



RECOMMENDATIONS FOR INCENTIVE SCHEMES WP5, TASK 5.3

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AUTHOR(S):

Lars Christian Larsen (VERT), Dr. Martin Lehmann (M+H)

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TABLE OF CONTENTS

1. INTRODUCTION	8
1.1. CONTRIBUTIONS OF PARTNERS	8
2. OBJECTIVES AND EXPECTED IMPACT	9
3. DESCRIPTION OF TECHNICAL/SCIENTIFIC ACTIVITIES	9
4. RESULTS AND DISCUSSION	10
4.1. SUMMARIZED RECOMMENDATIONS	11
5. DEVIATIONS FROM THE PLAN	11
6. LINKS WITH OTHER WPS	11
7. CONCLUSIONS	12
8. BIBLIOGRAPHY	12

LIST OF TABLES

Table 1 Contributions of partners	8
Table 2 Summary of recommendations for the different AeroSolfd Solutions	12



LIST OF ABBREVIATIONS

ACRONYM	DESCRIPTION
PN	Particle number
WP1-3	Work packages in the Aerosolfd project
UFP	Ultra Fine Particles
PM	Particle Mass
TRL	Technology Readiness Level
ETH	Eidgenössiges Technische Hochschule
GPF	Gasoline Particle Filter
DI	Direct Injection
PFI	Portfuel Injection
KBA	Kraftfahrt Bundesamt, Germany
LEZ	Low Emissions Zone
DirtyTail	Phenomena identified by VERT
TTG	Typeteilegenehemigung
DPN	Diesel Particle Number
RPM	Rounds per minute
BAT	Best Available Technology
ESG	Environmental Social Governance
VERT	Verification of Emission Reduction Technologies
M+H	MANN + HUMMEL



PUBLISHABLE SUMMARY

AeroSolfd retrofit solutions—including gasoline particle filters (GPFs), brake dust particle filter, and stationary air purifier—offer a technically mature, economically efficient pathway to reduce harmful particle number (PN) emissions in urban and enclosed environments.

Recent findings presented by Dr. A. Mayer at the 2025 ETH Nanoparticle Conference (Mayer 2025) demonstrate that targeting the top 10% of high-PN-emitting gasoline vehicles could yield a benefit–cost ratio of 1:12, when accounting for avoided health costs and mortality. These figures confirm the economic rationale for retrofit incentives when integrated into PN-based inspection frameworks.

Furthermore, AeroSolfd’s D4.1 Sustainability Framework underscores how PN-focused retrofit deployment also supports wider ESG goals, including improved air quality, social equity, and green job creation. These benefits justify public investment and regulatory support to ensure rapid and fair market adoption.

The AeroSolfd project explores retrofit solutions aimed at reducing tailpipe and non-tailpipe particle number (PN) emissions in urban and semi-enclosed environments. Of its seven Work Packages, Work Packages 1 to 3 focus specifically on technological interventions for PN emission reduction: WP1 targets tailpipe PN emissions via retrofitted gasoline particle filters (GPFs); WP2 addresses brake wear PN emissions from trucks and trains through capture-at-source technologies; and WP3 introduces filtration systems to reduce airborne PN in underground and semi-enclosed public transport infrastructure. These solutions target existing vehicles and installations, complementing OEM systems without competing with them. This document presents the policy context, supporting evidence, and incentive mechanisms necessary to commercialise tail pipe retrofit only but can be used as a template to expand to WP2 and WP3 after completion of the AeroSolfd project.

1. INTRODUCTION

The AeroSolfd project explores retrofit solutions aimed at reducing non-tailpipe and tailpipe emissions in urban and semi-enclosed environments. Of its seven Work Packages, Work Packages 1 to 3 focus specifically on technological interventions for emission reduction: WP1 targets tailpipe emissions via retrofitted gasoline particle filters (GPFs); WP2 addresses brake wear particle emissions from trucks and trains through capture-at-source technologies; and WP3 introduces filtration systems for underground and semi-enclosed public transport infrastructure. These solutions target existing vehicles and installations, complementing OEM systems without competing with them. This document presents the policy context, supporting evidence, and incentive mechanisms necessary to commercialise these technologies across Europe.

Particle number (PN) emissions, particularly ultrafine particles (UFPs), remain a critical health risk, especially in urban environments and enclosed transport settings. While particulate matter (PM) remains a regulated metric, scientific and regulatory consensus increasingly emphasises PN due to its relevance to health and its ability to reflect real-world emission behaviours more accurately. The AeroSolfd project delivers retrofit technologies with high technical readiness (TRL 8), targeting these previously non-regulated PN sources. These solutions can be deployed immediately in the field, complementing existing vehicle fleets and infrastructure. The following sections elaborate on each solution’s function, demonstrated performance, and necessary regulatory and financial incentives to achieve broad uptake. The findings are based on AeroSolfd field demonstrations, scientific assessments, policy feedback, and stakeholder consultations, from the ETH Zurich Focus Group (June 2023).

