SUSTAINABILITY FRAMEWORK, INFORMATION REQUIREMENTS AND DATA COLLECTION PLAN

WP4, TASK 4.1

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Work Package Lead	NFA
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DoA	The framework and key assessment projects to be included for the overall retrofit sustainability assessment in Task 4.4 will be identified in close collaboration with the product manufacturers in WP1-WP3 and WP5. A phase-gate innovation risk governance framework considering sustainability, safety-by-design through the production and product life-cycle developed in the EU H2020 caLIBRAte project and recognized by the EU innovation radar combined with a specific framework for the automotive industry will be used as a starting point for the sustainability framework. The analysis will cover a 360° evaluation of each product

line to identify assessment areas to be covered besides the pre-identified topics: technical performance, production safety and circularity, regulatory compliance, exposure and risk-benefits for workers, passengers and general public health as well as the environmental, economic and market, societal and ethical drivers and barriers. The specific methods and data required to make the framework assessments will be identified including standard information requirements to complete and lifecycle analysis (LCA) by the GaBi software and a data collection plan will be established. Phase-gate "go", "rework" and "stop" criteria will be developed considering confidence and threshold values for acceptance in collaboration with the innovation leaders and relevant stakeholders to ensure a participatory process

DATE	VERSION	AUTHOR	COMMENT
29/07/2022	0.1	Keld Alstrup Jensen	First draft of deliverable v. 0.1 with list of content shared for comments and written partner contributions
13/04/2023	1.0	Biase Liguori	Version 1.0 circulation of elaborated deliverable with request for further written partner contributions
21/09/2023	1.1	Biase Liguori	Version 1.1 with all primary author contributions on LCA, SLCA, and risk scoping results circulated for internal review and additional input
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28/10/2023	3.2	Keld Alstrup Jensen	Version 3.2 with updated risk scoping score plots after validation with WP1, 2, and 3 and associated text; data collection plan, and finalization and content review.
29/10/2023	3.3	Biase Liguori	Version 3.3. Final revision; Submitted to project office for review and approval.
30/11/2023	3.4	Biase Liguori	Version 3.4. Revised version; based on the project officer request.

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TABLE OF CONTENTS

1. INTRODUCTION 9
1.1. PURPOSE AND TARGET GROUP 9
1.2. CONTRIBUTIONS OF PARTNERS 9
2. OBJECTIVES AND EXPECTED IMPACT 10
2.1. OBJECTIVES 11
2.2. EXPECTED IMPACT 11
3. DESCRIPTION OF TECHNICAL/SCIENTIFIC ACTIVITIES 11
4. RISK ASSESSMENT ALONG THE LIFE CYCLE 13
4.1. RISK SCOPING 13
4.1.1. TAILPIPE FILTER 13
4.1.2. BRAKE DUST FILTER 18
4.1.3. FILTER SQUARES 21
4.2. HUMAN RISK ASSESSMENT METHODS 24
4.2.1. EXPOSURE ASSESSMENT 24
4.2.2. HAZARD ASSESSMENT 25
4.2.3. RISK ASSESSMENT 26
4.3. ENVIRONMENTAL RISK ASSESSMENT METHODS ALONG THE LIFE CYCLE 26
4.4. FORESEEN INFORMATION REQUIREMENTS AND DATA COLLECTION PLAN 26
5. ENVIRONMENTAL LIFECYCLE ASSESSMENT 28
5.1. METHODOLOGY USED IN AEROSOLFD 28
5.2. FORESEEN INFORMATION REQUIREMENTS AND DATA COLLECTION PLAN 30
6. SOCIAL LIFECYCLE ASSESSMENT 33
6.1. METHODOLOGY USED IN AEROSOLFD 33
6.2. FORESEEN INFORMATION REQUIREMENTS AND DATA COLLECTION PLAN 39
7. OVERALL SUSTAINABILITY ASSESSMENT 41
7.1. UN SUSTAINABILITY GOALS AND RELEVANT SUSTAINABILITY FRAMEWORKS 41
7.2. OVERALL SUSTAINABILITY FRAMEWORK FOR AEROSOLFD 42
7.2.1. ENVIRONMENTAL IMPACT ON HISTORICAL BUILDINGS 45
7.3. DATA COLLECTION PLAN FOR OVERALL SUSTAINABILITY ASSESSMENTY 48
8. DEVIATIONS FROM THE PLAN 58
9. LINKS WITH OTHER WPS 58

10. CONCLUSIONS AND RECOMMENDATIONS ... 59
12. BIBLIOGRAPHY ... 60
13. ANNEX ... 62
BILL OF MATERIALS (BOM) ... 62
PROCESSES INVENTORY ... 63
THE CRITICAL ANALYSIS OF THE HOTSPOTS ... 64
PERCENTAGE OF SUPPLIERS THE ENTERPRISE HAS AUDITED WITH REGARD TO THE ELEMENTS IN TOR, AND COMPLIANCE LEVELS? ... 65
UN SDGS INDICATORS AND TARGETS IN AEROSOLFD ... 80
SUSTAINABILITY FRAMEWORK OVERVIEW ... 86

LIST OF TABLES

Table 1 Overview of the partner contributions for completion of D4.1 ... 10
Table 2 Stakeholders to be considered during the Social Impact Assessment ... 34
Table 3 List of possible social impacts ... 36
Table 4 Evaluation of Impacts ... 37
Table 5 TAILPIPE data collection plan ... 49
Table 6 BRAKE DUST FILTER data collection plan ... 51
Table 7 FILTER SQUARES data collection plan ... 54

LIST OF FIGURES

Figure 1. Link between D4.1 and activities in WP4. ... 9

Figure 2 LCRS scores of the potential exposure during the different steps along the LC of the tailpipe filter solution considering: a) workers; b) the public; c) ambient air; d) waters; and d) soil. The squared symbols in c, d, and e provides the overall median ... 17

Figure 3 LCRS scores of the potential exposure during the different steps along the LC of the brake wear filter solution considering: a) workers; b) the public; c) ambient air; d) waters; and d) soil. The squared symbols in c, d, and e provides the overall media ... 21

Figure 4 LCRS scores of the potential exposure during the different steps along the LC of the area air-filtration solution considering: a) workers; b) the public; c) ambient air; d) waters; and d) soil. The squared symbols in c, d, and e provides the overall med... 24

Figure 5 The main phases of an LCA 28
Figure 6 the life cycle phases 29
Figure 7 an example of the value-corrected substitution method 31
Figure 8 Social Life Cycle Impact Assessment Framework 33
Figure 9 Groups that shall be screened for identifying stakeholders 34
Figure 10 Assessment system from categories to unit of measurement. Adapted from Benoit et al., 2007 40
Figure 11 Sketch representing the conceptual framework approach 41
Figure 12 the sustainability impact dimension and UNSDGs in AeroSolfd 42
Figure 13 conceptual framework for the sustainability assessment in AeroSolfd 44
Figure 14 conceptual strategy for the overall sustainability framework and process for identification of information requirements 47

LIST OF ABBREVIATIONS

ACRONYM	DESCRIPTION
LC	Life Cycle
RA	Risk Assessment
LCRA	Risk Assessment along the Life Cycle
LCRS	Risk Scoping along the Life Cycle
HRA	Human Risk Assessment
ERA	Environmental Risk Assessment
LCA	Life Cycle Assessment
S-LCA	Social Life Cycle Assessment

PUBLISHABLE SUMMARY

The objective of this work was to define the framework for retrofit sustainability assessment and data requirements and data collection plan for each of the AeroSolfd retrofit solutions.

The sustainability framework was built round-table consultations within the WP4 partners engaged, namely: M+H, IUTA, CSIC, NFA, CENEX, VERT, INTEC, starting from a conceptual (top-down approach) framework which was further refined based on each of the retrofit case-specific scenarios (bottom-up approach) and risk scoping analysis (preliminary risk assessment along the value chain).

Hence the framework was tailored to the AeroSolfd solutions, the data requirements were identify and the data collection plan, for the overall sustainability assessment, was developed.

A combination of qualitative and quantities data will be collected (measured, literature review, derived, or modelled) as well as read-across information, due to the innovation stage and practical limitations, will be identified to map the entire value chain for each the AeroSolfd retrofit solutions.

1. INTRODUCTION

The final aim of AeroSolfd WP4 is to develop an (overall) sustainability assessment of the retrofit solutions implemented and applied for the tailpipe, brake systems and closed environments product line. A pre-requisite for reaching this objective is establishment of a framework that allows the overall sustainability assessment including the types of methods and data needs.

1.1. PURPOSE AND TARGET GROUP

The purpose of D4.1 is to establish the overall approach and identify the data needs and data collection plan (including knowledge gaps and potential priorities for measurements) for the overall sustainability assessment to be conducted for each of the three retrofit solutions. Each of the overall sustainability assessments involves a human (worker and public) risk assessment for relevant priority risks identified along the products' life-cycle, an LCA (environmental life-cycle assessment), an S-LCA (social life-cycle assessment).

The intended target groups are:

1) The project itself to establish the framework for the prospective analysis and identify the data needs and data collection strategy for WP4 Task 4.2, Task 4.3 and Task 4.4. This is illustrated in the Figure below.
2) External stakeholders interested in risk assessment, LCA, S-LCA, and overall sustainability analysis of innovations in the area of retrofit solutions to reduce traffic-induced air-pollution from petrol cars, brakes and public transport, such as metro's.

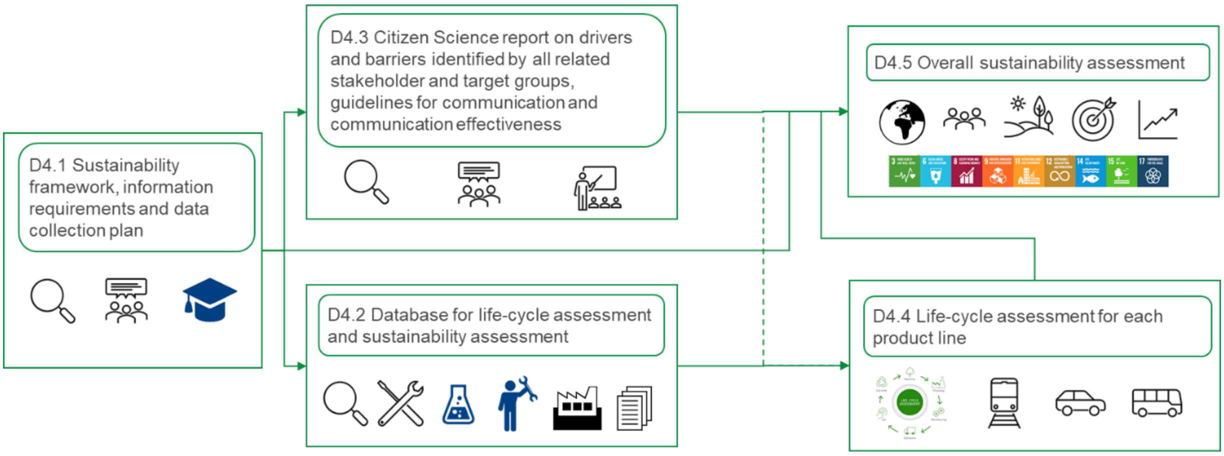


Figure 1. Link between D4.1 and later deliverables in WP4 ending with the life-cycle analysis and overall sustainability assessment.

