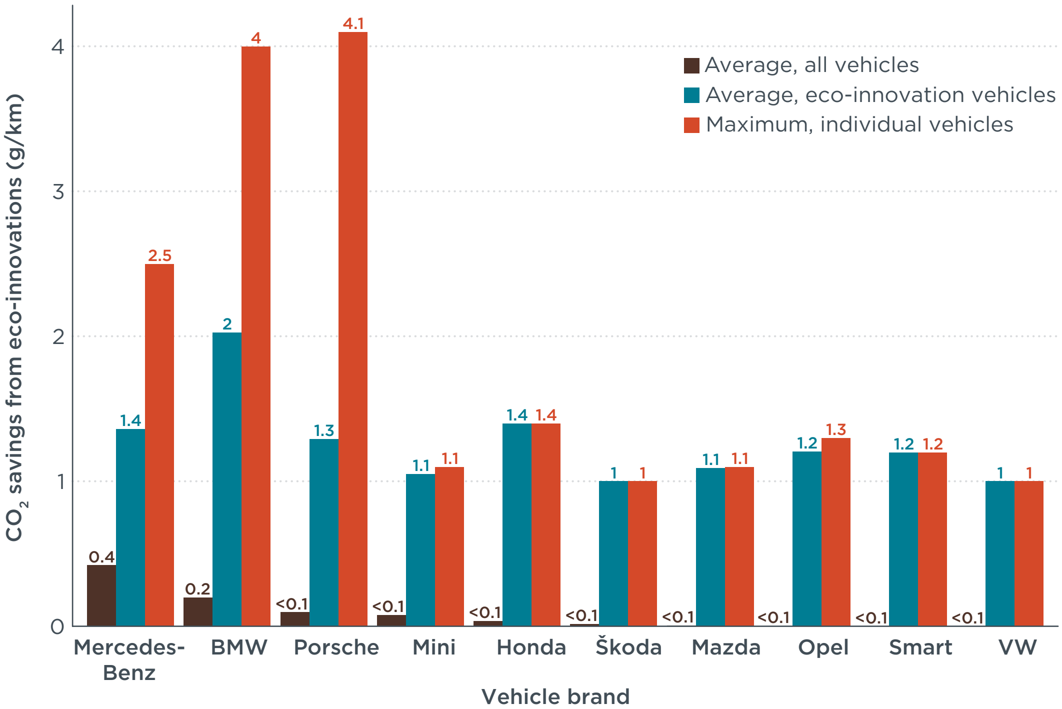

Figure 5. CO_2 savings from eco-innovations by vehicle brand in 2017, sorted by brand-average CO_2 savings.

Low market penetration is the key reason why fleet-average CO_2 savings from eco-innovations were insignificant to date. However, as pressure builds on manufacturers to meet 2020/21 CO_2 targets, eco-innovations are expected to increase in importance.[9] Changes in CO_2 standards and eco-innovations regulations, as well as the sheer breadth of technologies that could qualify as eco-innovations in the future, are expected to help off-cycle technologies gain momentum, as discussed below.

Compared with previous standards, the post-2020 standards proposal suggests altering eligibility criteria, allowing air condition systems to qualify as eco-innovations as of 2025. Because air condition systems are installed in virtually all modern cars, and efficiency

9 European Commission, "Impact Assessment Accompanying the Document Proposal for a Regulation of the European Parliament and of the Council Setting Emission Performance Standards for New Passenger Cars and for New Light Commercial Vehicles as Part of the Union's Integrated Approach to Reduce CO_2 Emissions from Lightduty Vehicles and Amending Regulation (EC) No 715/2007 — Part 1/2" (Brussels: European Commission, November 8, 2017). https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/swd_2017_650_p1_en.pdf.

improvements in those systems could reduce CO_2 emissions by at least 1–2%,[10] this change could significantly contribute to the uptake of eco-innovations. The proposal also suggests reviewing the 7 g/km cap on eco-innovation contributions for compliance purposes as of 2025. These changes could allow eco-innovations to account for a growing share of CO_2 emission reductions.