1.1. CONTRIBUTIONS OF PARTNERS

The main contributing partner of this Deliverable are VERT and M+H. All contributions are listed in Table 1

Table 1 Contributions of partners

PARTNER SHORT NAME	CONTRIBUTIONS
M+H	Representing WP2 and WP3 retrofit product
Steinbeis	Steinbeis to support the document content in context of WP5
VERT	Representing WP1 retrofit product and technology

2. OBJECTIVES AND EXPECTED IMPACT

The objective of this deliverable is to develop recommendation for incentive schemes for adopting retrofit solutions. As the products and technology demonstrated in AeroSolfd do not have obvious benefits to the individual consumer the expected impact of this Deliverable is to establish a tool for policymakers to implement the right measures to adopt retrofit solutions into the market. This is explained in detail for WP1 tailpipe retrofit particle filter and serves as example for the other solutions. Further steps towards exploitation are elaborated in Deliverable D5.6 for each AeroSolfd solution. Measures can be regulation with or without financial support/subsidies.

3. DESCRIPTION OF TECHNICAL/SCIENTIFIC ACTIVITIES

The tailpipe retrofit gasoline particle filter has been selected as example for the AeroSolfd solutions and recommendations have been derived based on this application. This solution offers the advantage of building up on experience with retrofit solutions for diesel engines which serve as lessons learned.

WP1 addresses PN emissions from older gasoline vehicles that lack OEM filtration systems and are disproportionately responsible for ultrafine PN pollution (AeroSolfd Teilbericht¹ 4.2 & 4.3). The solution developed under AeroSolfd is a retrofit gasoline particle filter (GPF) designed to be installed on vehicles with direct Injection (DI) and port fuel injection (PFI) engines that otherwise meet Euro 3–6 emission standards but emit high PN levels. (AeroSolfd Teilbericht TR4.4) Both in a compliant and non-compliant condition. The product is modular, uses wall-flow filter technology similar like OEM systems applied for Euro6d, but without catalytic coating. Regeneration has been proven to work by natural oxidation during normal operation. It is supplied as a complete retrofit kit, including mounting hardware and backpressure monitoring. The system has been independently tested and TTG type-approved by KBA, showing >99% efficiency across a broad PN spectrum.

This plug-and-play solution can be installed within 1–2 hours by a certified workshop and includes electronic traceability for inspection. Field testing confirmed effectiveness under transient urban driving. It is intended for deployment in urban LEZs or where in-service compliance and or Dirtytail mitigation requires PN control.

In the AeroSolfd Deliverable D1.6 a detailed report is included on large-scale PN screening methodology through a test conducted by TCS in Switzerland: Technical Inspection (NPTI) initiative. Over 1,000 gasoline vehicles were measured using AVL DiTest PN-counters during real inspection workflows. The results demonstrated a highly skewed emission distribution: the top 5-10% of vehicles were responsible for 90-95% of PN emissions. (AeroSolfd Teilberich 4.3). On the contrary, vehicles equipped with GPFs showed emissions in some cases below ambient levels, validating both the efficiency and the need for retrofit solutions.

The NPTI tests involved standardised measurement at 2500 rpm under two load conditions, with adjustment for ambient PN background. The use of metrics like the corrected PN flow rate (DPN) and the pollution ratio (vg) helped characterise high emitters robustly. The ETH Zürich Focus Group and

¹ Teilbericht is a series Reports used by VERT in The AeroSolfd project to compile Deliverables

Swiss authorities endorsed this method as a foundation for future regulation and inspection-linked retrofit enforcement, and it has been partly introduced in Belgium and the Netherlands.

4. RESULTS AND DISCUSSION

By anchoring retrofit innovation in PN compliance and evidence-based inspection, AeroSolfd technologies can deliver tangible air quality benefits across Europe's most pollution-exposed environments. Dr. A. Mayer's 2025 benefit–cost analysis, presented at the ETH Nanoparticle [\[12\]](#), quantified the economic efficiency of GPF retrofits in older gasoline vehicles. His findings showed that targeting the top 10% of emitters (Dirtytail) could yield a cost-to-benefit ratio of 1:12 when factoring in avoided health impacts, hospitalisations, and mortality. This reinforces the case for prioritising retrofit investment through regulatory and funding frameworks, especially when guided by accurate PN inspection implementation and data.

The AeroSolfd Deliverable (D4.1) Sustainability Framework offers further context for the strategic role of incentives, especially as retrofit technologies align with broader environmental, social, and governance (ESG) principles. The framework proposes that effective retrofit uptake can support not only emission reduction targets but also enhance local air quality, reduce health-related inequalities, and stimulate green jobs. By quantifying sustainability gains across environmental and social dimensions, this document reinforces the value of embedding AeroSolfd solutions in integrated climate, health, and equity policies.