The process in Task 4.1 and D4.1 also includes a first sustainability awareness raising among the innovators where early-phase interventions to improve safety and sustainability could be made.

1.2. CONTRIBUTIONS OF PARTNERS

The partner contributions for completion of D4.1 are summarized in Table 1.

Table 1 Overview of the partner contributions for completion of D4.1

PARTNER SHORT NAME	CONTRIBUTIONS
NFA	Led task 4.1 and D4.1. NFA developed the risk scoping approach and risk scoping analysis, conceptualization and finalization of the sustainability interim and final framework for each of the retrofit solution and their risk assessment approach and the data collection plan. NFA drafted chapter 1,2,3,7, and 8 and the final overall revision of the deliverable.
IUTA	Reviewed and updated the environmental risk scoping and risk assessment approach and reviewed the deliverable.
CENEX	Contributed to development of the overall sustainability framework and in particular led description of the LCA model, drafting of chapter 5 on LCA and identification of relevant data needs and reviewed the deliverable.
INTEC	Contributed to development of the overall sustainability framework and in particular development and description of the S-LCA model, drafting of the chapter 6 on the S-LCA and identification of relevant data needs and reviewed the deliverable.
MANN+HUMMEL	Contributed with information and exchange for risk scoping of the brake-dust filter (WP2) and filter squares (WP3) retrofit solutions and reviewed the deliverable.
VERT	Contributed with information and exchange for risk scoping of the retrofit gasoline particle filter (WP1) and reviewed the deliverable.
CSIC	Contributed to the data collection plan and reviewed the deliverable.

2. OBJECTIVES AND EXPECTED IMPACT

The aim of this task is to establish the overall AeroSolfd sustainability framework building on and merging the applicable concepts for Risk Assessment, Life Cycle Assessment (LCA), and Social Life Cycle Assessment (S-LCA) and identify the related information requirement and data collection plan for each of the assessment procedures. The final different assessment procedure needs are tailored to suite each of the three retrofit solutions in the project.

The starting point for development of the overall sustainability framework was considered to build on the stage-gate nano-risk innovation governance framework, developed in the EU H2020 caLIBRAte and Gov4Nano projects and combine it with the sustainability framework developed for the automotive industry (Jasinsky et al., 2016). The stage-gate innovation governance model combines a Cooper-like Stage-Gate innovation funnel model with specific risk specific risk governance including human and environmental risk assessment developing along the innovation stages. The risk governance approach aligns with the ISO 21505 Risk governance framework while all the specific assessments approaches can align with all different relevant standards.

This governance framework is further revised considering how the expected outcome of AeroSolfd project could contribute to the UN Sustainable Development Goals (SDG) and support the ambitions in the Chemicals Strategy for Sustainability (CSS, 2020) and the European Green Deal (2021).

Since the proposal was submitted, several potentially relevant new policy ambitions have been published that need consideration in our final framework and analysis. These include: Zero Pollution Action Plan; Circular Economy Action Plan; EU's 2030 Climate Target on the way to climate neutrality; Materials 2030 Manifesto; Advanced Materials Initiative 2030 (AMI2030); Strategic Research and Innovation Plan for safe and sustainable Chemicals and Materials.

2.1.OBJECTIVES

For each retrofit solution, the objectives are to:

- Establish of the overall sustainability assessment framework indicators and midpoints to contribute the specific endpoints (UN SDG).
- Establish the human risk assessment approach(es) to address worker and public health impacts.
- Establish the environmental risk assessment approach(es) to address the impact on air, soil and water.
- Establish and detail the life cycle assessment model to be applied for environmental LCA.
- Establish and detail the life cycle assessment model to be applied for S-LCA
- Identify the overall data needs and data collection plan to conduct the above-mentioned assessments.

2.2.EXPECTED IMPACT

A state-of-the art framework for overall sustainability assessment for petrol car exhaust and brake-wear particle filters as well as area filtration devices based on risk assessment, life-cycle assessment, social life-cycle assessment as stand-alone input. It is anticipated that, when complete and demonstrated, the developed framework can serve as an approach for future improved sustainability assessments of retrofit solutions relevant for improving quality of life by reduced air-pollution.

3. DESCRIPTION OF TECHNICAL/SCIENTIFIC ACTIVITIES

Starting from the preliminary overarching risk innovation governance framework from the EU H2020 caLIBRAte (tool-supported nano-risk innovation governance framework), Gov4Nano (further developed nano-risk innovation governance framework) and the automotive sustainability framework from Jasinsky et al. (2016); and identified SDG as reference endpoints, a preliminary analysis and brainstorming of its applicability to the retrofit solutions was performed with the partners engaged in the WP4 (NFA, IUTA, CSIC, CENEX, INTEC, VERT and M+H). The aim was to assess whether the combination of these approaches would: 1) still be considered applicable to establish the overall framework for AeroSolfd; 2) whether the different frameworks had important gaps considering the application domains in AeroSolfd; and 3) when suitable identify the potential midpoints and associated methods to generate the output. The discussion had particular focus on the Risk Assessment (RA) of exposures to chemicals and particles during the product's life-cycle (from manufacturing to recycling and disposal) and in service benefits, environmental Life Cycle Assessment (LCA), and the Social Life Cycle Assessment (S-LCA). These approaches were set as the boundaries for investigation in the Risk Innovation Governance approach.

The results from the brainstorming process were used by NFA to draft top-down an overarching sustainability framework with partner contributions from INTEC (S-LCA inspired by the EU H2020 NANORIGO projects' social and ethical risk governance framework) and CENEX (LCA using the GaBi tool). This draft framework was consulted and discussed in several rounds within WP4 and consulted with WP1, WP2, and WP3 (NFA, IUTA, CSIC, CENEX, INTEC, VERT and M+H). After numerous attempts, it was found that it was difficult to advance to a concrete operational framework for each of the three retrofit solutions following the top down approach. Challenges were a.o. at the framework level, difficulties due topical overlaps between the different established RA (leads: NFA, IUTA), LCA (lead: CENEX) and S-LCA (lead: INTEC) approaches, but also difficulties in detailing the critical aspects in the production, use, service, and end-of-product life / recycling for the retrofit solutions. The latter is to a high degree related to how advanced the innovations have progressed along the innovation funnel.

To obtain more precise information, a bottom-up approach was established by NFA in which the innovators (VERT and M+H in WP1, WP2 and WP3) were asked to describe the materials and elements constituting their products as well as the established and anticipated processes during production, installation, use, decommissioning, recycling and disposal. The interview (NFA, CENEX and INTEC with VERT and M+H) followed a life-cycle risk scoping (LCRS) scheme that we established as part of Task 4.1. The interview results were used by NFA to identify the potentially critical exposure and processes and interpreted in regards to potential risks for which we ranked the potential amplitude and duration of exposure to give a final exposure potential for each of the key work, use, and recycling end-of-life processes. The scores were checked by the innovators and the final RS-LCA result was used to establish specific frameworks and anticipated general data requirements to enable RA (leads: NFA, IUTA), LCA (lead: CENEX) and S-LCA (lead: INTEC) and overall sustainability assessment (Lead NFA) of each of the individual retrofit solutions.

The final step was to outline the data collection plan for Task 4.2 to complete the RA (Task 4.3 and 4.4), LCA (Task 4.3), S-LCA (Task 4.3) and the final overall sustainability analyses (Task 4.4) building on the framework herein.

4. RISK ASSESSMENT ALONG THE LIFE CYCLE

Risk assessment includes the assessment of both the hazard (human and eco-toxicity) and exposure to a substance or mixture of substances. Besides consideration of the specific hazard of the exposure, the characteristics (level and duration) of exposure are important factors for understanding the risk.

In the AeroSolfd project, we are requested to assess the risk along the life cycle (LCRA) for each of the three innovative retrofit solutions. Conceptually, a LCRA involves risk assessment from the production of raw materials and chemicals, and downstream through production, use, service to recycling, waste and re-use.

During an innovation process, there are typically not quantitative information available on all risks parameters. Consequently, assessment methods may range from qualitative to quantitative. Initially, for identification of most apparent and critical risks, it is recommended to perform a risk mapping along the expected LC to scope and prioritize the risk assessments to be conducted as part of the innovation project. Different approaches may be applied for risk scoping, ranging from purely qualitative considering severity and frequency and/or duration to numeric risk scaling. In AeroSolfd, we established a numeric LC risk-scoping analysis (LCRS) for each of the retrofit solutions for identifying the expected exposures and scenarios to be initially considered and further addressed in the overview of methods to be applied.

4.1. RISK SCOPING

A LC risk scoping approach was established considering both the potential human (occupational and public) and environmental risks for each of the three retrofit solutions. LC steps were established for each of the three retrofit solutions starting at the production of the products and ending with the potential end-of-life of the product by recycling and waste. Scaling was set as 0-10 for the relative exposure or release level and potential duration, respectively. These scores are multiplied to provide LC exposure/release scores that consequently can range between 1 and 100.

The LC stages and processes (known or anticipated) in each of three innovative retrofit solutions were identified via interviews and consultation with WP1, WP2 and WP3. WP4 then proposed the scores for each of these processes and re-consulted with WP1, WP2 and WP3 for final scoring. Figure 2, Figure 3 and Figure 4 show the LCRS results for the tailpipe filter, the brake-wear filter, and filter squares, respectively.

4.1.1. TAILPIPE FILTER

The tailpipe filter component materials consist of an exhaust canning and filter substrate. The canning is based on Stainless steel and some expanding fibre mat material, and the un-coated filter substrate consists of a 300 CPSI (Cells per square inch) extruded, high porous (approx 45%), honeycomb structure made from industrial mineral Cordierite, nominally $Mg_2Al_3(AlSi_5O_{18})$[1]. The tailpipe filter manufacturing work process consist in assembling the filter unit into a stainless steel casing – the canning, that can be mounted and replace the muffler/silencer in an existing exhaust system. The existing silencer or a piece of pipe is cut out and the particle filter unit is mounted by flanging or welding depending on the space envelope available on the specific vehicle. The main assembly process consists of mechanical

[1] https://www.corning.com/worldwide/en/innovation/materials-science/ceramics/what-is-cordierite.html

assembling of unit, metal forming and welding. The welding process is a combination between personal and robotic welding.

In use, the filter thermally oxidizes the soot captured during idling, so no soot accumulation is expected in the filter. No emissions of the cordierite filter material are expected during use other than minuscule CO_2 from Soot/carbon oxidation during the regenerating/self-cleaning process. Analysis of secondary emissions part of the testing matrix in WP1 to document this claim

At the end of service-life the tailpipe with the filter substrate and OE mounted three way catalyst (TWC) will be demounted and is expected to be divided by cutting into pieces separating substrate and noble metal catalysts from the remaining tail-pipe, including the retrofit particle filter unit. The particle filter unit is expected to be recycled along with the steel tailpipe materials and processes would likely involve, dividing into smaller pieces, shredding, cleaning, containerization and melting. Release from the filter unit and degradation is expected only in case of accidents.