The regulation governing the approval of eco-innovations was amended in early 2018 in order to accommodate the introduction of the Worldwide Harmonized Light Vehicles Test Procedure (WLTP).[11] Despite its more realistic test procedure, most approved eco-innovations are expected to fall outside the WLTP and would remain eligible as eco-innovations, but the level of CO_2 savings is uncertain.[12] As of March 2018, eco-innovation applications can use the WLTP to measure CO_2 savings. Applicants will be required to use the WLTP starting in 2020, but the NEDC may continue to be used until the end of 2019. How CO_2 savings will be converted from NEDC to WLTP remains uncertain at the time of writing. The amendment also overhauls the innovativeness requirement in an attempt to future-proof the approval procedure: Instead of using 2009 as a baseline for determining whether technologies can be considered innovative, as of 2020 the baseline is defined as 4 years before the year of application. For instance, a technology will be considered innovative in 2020 if it was available in less than 3% of vehicles sold in 2016.

The amended regulation also includes a number of additional changes that incentivize the uptake of eco-innovations:

» The threshold on minimum CO_2 savings was reduced from 1 g/km to 0.5 g/km if savings are measured against the WLTP.
» Component suppliers and vehicle manufacturers applying for eco-innovation credits may propose a simplified measurement method or pre-defined values for CO_2 savings.
» Where technologies produce CO_2 savings independent of vehicle characteristics, component testing—as opposed to vehicle testing—can be conducted to measure CO_2 savings.
» Groups of manufacturers and suppliers can jointly apply for eco-innovations.

There is a large set of technologies that could conceivably yield eco-innovations credits. As part of the technology cost evaluation accompanying the post-2020 proposal, more than 20 potential eco-innovation technologies were considered.[13] Many of these technologies have not yet been approved, indicating that technological opportunities for eco-innovations are far from exhausted.

Combined with the pressure on manufacturers to meet both 2020 and post-2020 CO_2 targets, changes in CO_2 standards and eco-innovations regulations, and the level of untapped technological opportunities, indicate that eco-innovations are likely to gain momentum in the future.

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10 Nikiforos Zacharof et al., "Review of in Use Factors Affecting the Fuel Consumption and CO_2 Emissions of Passenger Cars," JRC Science and Policy Report (Luxembourg: European Commission, 2016). https://doi.org/10.2790/140640.

11 European Commission, "Commission Implementing Regulation (EU) 2018/258 of 21 February 2018—amending Implementing Regulation (EU) No 725/2011 for the Purpose of Adjusting It to the Change in the Regulatory Test Procedure and Simplifying the Administrative Procedures for Application and Certification," February 21, 2018. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R0258.

12 European Commission, "Impact Assessment Accompanying the Document Proposal for a Regulation of the European Parliament and of the Council Setting Emission Performance Standards for New Passenger Cars and for New Light Commercial Vehicles as Part of the Union's Integrated Approach to Reduce CO_2 Emissions from Lightduty Vehicles and Amending Regulation (EC) No 715/2007 — Part 1/2." https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/swd_2017_650_p1_en.pdf

13 See p.25 of Nikolas Hill et al., "Improving Understanding of Technology and Costs for CO_2 Reductions from Cars and LCVs in the Period to 2030 and Development of Cost Curves," Report for DG Climate Action, February 25, 2016, https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ldv_co2_technologies_and_costs_to_2030_en.pdf.

SUMMARY AND RECOMMENDATIONS

While 25 eco-innovations for passenger cars have been approved to date, less than half have made it to market. Fleet-average CO_2 savings from eco-innovations remained low in 2017, at less than 0.04 g/km. This value is likely to underestimate CO_2 savings due to approximately half of EU member states not providing reliable monitoring data on eco-innovations; however, fleet-average CO_2 savings were still likely well below 1 g/km. Nevertheless, select vehicles achieved CO_2 savings upward of 4 g/km, and future CO_2 targets are expected to accelerate eco-innovations uptake. In addition, a recent amendment to the eco-innovation regulation simplifies the process of approving eco-innovations, incentivizing vehicle manufacturers and component suppliers to market more technologies.

Because eco-innovations are expected to have greater significance in future CO_2 standards, it seems prudent to ensure the regulations are immune to manipulation and remain relevant in the future. The experience of the United States shows that off-cycle technologies and related regulations should be closely monitored in order to avoid adverse impacts on fuel efficiency standards.[14] As eco-innovations gain momentum in the EU, technical details in the measurement procedure, particularly pertaining to uncertainties in usage factors, deserve more scrutiny from regulators and researchers alike. Similarly, the methodology for converting CO_2 savings measured by the NEDC to WLTP-measured CO_2 savings has yet to be determined. This could dilute the eco-innovations mechanism if the conversion overestimates the CO_2 savings after the transition. Member states must also ensure that eco-innovations and associated savings are reported to the European Environment Agency—only then can eco-innovations be tracked with certainty.

