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Regulate reality in vehicle emission policy

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Check for updates

Vehicle emission standards have long been based on laboratory tests. We argue that policymakers now can and should regulate vehicles also based on real-world data. Europe's performance-based regulation of plug-in hybrid vehicles can help develop more adaptive and evidence-based policies for transportation, energy, and environment.

For decades, vehicle emission regulations have been a cornerstone of air quality and climate policy¹. They have helped cut smog, improve urban health, and stimulate innovation: leading to catalytic converters, cleaner combustion engines, and the growth of electric vehicles². Regulatory frameworks now exist across all major markets, including the EU, U.S., China, India, and Japan³. But the scientific foundations of these regulations are still mostly laboratory tests.

Historically, type-approval procedures have relied on standardized driving cycles performed under controlled conditions (Fig. 1). These tests, such as the New European Driving Cycle (NEDC) and its successor, the Worldwide Harmonized Light Vehicles Test Procedure (WLTP), provide reproducible emissions and fuel consumption figures⁴. Yet they fall short in capturing how vehicles are actually used^{5–7}. Test cycles typically assume mild acceleration, flat terrain, and consistent ambient conditions, assumptions that rarely match the variability of real-world driving.

As a result, type-approval values systematically underestimate actual emissions. In Europe, real-world CO₂ emissions of combustion engine vehicles are on average 40% higher than New-European-Driving-Cycle values, 20% higher than those according to the Worldwide Harmonized Light Vehicles Test Procedure, and even 300–500% higher for plug-in hybrid electric vehicles. These gaps distort vehicle design and supply, undermine policy credibility and delay climate progress^{8,9}.

Regulators now have better tools and better data than ever before, and reliance solely on laboratory tests is no longer acceptable. A transition to real-world regulation will be complex but also transformative. We argue that a fundamental shift is both feasible and necessary: regulation of laboratory performance must be turned into regulation of real-world emissions.

Better data are available

For the first time in emission regulation history, policymakers are beginning to have the data infrastructure to regulate real-world emissions. Since 2021, the European Union has mandated all new cars to record real-world fuel consumption via On-Board Fuel Consumption Monitoring systems. More than 6.5 million vehicles are now reporting annual data, enabling comprehensive insights into fleet-level emissions under actual usage patterns¹⁰. In California, the Bureau of Automotive Repair has been collecting data via the On-Board Diagnostic that monitors emission control system components since 2000¹¹. These and similar sources are used primarily to update regulatory requirements, but they also create the foundation for a regulatory

paradigm shift towards observed performance, instead of idealized lab conditions.

This shift is not without precedent. In response to the diesel emissions scandal, European regulators introduced Real Driving Emissions (RDE) tests for nitrogen oxides (NO_x), using mobile measurement devices attached to cars during on-road trips¹². The Real Driving Emissions protocol revealed just how far off laboratory figures had been and forced manufacturers to cut real-world NO_x emissions from diesel vehicles significantly. The integration of RDE into formal compliance procedures demonstrated that real-world regulation works and leads to measurable air quality improvements.

Towards performance-based regulation

In fact, regulation of real-world vehicle emissions would be the natural next step towards applying performance-based regulations to vehicle emissions. Performance-based regulation itself is a long-standing concept in environmental policy regulating utilities, buildings, factory emissions but also nuclear and traffic safety¹³. Performance-based regulation focuses on achieving measurable, real-world outcomes rather than prescribing specific processes or test procedures¹⁴. It allows innovative designs that meet standards without mandating specific methods.

The core principle is simple: define clear performance targets and allow regulated entities flexibility in how they achieve them. This approach encourages innovation, improves cost-effectiveness, and focuses oversight on demonstrable results rather than procedural compliance. However, it also demands robust measurement systems, transparent data governance, and sophisticated monitoring capabilities to verify that intended outcomes are indeed achieved.

The case of plug-in hybrid electric vehicles

Plug-in hybrid electric vehicles are a compelling case for why performance-based policies that are based on real-world data are urgently needed. These vehicles combine an electric drivetrain with a combustion engine and rely heavily on usage behavior. Laboratory cycles assume daily charging and short trips, which results in low official CO₂ values. But most drivers do not charge daily, and many travel longer distances. As a result, average real-world fuel consumption is several times higher than reported through the Worldwide Harmonized Light Vehicles Test Procedure¹⁵. This discrepancy creates a policy blind spot: vehicles often appear cleaner and more efficient in regulation than they really are. Data gathering and analysis by researchers and non-governmental organizations has been slow, limited by budget and data sharing regulations. These efforts have produced useful updates but rarely led to large-scale action.