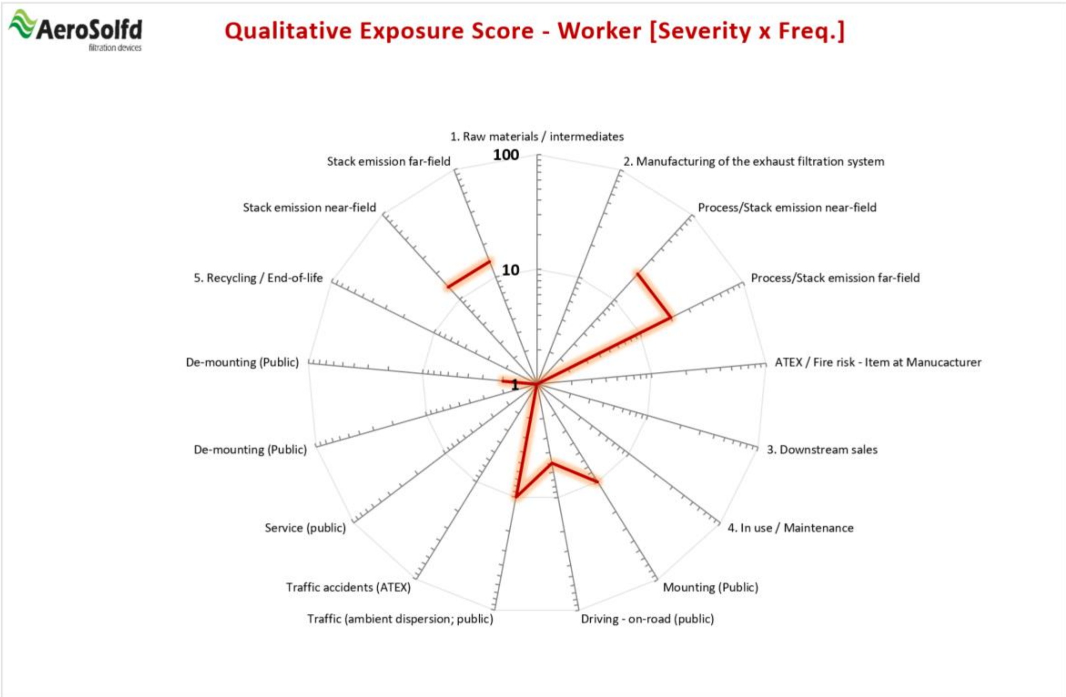
The most important occupational exposure scenarios are anticipated to be associated with manufacturing of the filter unit (assembling the filter unit and cleaning of the workplace) as well as in connection with mounting and demounting. Filter manufacturing and re-cycling processes are highly industrialized with a high degree of automation and protection.

During mounting metal cutting and welding is performed on the existing tailpipe. The filter material, cordierite, is described as fragile and brittle and dust may be released during handling of the pure mineral filter in the assembly phase, but there is also a hypothetical risk of cordierite in tailpipe emissions during use; especially if the filter unit is mechanically damaged. Accidental dropping of the tailpipe particle filter during mounting and exchange may certainly result in release of the filter material and soot if not disintegrated during use, but the levels of potential / accidental release of both filter material and soot is not known. However, in case of used filters, captured combustion particles are expected to be very low as they are expected to be thermally disintegrated during use. Finally, it is anticipated that the tailpipe filter unit will be cut and shredded and re-used for new steel. The filter material itself will be processed, grinded and milled for waste treatment and the steel parts will be re-smelted. During such processes there are several possible exposures to metal and catalyst dust that may be relevant to consider (shredding, cleaning, maintenance, recovery such as bagging or containerisation).

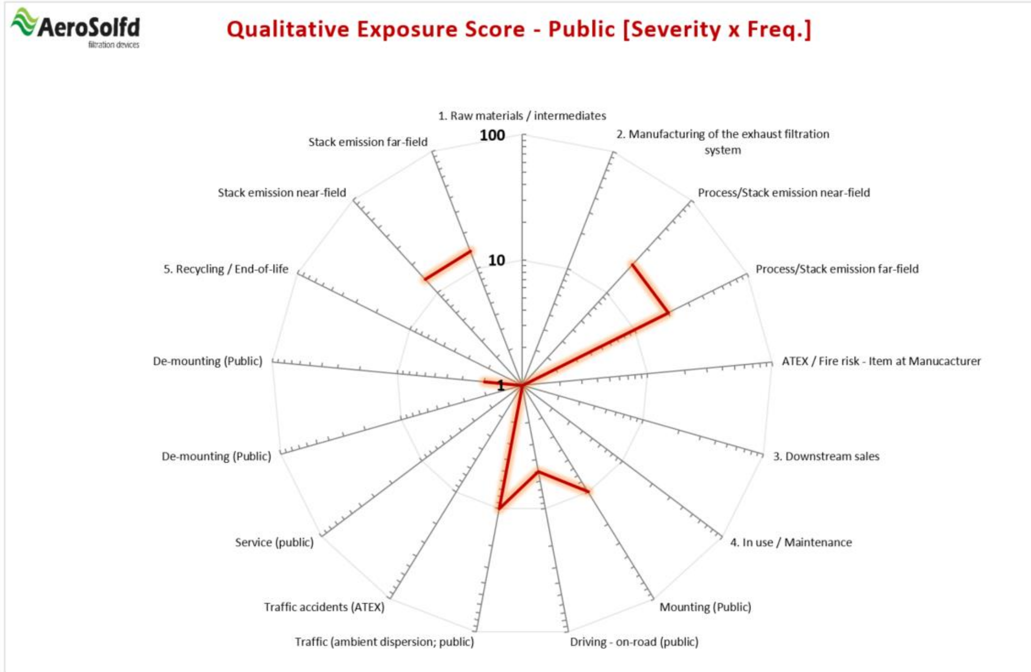
Public exposure is considered relatively low in the product life-cycle. The highest exposure potentials are related to factory release of dust where the ambient air may be contaminated by fine dust and fumes from cordierite, metal cutting and welding penetrating through the filter systems and building envelope. Similarly, release to the ambient air resulting in public air-pollution exposure to dust and welding fumes may occur via workshop emissions during mounting and de-mounting processes. Yet, these releases and resulting exposure in the public is considered very low to low. During recycling, public exposure may occur to cordierite, metal dust and fumes released via stack emissions and passage through the building envelope during recycling. These exposures are expected to local and of very low to low scale.

Environmental release was assessed for similar processes and summarized in Figure 2c (air), d (water) and e (soil). The peak potentials for release to air coincides with the scenarios with highest potentials for human exposure among which cleaning processes and shredding is considered to be the most potent ambient release scenarios to both cordierite and steel dust. It is anticipated that process filtration has high efficiency. Considering release to aquatic environment, the risk of release is generally considered low and connected primarily to manufacturing and recycling where sedimentation of dust released in stack and building envelope emission, released filter dust, as well as accidents where release may occur from waste streams and containers. Potential soil contamination seems to be mostly relevant for sedimentation of released dust during manufacturing and recycling. It should be noted that the thermal oxidation of soot will result in CO_2 emissions as well as potential emission of other reaction products and this should be taking into account in the future assessments of environmental effects.

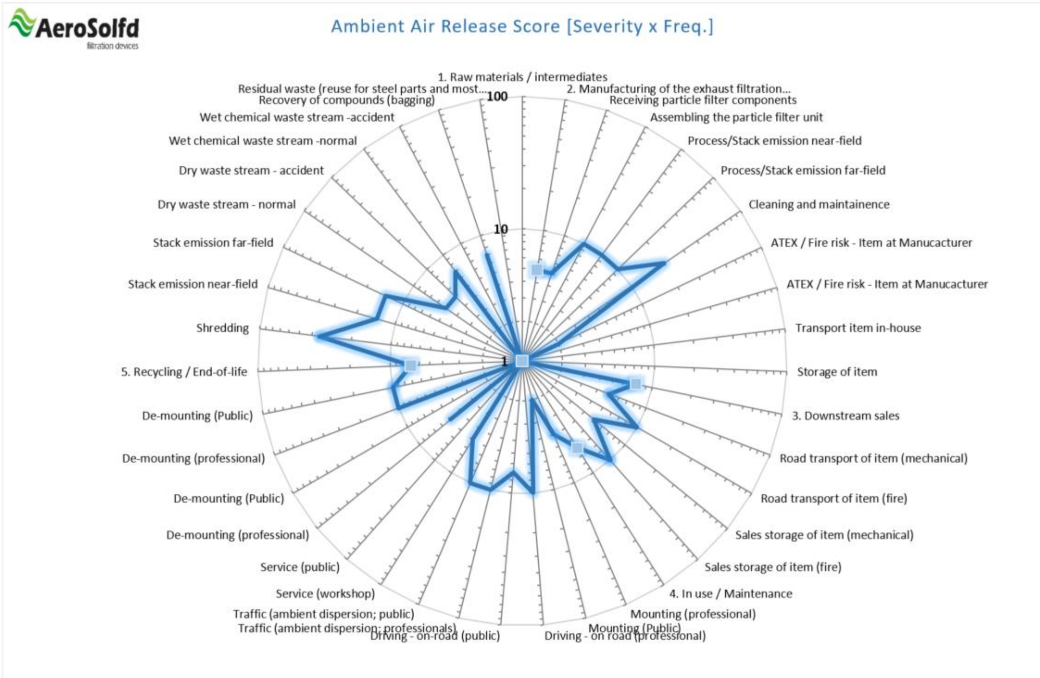
a)



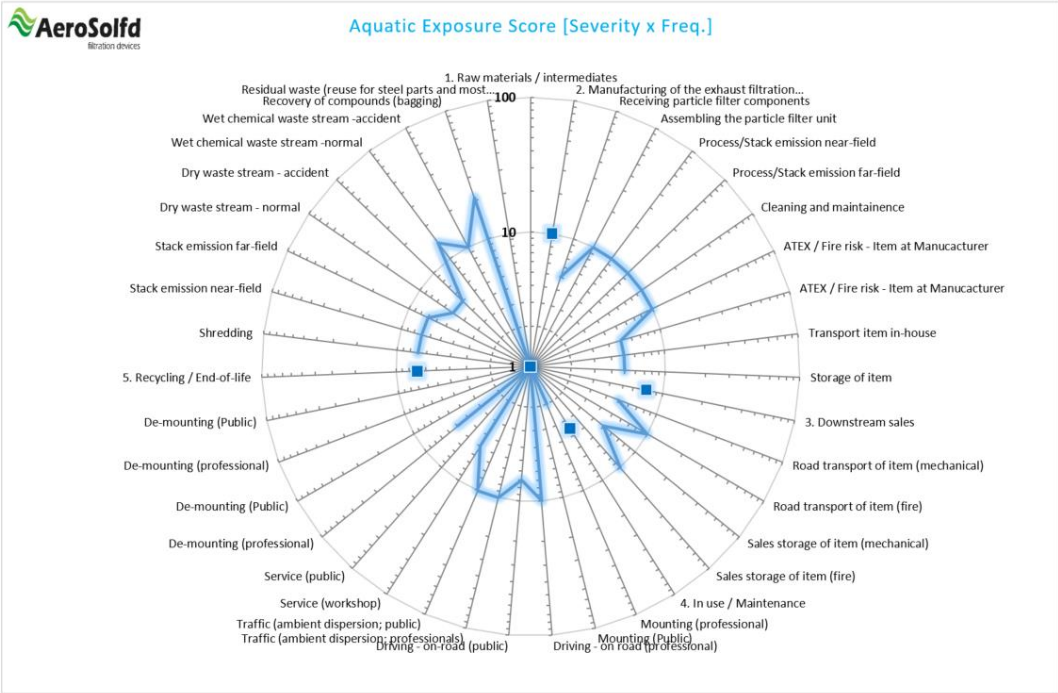
b)