Incentive schemes have been proposed in various forms and structures all with the purpose of promoting retrofit on mobile and stationary heavy duty diesel engine applications locally in bigger cities, regionally or countrywide. All incentive schemes structured under the assumption that every operator and vehicle owners would not retrofit such a product/technology without some sort of direct or indirect compensation. Compensation being direct financial support to the purchase and installation and/or different discounts in road tax, geographical accessibility (environmental/congestion zones), or other rebates. For public services, typically bus routes, the compensation has been different premium payments and/or pre-conditions for bidding the tender.

Incentive schemes have been financially covering from 10 to almost 100% of the investment (in Europe limited by the de-minimis rule) but very few schemes have supported the required service and maintenance of such systems. Financial incentive schemes can often lead to unnecessary speculation and cost structures on the supply side that is not governed by normal competition and market forces and is not in the interest of the customer. In all programs the compensation has been carefully structured to mitigate claims of unfair competition among and between operators and industries, cost effectiveness/profitability of operation, and the political ambition of improving air quality and at the same time guarantee highest emission reduction quality by certification according to the widely accepted VERT-defined BAT and periodic technical inspection PTI.

Obvious advantages of incentive schemes are that it can reduce the political cost of demanding retrospective compliance, meaning improving older vehicles to a newer standard, by compensating the owner if the upgrade/retrofit is applied. In theory nobody would do so without the compensation, so the economic deadweight loss is almost zero. The next challenge is, at what level the financial

compensation must reach to achieve adequate commercialization in numbers, so the overall target of improved air quality is measurable and in line with the goals.

The alternative is regulation that prevent non-compliant vehicles to operate. Although this is a more complex task as it has often been difficult to combine with the regulation of emission levels for new vehicles, it proved to be much more successful as VERT projects for Switzerland, Israel, Iran and Chile and mining applications show (Rubino et. Al).

As improvements in air quality (PN, black carbon, nanoparticles and NOx) and improvement in human health as well as strong contribution to global warming mitigation is a political responsibility, it is the AeroSolfd project's general recommendation that incentive schemes shall not be only financial either directly or indirectly and must be governed by mandatory regulation (AeroSolfd Response).

4.1.SUMMARIZED RECOMMENDATIONS

- Establish EU and national regulatory frameworks mandating PN-based compliance and retrofit enforcement.
- Enabling cities to implement regulations targeting on realizing the positive ES-LCA effects of the AeroSolfd solutions. (Aerosolfd Teilbericht 9.1)
- Secure stable funding through green mobility, health, and air quality instruments specifically targeting PN reduction.
- Ensure institutional uptake through ESG criteria and green procurement aligned with PN-reduction targets.
- Combine regulation with short-term financial support to enable transition and scale.
- Deploy awareness and engagement programs to educate operators and citizens on PN impacts.
- Utilise AeroSolfd data and validation tools in EU consultations and climate/health frameworks.
- Roll out NPTI schemes with affordable PN sensors and link them to mandatory retrofit action.
- Define and adopt harmonised PN testing protocols, including calibration, background correction, and fuel-specific considerations, to ensure cross-border consistency and credibility.
- Pilot PN-based policies in early-adopter cities and elevate successful models to UNECE and EU platforms.

5. DEVIATIONS FROM THE PLAN

No observed deviation except for timing delay

6. LINKS WITH OTHER WPS

Linked with WP1, WP2, WP3 and WP4



7. CONCLUSIONS

A combined incentive strategy is recommended based on the totality of evidence presented in this document and summarized in Table 2 :

Regulation is imperative, especially for WP1 and WP2. The ETH Zurich Focus Group, TR-4.3 analysis, and multiple SAE and VERT presentations stress that without mandatory inspection regimes and retrofit obligations—particularly for high-emitting gasoline vehicles—market penetration of GPFs will remain limited.

Funding mechanisms are necessary but transitional, supporting adoption in the early market phase, particularly for WP2 (brake systems) and WP3 (air purification in semi-enclosed spaces). These should focus on health co-benefits, ESG compliance, and infrastructure investment.

Table 2 Summary of recommendations for the different AeroSolfd Solutions

Work Package Product	Funding	Regulation	Combination
WP 1 Tail pipe retrofit	(for pilot cases only)	Highly recommended	Not Recommended
WP2 Brake Dust	Recommended	Highly recommended	Highly recommended
WP3 Semi-closed Env	Highly recommended	Highly recommended	Highly recommended

The clear recommendation is:

Regulation first, funding to accelerate. This ensures that retrofit solutions are deployed where they are most needed, without waiting for full market readiness or voluntary uptake.

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