This is now changing. The European Commission is using on-board fuel consumption monitoring data in 2025 to adjust how plug-in hybrid electric vehicles count toward manufacturers' fleet CO₂ targets¹⁶. Real-world usage patterns collected from the entire fleet of plug-in hybrid electric vehicles sold, such as electric driving share, will be used to weight each vehicle's emissions contribution.

The inclusion of real-world data marks a historic move in emission regulation: observed data from everyday driving will directly influence regulatory compliance in a major emissions policy framework. A similar

public trust, policy integrity, and climate progress, it is time to regulate what happens on the road.

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References

1. Beaton, S. P. et al. On-road vehicle emissions: regulations, costs, and benefits. *Science* **268**, 991–993 (1995).
2. Wallington, T. J., Anderson, J. E., Dolan, R. H. & Winkler, S. L. Vehicle emissions and urban air quality: 60 years of progress. *Atmosphere* **13**, 650 (2022).
3. Singh, S. et al. An overview of vehicular emission standards. *Mapan* **38**, 241–263 (2023).
4. Tsiakmakis, S. et al. *From NEDC to WLTP: Effect on the Type-Approval CO2 Emissions of Light-Duty Vehicles* Vol. 50 (Publications Office of the European Union, 2017).
5. Dornoff, J., Tietge, U. & Mock, P. *On the Way to "real-world" CO2 Values: The European passenger car market in its first year after introducing the WLTP*. ICCT White paper 2024, <https://theicct.org/publication/real-world-CO2-emission-values-vehicles-Europe-jan24/> (2020).
6. Zhang, L., Hu, X., Qiu, R. & Lin, J. Comparison of real-world emissions of LDGVs of different vehicle emission standards on both mountainous and level roads in China. *Transportation Research Part D: Transport and Environment* **69**, 24–39 (2019).
7. Pathak, S. K., Sood, V., Singh, Y. & Channiwala, S. A. Real-world vehicle emissions: their correlation with driving parameters. *Transportation Research Part D: Transport and Environment* **44**, 157–176 (2016).
8. Ntziachristos, L. et al. In-use vs. type-approval fuel consumption of current passenger cars in Europe. *Energy Policy* **67**, 403–411 (2014).
9. Aksen, J., Plötz, P. & Wolinetz, M. Crafting strong, integrated policy mixes for deep CO2 mitigation in road transport. *Nat. Clim. Chang.* **10**, 809–818 (2020).
10. EEA: Real-world emissions. Data. <https://climate-energy.eea.europa.eu/topics/transport/real-world-emissions/data> (2025).
11. California Air Resources Board: OBD II Regulations and Rulemaking, <https://ww2.arb.ca.gov/resources/documents/obd-ii-regulations-and-rulemaking> (2025).
12. European Commission: Testing of emissions from cars. https://ec.europa.eu/commission/presscorner/detail/da/memo_18_3646 (2018).
13. Coglianese, C., Nash, J. & Olmstead, T. Performance-based regulation: prospects and limitations in health, safety, and environmental protection. *Admin. L. Rev.* **55**, 705 (2003).
14. Coglianese, C., Bignami, J. B., Keleman, D., Levi-Faur, D. & Zaring, D. Performance-based regulation: concepts and challenges. *Comparative law and regulation: understanding the global regulatory process*, 403. <http://onlinepubs.trb.org/onlinepubs/PBRLit/Coglianese3.pdf> (2016).
15. Plötz, P., Moll, C., Bieker, G. & Mock, P. From lab-to-road: Real-world fuel consumption and CO2 emissions of plug-in hybrid electric vehicles. *Environ. Res. Lett.* **16**, 054078 (2021).
16. Commission Regulation (EU) 2023/443 of 8 February 2023 amending Regulation (EU) 2017/1151.
17. California Air Resources Board: Advanced Clean Cars II Amendments – Second Public Workshop, June 26, 2024. https://ww2.arb.ca.gov/sites/default/files/2024-06/2024_06_26_ACC%20II%20Amendments%20Workshop%20Presentation_ADA.pdf#page=1.00 (2024).

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