AeroSolfd
filtration devices
Qualitative Exposure Score - Public [Severity x Freq.]
1. Raw materials / intermediates
2. Manufacturing of the exhaust filtration system
Process/Stack emission near-field
Process/Stack emission far-field
ATEX / Fire risk - Item at Manucacturer
3. Downstream sales
4. In use / Maintenance
Mounting (Public)
Driving - on-road (public)
Traffic (ambient dispersion; public)
Traffic accidents (ATEX)
Service (public)
De-mounting (Public)
De-mounting (Public)
5. Recycling / End-of-life
Stack emission near-field
Stack emission far-field
100
10
1

c)


AeroSolfd
filtration devices
Ambient Air Release Score [Severity x Freq.]
1. Raw materials / intermediates
2. Manufacturing of the exhaust filtration...
Receiving particle filter components
Assembling the particle filter unit
Process/Stack emission near-field
Process/Stack emission far-field
Cleaning and maintainence
ATEX / Fire risk - Item at Manucacturer
ATEX / Fire risk - Item at Manucacturer
Transport item in-house
Storage of item
3. Downstream sales
Road transport of item (mechanical)
Road transport of item (fire)
Sales storage of item (mechanical)
Sales storage of item (fire)
4. In use / Maintenance
Mounting (professional)
Mounting (Public)
Driving - on road (professional)
Driving - on-road (public)
Traffic (ambient dispersion; professionals)
Traffic (ambient dispersion; public)
Service (workshop)
Service (public)
De-mounting (professional)
De-mounting (Public)
De-mounting (professional)
De-mounting (Public)
5. Recycling / End-of-life
Shredding
Stack emission near-field
Stack emission far-field
Dry waste stream - normal
Dry waste stream - accident
Wet chemical waste stream -normal
Wet chemical waste stream -accident
Recovery of compounds (bagging)
Residual waste (reuse for steel parts and most...
100
10
1

d)



c)

e)

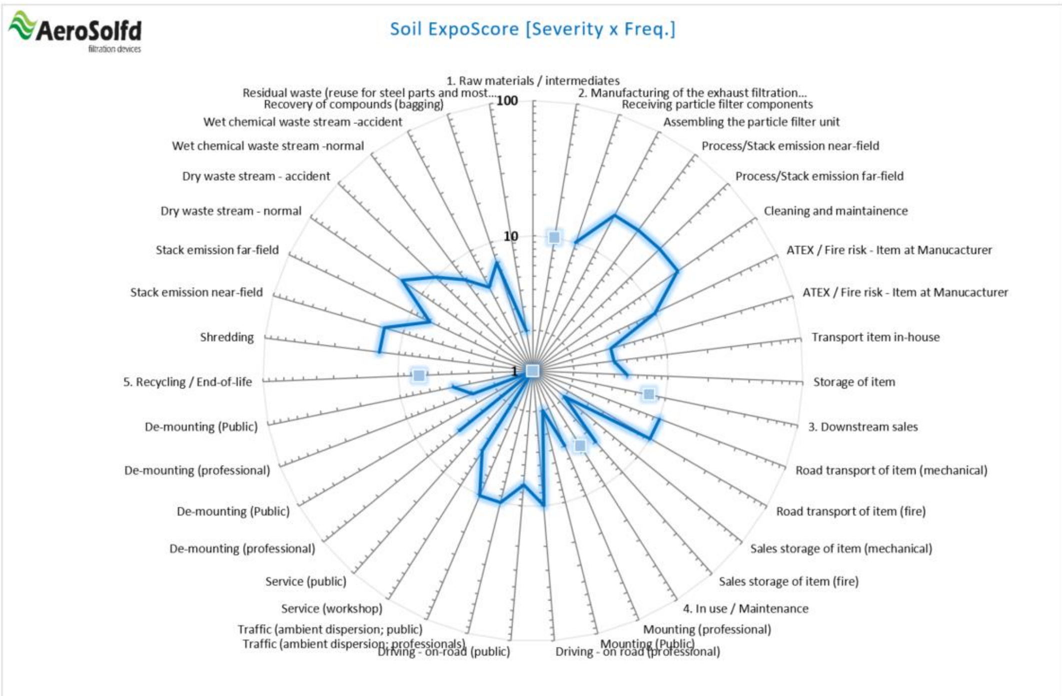


Figure 2 LCRS scores of the potential exposure during the different steps along the LC of the tailpipe filter solution considering: a) workers; b) the public; c) ambient air; d) waters; and e) soil. The squared symbols in c, d, and e provides the overall median for each life cycle stage.

4.1.2. BRAKE DUST FILTER

The brake dust particle filter (BDPF) component materials consist of Steel parts, screws and bolts – Corrosion Resistant CrNi-steel and Metal Fibers for the filter cage. The BDPF is designed as a retrofit solution that can be mounted on the brake carrier by using a pneumatic or electric screwdriver. To mount the BDPF on an existing brake system, the brake carrier needs to be adapted and adjusted with mounting holes. Hence, some steel drilling is required.

The BDPF reduces the brake dust emission of a vehicle (bus). The BDPF will be mounted on the brake carrier and encloses the brake disc. During a brake process, the brake dust will be collected in the filter media of the BDPF.

The service part is the cage with the filter media. In principle, cleaning the filter medium is conceivable, but it must be ensured that the washed-out brake dust does not get into the surroundings or the environment. Therefore, cleaning of the filter media is not recommended.

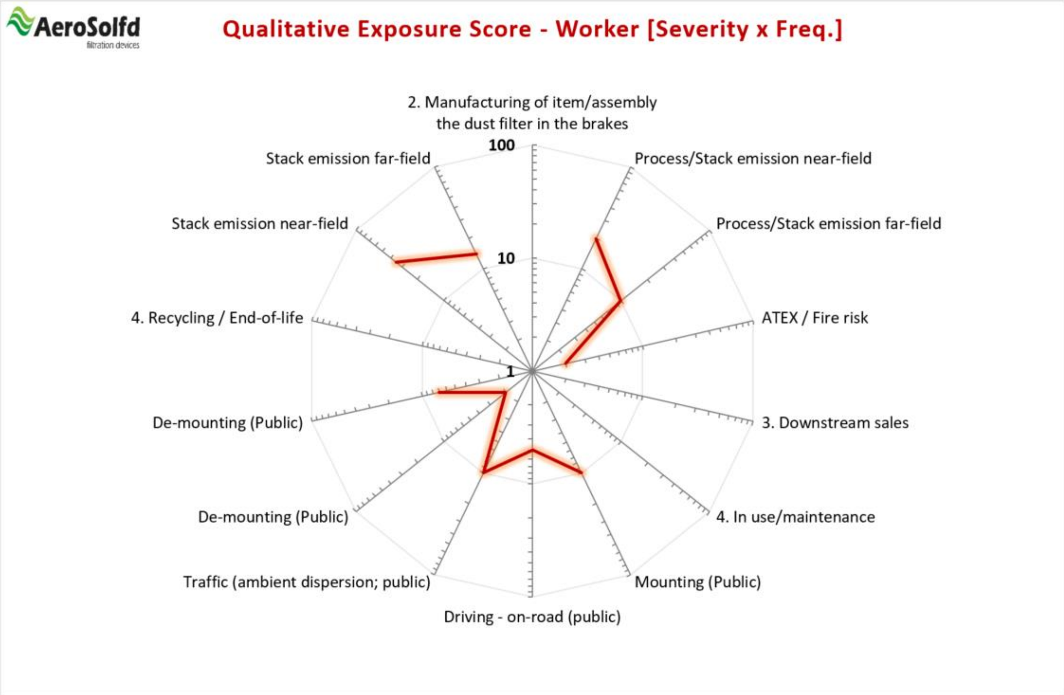
The most important occupational exposure scenarios are anticipated to be associated with manufacturing of the filter unit (assembling the filter unit and cleaning of the workplace) as well as in connection with mounting and demounting. Most assembly is mechanic, but the 3D printed steel fiber filter cages are assembled by laser welding, which is expected to result in ultrafine particle emissions. Filter manufacturing and re-cycling processes are highly industrialized with a high degree of automation and protection. The 3D printing of the filter cage is performed upstream involves several steps (e.g., adding powder precursor and recovery of excess powder, emission during printing, polishing steps) that can be associated exposure risks. However, as it is a supplied product, it is out of scope for the project.

Negligible exposure is expected during mounting while some exposure to brake-wear dust may occur during exchange and service. - Especially in case of accidental dropping of the filter service part. Finally, it is anticipated that the filter service part will be discarded of and melted as a unit for steel recycling. Yet, it may also be cut and shredded prior to melting. Therefore, there are several possible release and exposures to brake-wear dust (shredding, cleaning, maintenance, recovery such as bagging or containerisation), which needs clarification in the next step.

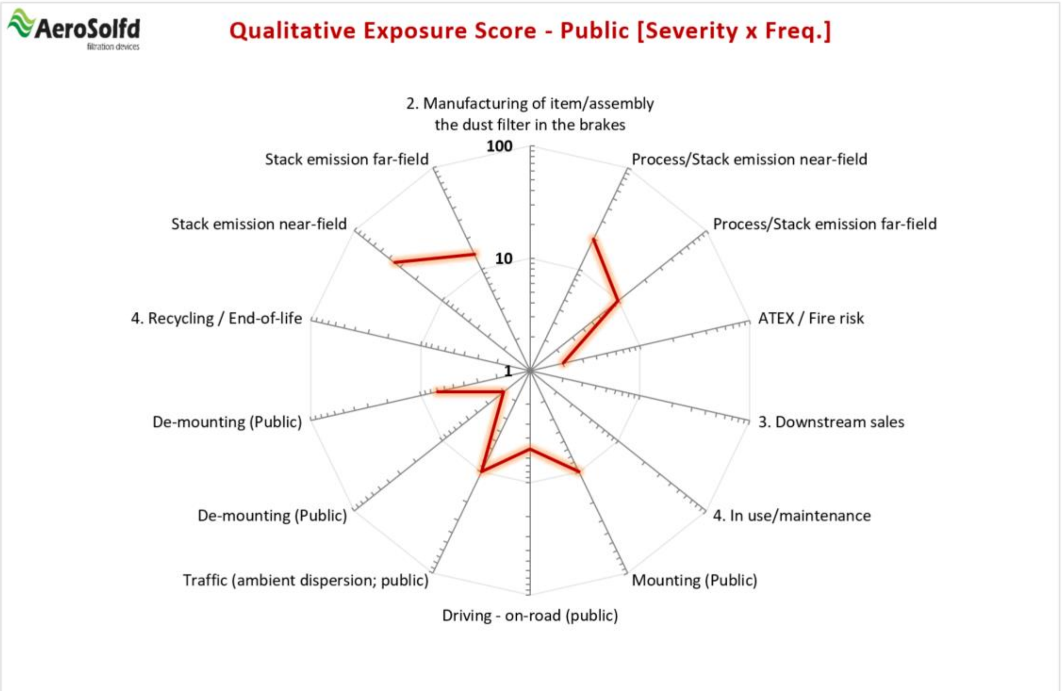
Public exposure risk is generally considered very low in the entire product life-cycle. The highest exposure potentials are related to factory release of particles production and assembly. During recycling, public exposure may occur to brake wear dust released via stack emissions and passage through the building envelope during recycling. Exposure may also occur to public individuals if they themselves remove / exchange the brake wear filter.