Although technologies must meet novelty criteria in order to be approved as eco-innovations, there is no mechanism to ensure that the technologies are still innovative when they are sold in new vehicles, potentially many years after approval. Given the rapid pace of technological developments in the vehicle market, it seems prudent to ensure that eco-innovation technologies are not awarded CO_2 savings after they become standard technologies in new vehicles. The design of such a mechanism could be similar to the existing novelty criteria for eco-innovations: Once a certain technology is installed in a sizeable share of new vehicles, the technology could no longer be considered innovative and CO_2 savings from approved eco-innovations would no longer count toward manufacturers' CO_2 targets.

Regulations concerning the approval and certification of eco-innovations include provisions for the European Commission to verify CO_2 savings on an ad hoc basis. If discrepancies are identified, the manufacturer has 60 days to provide evidence that the certified CO_2 savings are accurate; otherwise the CO_2 savings will be disregarded for compliance purposes. This mechanism could be bolstered by regular—rather than ad hoc—verification of certified CO_2 savings and by introducing penalties for exaggerated values.

Eco-innovations affect the achievability and cost-effectiveness of CO_2 standards. By rewarding CO_2 savings outside of type-approval conditions, eco-innovations allow manufacturers to use the most cost-effective real-world fuel efficiency technologies. However, these cost savings were not considered in impact assessments accompanying proposed post-2020 CO_2 standards, unnecessarily inflating estimated compliance costs.

14 Nic Lutsey and Aaron Isenstadt, "How Will Off-Cycle Credits Impact U.S. 2025 Efficiency Standards?" (International Council on Clean Transportation, March 27, 2018). https://www.theicct.org/publications/US-2025-off-cycle.

Lastly, the regulations should balance eco-innovations against the growing gap between real-world and type-approval CO_2 values of European passenger cars. [15] The growing gap calls into question why vehicle manufacturers are rewarded for eco-innovations—technologies that deliver additional real-world CO_2 savings—when the bulk of efficiency technologies appears to have the reverse effect, delivering more CO_2 savings during type approval than during real-world operation. The draft for post-2020 light-duty vehicle CO_2 standards proposes collecting large-scale, real-world fuel consumption data for market surveillance purposes. These data could be used to systematically quantify the gap between real-world and type-approval CO_2 emission values. If the gap increases over time, regulators should lower the 7 g/km cap on CO_2 savings from eco-innovations. The proposal suggests introducing a correction mechanism that would adjust reported CO_2 emission values in case of significant deviations between type-approval and market surveillance measurements.[16] Because this correction mechanism would incentivize manufacturers to market technologies that furnish real-world CO_2 savings, the need for the eco-innovations provision should be re-evaluated once market surveillance data become available.[17]

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15 Uwe Tietge et al., "From Laboratory to Road: A 2017 Update of Official and 'Real-World' Fuel Consumption and CO_2 Values for Passenger Cars in Europe" (The International Council on Clean Transportation, November 5, 2017). http://theicct.org/publications/laboratory-road-2017-update; European Commission Scientific Advice Mechanism, "Closing the Gap between Light-Duty Vehicle Real-World CO_2 Emissions and Laboratory Testing," November 11, 2016. https://ec.europa.eu/research/sam/pdf/sam_co2_emissions_report.pdf.

16 See p. 9 of European Commission, "Proposal for a Regulation of the European Parliament and of the Council Setting Emission Performance Standards for New Passenger Cars and for New Light Commercial Vehicles as Part of the Union's Integrated Approach to Reduce CO_2 Emissions from Light-Duty Vehicles and Amending Regulation (EC) No 715/2007," November 8, 2017. https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/com_2017_676_en.pdf.

17 Jelica Pavlovic et al., "Dealing with the Gap between Type-Approval and In-Use Light Duty Vehicles Fuel Consumption and CO_2 Emissions: Present Situation and Future Perspective," *Transportation Research Record: The Journal of the Transportation Research Board*, March 14, 2018, 036119811875689, https://doi.org/10.1177/0361198118756894.