Environmental release was assessed for all life-cycle stages and summarized in Figure 3c (air),d (water) and e (soil). The peak potentials for release to air coincides with the scenarios with highest potentials for human exposure among which cleaning processes and shredding is considered to be the most potent ambient release scenarios to both cordierite and steel dust. It is anticipated that process filtration has high efficiency. Considering release resulting in aquatic exposure, the risk of release is generally considered low and connected primarily to manufacturing and recycling where sedimentation of dust released in stack and building envelope emission, and release in a potential wet chemical waste stream, as well as accidents, where release may occur from waste streams and containers. Potential soil contamination seems to be mostly relevant for sedimentation of released dust during manufacturing and recycling and dry waste streams.

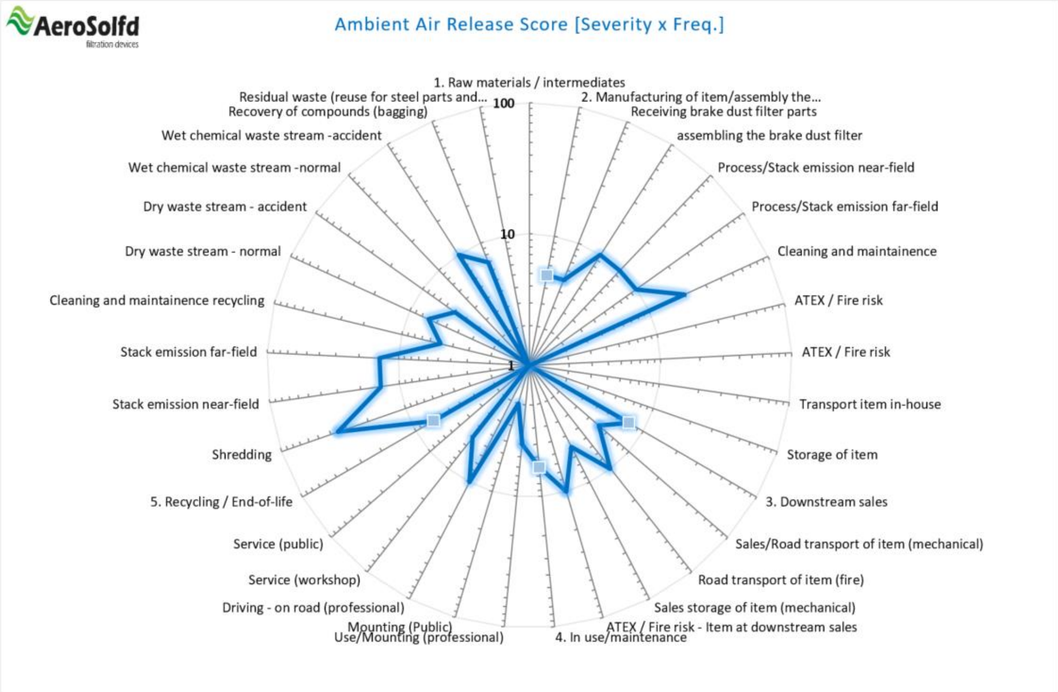
a)


Qualitative Exposure Score - Worker [Severity x Freq.]
2. Manufacturing of item/assembly the dust filter in the brakes
100
10
1
Process/Stack emission near-field
Process/Stack emission far-field
ATEX / Fire risk
3. Downstream sales
4. In use/maintenance
Mounting (Public)
Driving - on-road (public)
Traffic (ambient dispersion; public)
De-mounting (Public)
De-mounting (Public)
4. Recycling / End-of-life
Stack emission near-field
Stack emission far-field

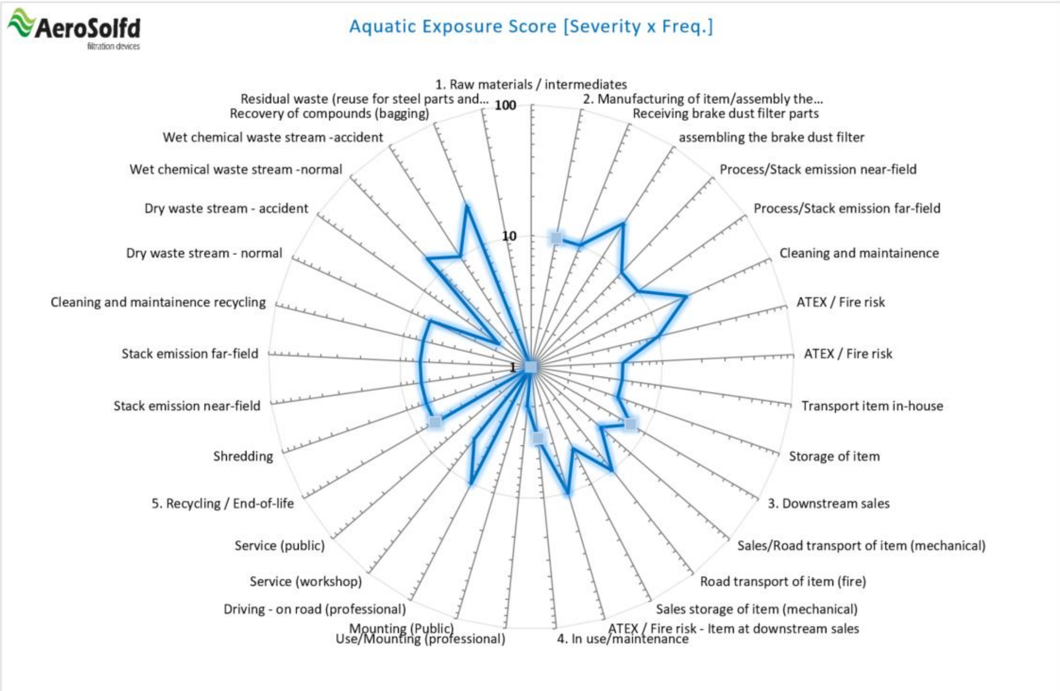
b)


Qualitative Exposure Score - Public [Severity x Freq.]
2. Manufacturing of item/assembly the dust filter in the brakes
100
10
1
Process/Stack emission near-field
Process/Stack emission far-field
ATEX / Fire risk
3. Downstream sales
4. In use/maintenance
Mounting (Public)
Driving - on-road (public)
Traffic (ambient dispersion; public)
De-mounting (Public)
De-mounting (Public)
4. Recycling / End-of-life
Stack emission near-field
Stack emission far-field

c)


AeroSolfd
filtration devices
Ambient Air Release Score [Severity x Freq.]
1. Raw materials / intermediates
2. Manufacturing of item/assembly the...
Receiving brake dust filter parts
assembling the brake dust filter
Process/Stack emission near-field
Process/Stack emission far-field
Cleaning and maintainence
ATEX / Fire risk
ATEX / Fire risk
Transport item in-house
Storage of item
3. Downstream sales
Sales/Road transport of item (mechanical)
Road transport of item (fire)
Sales storage of item (mechanical)
ATEX / Fire risk - Item at downstream sales
4. In use/maintenance
Use/Mounting (professional)
Mounting (Public)
Driving - on road (professional)
Service (workshop)
Service (public)
5. Recycling / End-of-life
Shredding
Stack emission near-field
Stack emission far-field
Cleaning and maintainence recycling
Dry waste stream - normal
Dry waste stream - accident
Wet chemical waste stream -normal
Wet chemical waste stream -accident
Recovery of compounds (bagging)
Residual waste (reuse for steel parts and...
100
10
1

d)


AeroSolfd
filtration devices
Aquatic Exposure Score [Severity x Freq.]
1. Raw materials / intermediates
2. Manufacturing of item/assembly the...
Receiving brake dust filter parts
assembling the brake dust filter
Process/Stack emission near-field
Process/Stack emission far-field
Cleaning and maintainence
ATEX / Fire risk
ATEX / Fire risk
Transport item in-house
Storage of item
3. Downstream sales
Sales/Road transport of item (mechanical)
Road transport of item (fire)
Sales storage of item (mechanical)
ATEX / Fire risk - Item at downstream sales
4. In use/maintenance
Use/Mounting (professional)
Mounting (Public)
Driving - on road (professional)
Service (workshop)
Service (public)
5. Recycling / End-of-life
Shredding
Stack emission near-field
Stack emission far-field
Cleaning and maintainence recycling
Dry waste stream - normal
Dry waste stream - accident
Wet chemical waste stream -normal
Wet chemical waste stream -accident
Recovery of compounds (bagging)
Residual waste (reuse for steel parts and...
100
10
1

e)

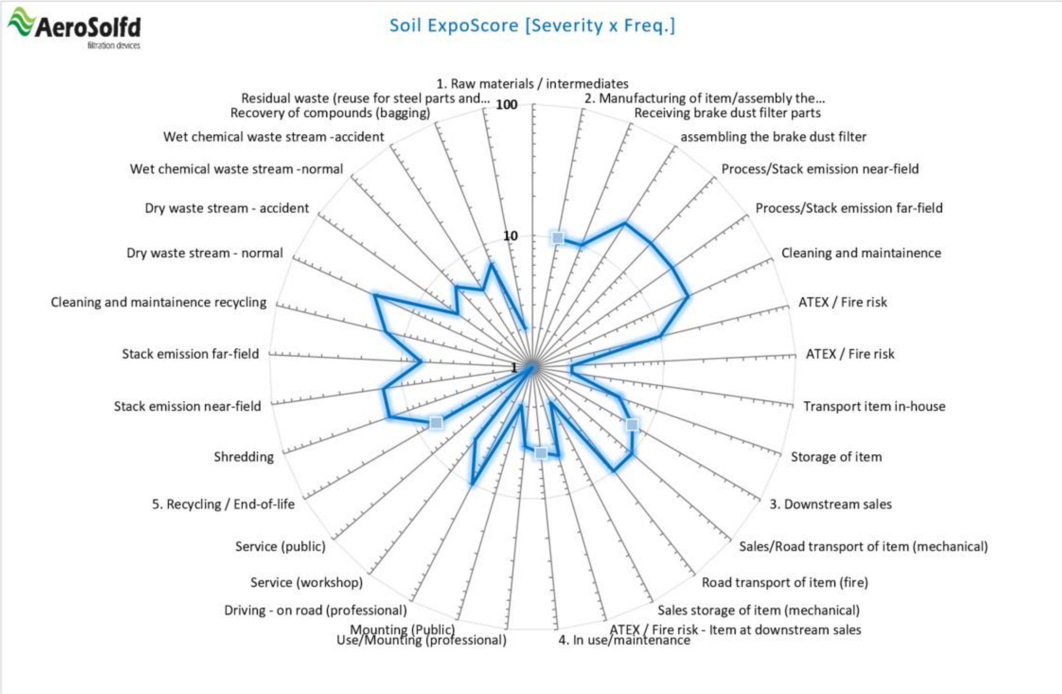


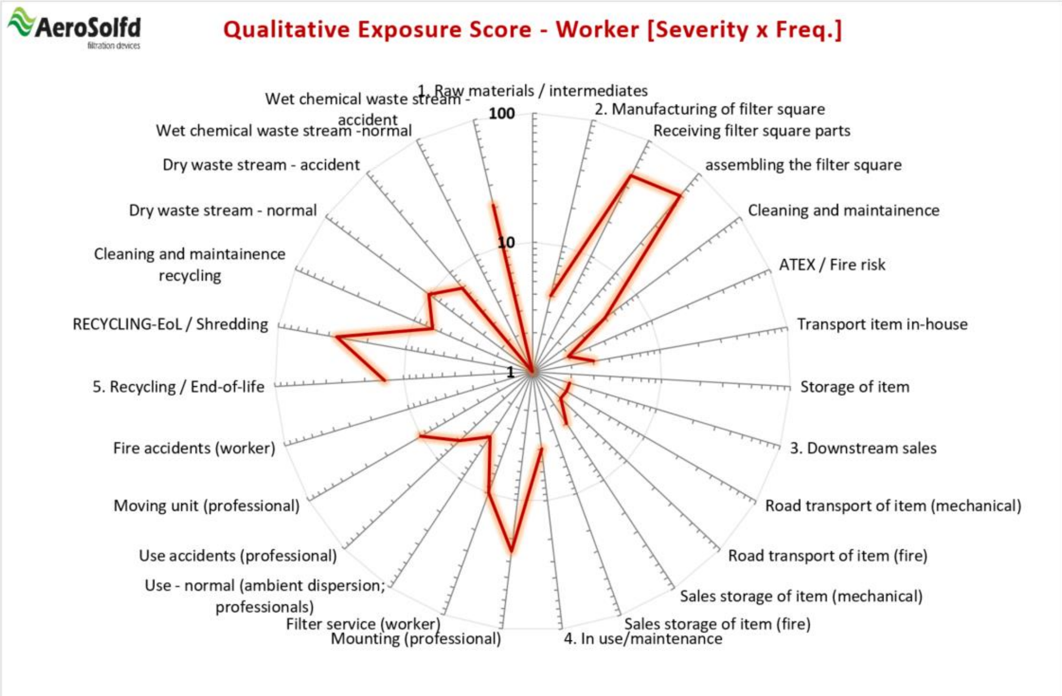
Figure 3 LCRS scores of the potential exposure during the different steps along the LC of the brake wear filter solution considering: a) workers; b) the public; c) ambient air; d) waters; and d) soil. The squared symbols in c, d, and e provides the overall median for each life cycle stage.

4.1.3. FILTER SQUARES

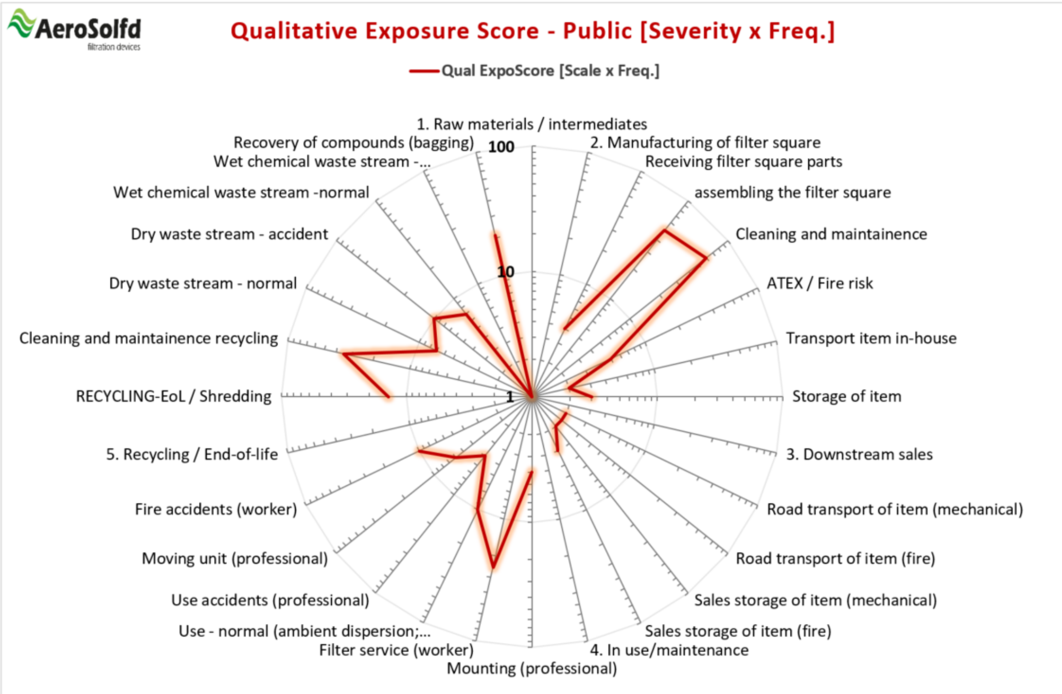
The filter squares component materials consist of Alloy quality low carbon steel; Cross bars & pipes; Mild steel studs; Non-alloy quality and structural steel; Sheet metal parts; Stainless steel bolt/screw/nut; Stainless steel socket; Stainless steel washer; Steel blind rivet; Steel self-tapping screw and Steel washer. The final filter material is still under investigation.

The filter square manufacturing work process consist in assembling and mounting of all the components. The assembling process of Frame by Welding and Fastening is made at supplier facilities. The other process of Mounting the Inlet and Outlet Grid by Riveting and manually by Fastening, as well as the Mounting of Covers, of Smoke Detector Base Plate, of the Intake Port is made at MANN+HUMMEL together with other complementary processes such as: the Sealing of Intake Port, the Assembly of Intake Port with Grounding Strap & Grounding Sticker, the Assembly of Acoustic Foam and the Assembly of Fan.

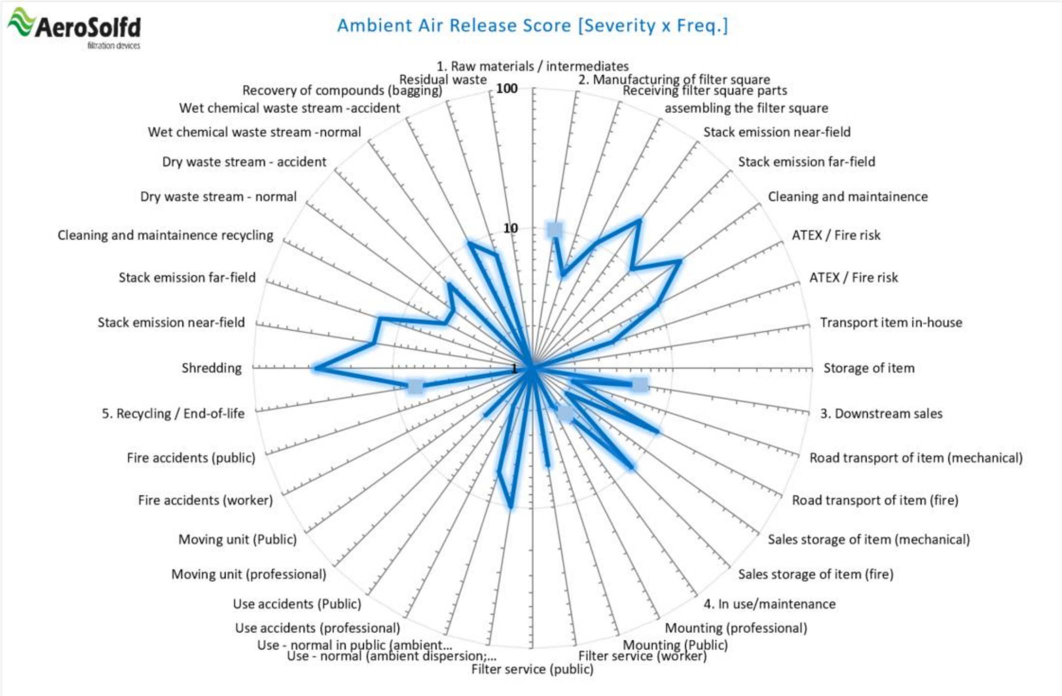
a)


AeroSolfd
filtration devices
Qualitative Exposure Score - Worker [Severity x Freq.]
1. Raw materials / intermediates
2. Manufacturing of filter square
Receiving filter square parts
assembling the filter square
Cleaning and maintainence
ATEX / Fire risk
Transport item in-house
Storage of item
3. Downstream sales
Road transport of item (mechanical)
Road transport of item (fire)
Sales storage of item (mechanical)
Sales storage of item (fire)
4. In use/maintenance
Mounting (professional)
Filter service (worker)
Use - normal (ambient dispersion; professionals)
Use accidents (professional)
Moving unit (professional)
Fire accidents (worker)
5. Recycling / End-of-life
RECYCLING-EoL / Shredding
Cleaning and maintainence recycling
Dry waste stream - normal
Dry waste stream - accident
Wet chemical waste stream -normal
Wet chemical waste stream - accident
100
10
1

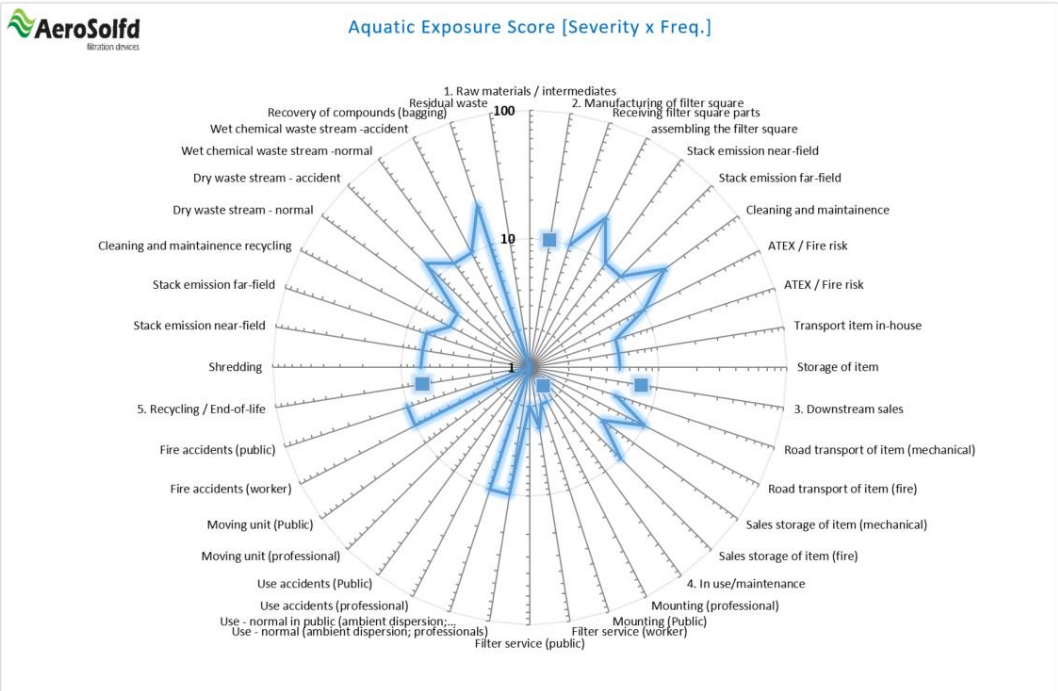
b)


AeroSolfd
filtration devices
Qualitative Exposure Score - Public [Severity x Freq.]
Qual ExpoScore [Scale x Freq.]
1. Raw materials / intermediates
2. Manufacturing of filter square
Receiving filter square parts
assembling the filter square
Cleaning and maintainence
ATEX / Fire risk
Transport item in-house
Storage of item
3. Downstream sales
Road transport of item (mechanical)
Road transport of item (fire)
Sales storage of item (mechanical)
Sales storage of item (fire)
4. In use/maintenance
Mounting (professional)
Filter service (worker)
Use - normal (ambient dispersion;...
Use accidents (professional)
Moving unit (professional)
Fire accidents (worker)
5. Recycling / End-of-life
RECYCLING-EoL / Shredding
Cleaning and maintainence recycling
Dry waste stream - normal
Dry waste stream - accident
Wet chemical waste stream -normal
Wet chemical waste stream -...
Recovery of compounds (bagging)
100
10
1

c)


AeroSolfd
Ambient Air Release Score [Severity x Freq.]
1. Raw materials / intermediates
2. Manufacturing of filter square
Receiving filter square parts
assembling the filter square
Stack emission near-field
Stack emission far-field
Cleaning and maintainence
ATEX / Fire risk
ATEX / Fire risk
Transport item in-house
Storage of item
3. Downstream sales
Road transport of item (mechanical)
Road transport of item (fire)
Sales storage of item (mechanical)
Sales storage of item (fire)
4. In use/maintenance
Mounting (professional)
Mounting (Public)
Filter service (worker)
Filter service (public)
Use - normal (ambient dispersion;...
Use - normal in public (ambient...
Use accidents (professional)
Use accidents (Public)
Moving unit (professional)
Moving unit (Public)
Fire accidents (worker)
Fire accidents (public)
5. Recycling / End-of-life
Shredding
Stack emission near-field
Stack emission far-field
Cleaning and maintainence recycling
Dry waste stream - normal
Dry waste stream - accident
Wet chemical waste stream -normal
Wet chemical waste stream -accident
Recovery of compounds (bagging)
Residual waste
100
10
1

d)


AeroSolfd
Aquatic Exposure Score [Severity x Freq.]
1. Raw materials / intermediates
2. Manufacturing of filter square
Receiving filter square parts
assembling the filter square
Stack emission near-field
Stack emission far-field
Cleaning and maintainence
ATEX / Fire risk
ATEX / Fire risk
Transport item in-house
Storage of item
3. Downstream sales
Road transport of item (mechanical)
Road transport of item (fire)
Sales storage of item (mechanical)
Sales storage of item (fire)
4. In use/maintenance
Mounting (professional)
Mounting (Public)
Filter service (worker)
Filter service (public)
Use - normal (ambient dispersion; professionals)
Use - normal in public (ambient dispersion;...
Use accidents (professional)
Use accidents (Public)
Moving unit (professional)
Moving unit (Public)
Fire accidents (worker)
Fire accidents (public)
5. Recycling / End-of-life
Shredding
Stack emission near-field
Stack emission far-field
Cleaning and maintainence recycling
Dry waste stream - normal
Dry waste stream - accident
Wet chemical waste stream -normal
Wet chemical waste stream -accident
Recovery of compounds (bagging)
Residual waste
100
10
1

e)

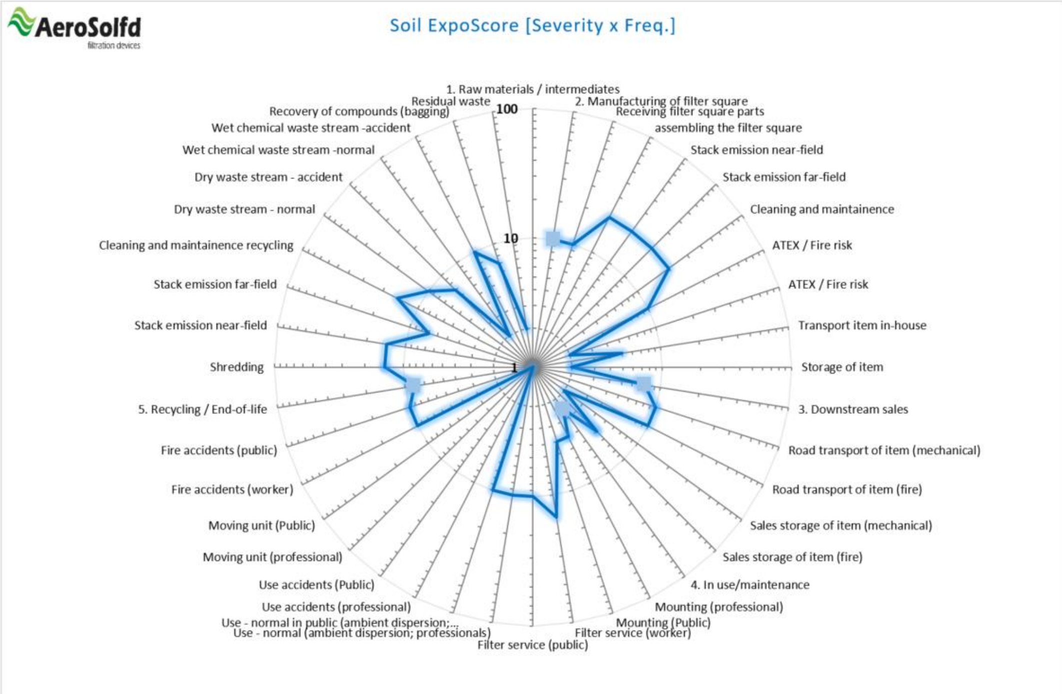


Figure 4 LCRS scores of the potential exposure during the different steps along the LC of the area air-filtration solution considering: a) workers; b) the public; c) ambient air; d) waters; and d) soil. The squared symbols in c, d, and e provides the overall median for each life cycle stage.

4.2. HUMAN RISK ASSESSMENT METHODS

According to WHO, inhalation of particulate air pollution in ambient air is causally related to various adverse health effects including lung cancer, cardiovascular diseases and respiratory diseases including asthma (WHO, 2023) (HEI, 2022). Animal studies have shown that inhalation of diesel engine exhaust, elemental carbon nanoparticles and various metal oxide particles causes cancer. Furthermore, inhalation of various soluble and insoluble particles induces acute phase response, which is causally related to cardiovascular disease (Hadrup, 2020). The particle types include combustion particles such as diesel engine exhaust particles, jet emission particles, welding fumes, soluble and insoluble metal oxide particles and sanding dust of composite materials (Heinrich, 1995) (Bendtsen, 2019) (Saber, 2016) (Gutierrez, 2023). In addition, intervention studies confirm that reduction of exposure to black smoke is accompanied by reduced mortality, primarily caused by reduced cardiovascular mortality (Clancy, 2002)). Several epidemiological studies in both children and adults confirm numerous adverse health effects of ambient air-pollution (Brumberg, 2021); (Stafoggia, 2022). Lately also specifically for the concentration of ultrafine air-pollution particles (Schwarz, 2023) (Ohlwein, 2019).

Conceptually, a risk assessment is performed by combining information on exposure (levels of specific external or internal exposure and its duration) and information on the hazard to the recipient (human or environmental organism). Different qualitative to quantitative risk assessment approaches can be applied depending the type and quality of available data and tradition in different domains.

4.2.1. EXPOSURE ASSESSMENT

A specific quantitative risk assessment requires quantitative information on the exposure (i.e. the chemical substance(s), it exposure characteristics (exposure duration, frequency and concentration of

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solid, liquid, gaseous; if solid its number and mass size-distribution or size-fractions such as ultrafine particles, PM_1, $PM_{2.5}$, PM_4/PM_5, PM_{10}, and Total Dust). For assessment of particle exposures, several different size-fractions exist, but only a few are used for regulatory risk assessment: $PM_{2.5}$ and PM_{10} is for assessment of ambient particulate air-pollution; PM_4 or PM_5 is used depending on country for assessment of respirable dust in the working environment while Total Dust is used for occupational exposure assessment when the exposure can be of health risk when also deposited outside of the alveolar compartment. As ultrafine particles from traffic are abundant and of particular concern, but normally only contributes minor to mass, it is important that both particle number concentration (PN or PNC) and mass-concentrations into account.

A first assessment of the potential human exposure was already made in the first stage Life-Cycle Risk Scoping (LCRS) analysis. This assessment is purely scaling based on qualitative assessment of the different possible exposure scenarios (scaled extent x duration) in which release could occur from the product or its manufacturing or recycling. The analysis did not include the effect on ambient air-pollution levels. However, the results already points towards product-related scenarios of potential concern and further investigation.

Occupational risk assessment is normally made for each substance (or dust mass concentration) and evaluated against an occupational exposure limit (OEL) and its underlying risk ratios (likelihood of outcome). When the exposure is complex a specific exposure limit can be derived based on the fractional contribution from each substance.

Overall, release measurements (that can lead to emission rates) are planned in WP1, WP2 and WP3 while ambient, indoor area and worker exposure measurements are planned in WP3 and WP4. These measurements all have focus on the particulate matter and specific compounds (size-distributions, number concentrations, PM_{10} PM_4/PM_5, $PM_{2.5}$ and ultrafine particles, BC (Black Carbon), EC (Elemental Carbon), OC (Organic Carbon), PAH's (Polycyclic Aromatic Hydrocarbon) and metals). When relevant gaseous and organic compounds will be assessed as well. This is particularly important for the ambient and closed-area studies. These levels of ambient and indoor air-pollution as well as occupational exposure are the basis for specific risk assessments.

A final exposure measurement strategy for each product line cannot be completed at this point, but will be defined after further investigation and clarification of manufacturing, mounting and down-stream processes.

In some cases, it is not possible to perform measurement-based exposure measurements. In these cases, we will use exposure modelling if possible, read-across from published relevant exposure scenarios or a qualitative ranking or score.

4.2.2. HAZARD ASSESSMENT

Based on data on the identified exposure scenarios for the three case studies, we will perform a hazard characterisation of the exposure constituents from 1) the production, recycling, and product-related emissions and 2) the air-pollution components for which exposure will be reduced. Most of the exposures are considered conventional (e.g., stainless steel welding, engine soot) and literature data and OELs will be available for these.

In regards to the ambient air-pollution, we will primarily use epidemiological data. In regards to brake-wear particles, there appears to be no specific hazard data for the moment. Therefore, we will to the extent possible also use data from animal studies to determine the specific toxicity of this type of exposure. If data are unavailable for the specific exposure components, we will perform hazard assessments using read-across in which we use information from other aerosol components for which we expect similar adverse effects by similar modes of action.

4.2.3. RISK ASSESSMENT

The final human risk assessment will be performed based on dose-response relationships identified in epidemiological studies, controlled human studies or intervention studies of emissions/exposures, which are similar to the exposures in the case studies.

We will estimate the reduced aggravated symptoms (e.g., asthma), disease, and mortality based on relevant intervention studies or epidemiological studies of exposures that are deemed relevant. We will make separate estimates for public exposure and occupational exposure, taking the likely exposure durations into account.

Workplace specific risk assessments may likely be possible based on the planned exposure measurements in WP3 and WP4.

4.3. ENVIRONMENTAL RISK ASSESSMENT METHODS ALONG THE LIFE CYCLE

The environmental risk assessment is made considering both the environmental impact and risk to environmental species.

Release and mass-flow analysis will be performed during demonstration activities in order to determine the baseline of emissions from brakes and in (semi-) closed environments. This will determine the ground reference for improving urban air quality and reducing the effect of polluting emission on water and air as well as preventing damage to historic buildings.

The hazard and effects on the environment of the used and emitted substances are collected and evaluated on the basis of existing ecotoxicity data and limit values for the individual substance groups and environmental compartments as well as the different target organisms. The potential risk for the environment results on the one hand from the exposure concentration in the different compartments and on the other hand from the predicted no effect concentrations (PNEC) for the different target organisms. Whether the particle size has an influence on toxicity will be clarified within the framework of the project. In addition to the risk to specific organisms, the extent to which transport to other compartments can occur will also be assessed. In addition to toxicity data, data on ageing will also be included.

The Environmental Risk assessment will be performed based on exposure concentrations and predicted no effect concentrations of the different substances for the different environmental compartments.

4.4. FORESEEN INFORMATION REQUIREMENTS AND DATA COLLECTION PLAN

Exposure assessments will be made based on emission- and exposure measurements as planned in the description of action. WP1, 2, and 3 provide specific emission and filtration efficacy measurements of the retrofit solutions as needed. This data will be used to estimate the impact on area and ambient exposure levels (e.g., particle number-size-distribution, $PM_{2.5}$, PM_{10}, metals, EC, BC, PAH) considering relevant scenarios to be defined. WP3 also provide specific exposure measurement at the bus depot and metro station platforms were filter squares are tested. In WP4, occupational exposure measurements are made at important exposure scenarios identified in the LCRS assessment. These measurements will include particle number-size-distribution measurements, PM_4, total dust, metals, EC/OC, BC, and PAH as necessary. Measurements will be made using integrated filter collection (dust size-fractions, EC/OC, PAH), real-time monitoring of particle number concentrations, particle size-distributions, and BC.

For hazard data, we will focus on the major air pollution-induced diseases, lung cancer, cardiovascular disease and respiratory disease. Based on the exposure assessments, we will identify studies with dose-response relationship for relevant exposures or exposure components. We will prioritize epidemiological studies, intervention studies and controlled exposures with relevant outcomes. Concerning epidemiological studies, we will prioritize systematic reviews and meta-analyses.

Risk assessment will be based on the epidemiological studies on dose-response relationships identified for the hazard assessment.

For Environmental Risk Assessment existing Ecotoxicity data and limit values for the individual substance groups and environmental compartments for different target organisms will be used.

Based on these data and expected exposure concentration the potential risks can be evaluated.

5. ENVIRONMENTAL LIFECYCLE ASSESSMENT

Life Cycle Assessment is used to determine the environmental impact of a product or service during their entire life cycle. The life cycle includes the mining of the materials, production of the components, transportation of the product, usage of the product and the end-of-life processes of the product.

Environmental impact comprises the emissions that occur during these life cycle phases and have an impact on the local or global environment (including humans). These relate not only to GHG emissions, but also include emissions such as (hazardous or toxic) particles and gasses, naturally occurring and waste emissions resulting from extracting materials from its environment (e.g., crude oil and ores).

5.1. METHODOLOGY USED IN AEROSOLFD

This LCA complies with the framework in the 14040-14044 standards defined by the International Organisation for Standardization (ISO STANDARDS BYISO/TC 207/SC 5 - Life cycle assessment, 2022). The LCA studies within the AeroSolfd project and for its partners are performed as described as summarized below and uses actual data (where available), supplemented with the use of GaBi databases by Sphera (Gabi Sphera, n.d.), which safeguards also compliance with the (aforementioned) ISO standards.

The main phases of an LCA are the following and are visually depicted in Figure 5:

1. *Goal and Scope Definition*; The reasoning for carrying out the research is defined. The required level of detail is described and basis for comparison is chosen.
2. *Life Cycle Inventory Analysis*; A model is created which illustrates the life cycle and the processes involved. Data is gathered to quantify the mass and emission flows.
3. *Life Cycle Impact Assessment*; The effect of the emissions and the usage of resources is analysed by grouping the quantified emissions and mass flows into a limited number of environmental impact categories.
4. *Life Cycle Interpretation*; The results are checked for consistency and completeness. They are then evaluated and reported in an informative way.

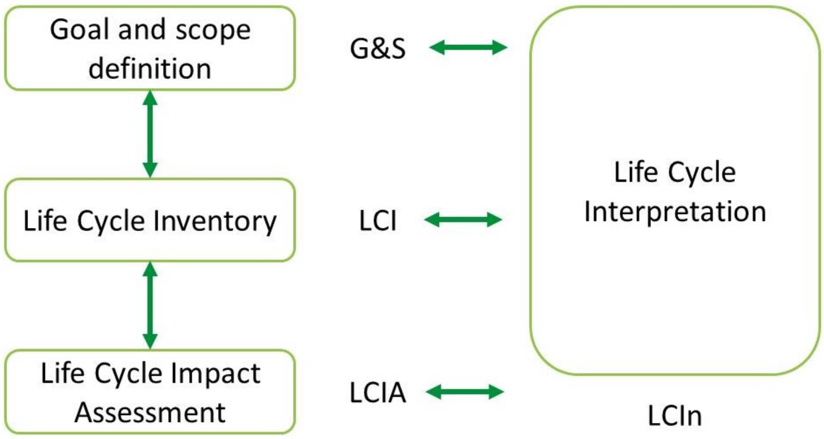

Figure 5 the main phases of an LCA

Goal and Scope definition and Life Cycle Inventory

The life cycle phases (visualized in Figure 6) that are being considered for the AeroSolfd project demo cases are the following:

- The extraction of all raw materials.
- The production and manufacturing of the parts.
- The transportation of the materials and parts to the manufacturing sites.
- The emissions associated with the use phase of the component. Including maintenance and repair.
- Lastly, through the end-of-life of the components themselves.

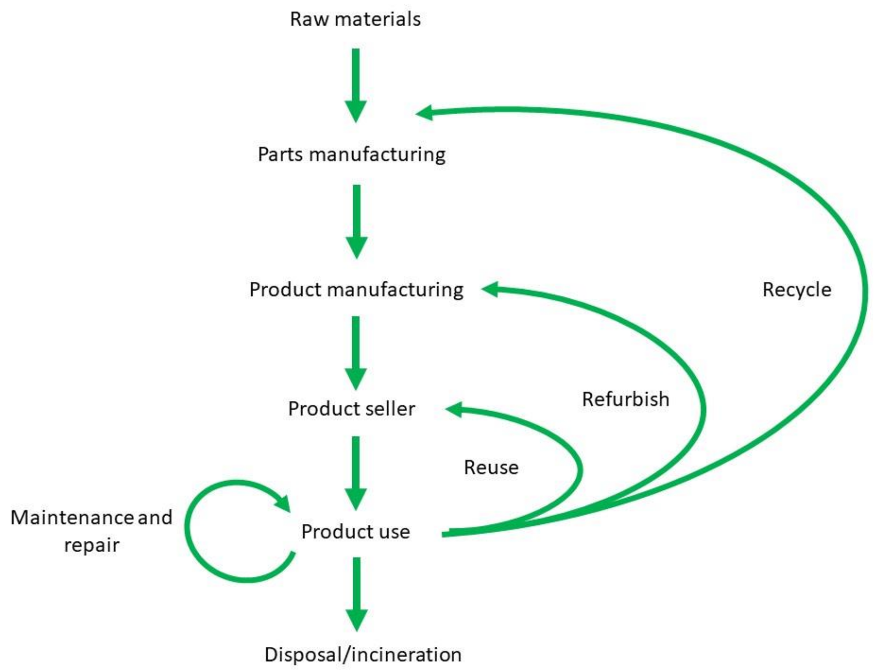

Figure 6 the life cycle phases

Life Cycle Impact Assessment

The environmental life cycle impact of the demo cases will be assessed and compared to their business-as-usual situation. This comparison will be made based on the environmental performance of the use-case and the benchmark, as determined by LCA practices, and analyses emissions, materials, energy consumption, and pollution throughout the life cycle of the use-case components. The LCA impact will be defined as all environmental effects falling under the impact categories and associated emissions specified in the ReCiPe 2016 impact assessment method. During a Life Cycle Impact Assessment (LCIA), all the emissions and resource extractions are categorized into a set of environmental impact scores by so-called characterisation factors. There are typically two types of characterization factors, midpoint level and end-point level indicators. ReCiPe specifically has 18 midpoint levels and 3 endpoint levels. An example of the translation into the different levels is as following: Increase in Carbon Dioxide increases the greenhouse effect which means it has an effect on the midpoint level indicator Global Warming. Global warming on its way damages by increase in causes, increase in malnutrition, damage to freshwater species and terrestrial species, which effect the end point level indicator Damage to Human Health and Damage to ecosystems.

5.2.FORESEEN INFORMATION REQUIREMENTS AND DATA COLLECTION PLAN

Temporal and geographical boundaries

This study mostly uses data extracted from the GaBi database. Other data comes from either literature studies or directly from the industrial plants (provided by the DEMO partners). All datasets that are used have to be valid until the end of the AeroSolfd project (2025). The geographical representativeness of the datasets is dependent on life cycle stage of the process. As default, the EU-28 (European Union, 28 countries) averages are used, unless specific knowledge of the region of production is known. For example, concerning the manufacturing of the retrofit brake dust particle filter, Germany is used as geographical region. When multiple datasets for one process are available, a quick analysis on the specific datasets needs to be performed. The criteria on the choice datasets are the following:

Geographical representativeness:

- Choose the dataset that is located in the specific region the process occurs.
- If unknown or unavailable, use EU-28 (European) averages.
- If unavailable, use the Global (GLO) averages.

Temporal representativeness:

1. Choose the dataset which reference year falls under the 'years of manufacturing' of the benchmark vehicle.
2. If unavailable or when multiple datasets fall under this requirement, choose the dataset with the most recent reference year.

Treatment of recycled materials

Allocation of the recycling and reuse of the materials is important in LCA. The method in this LCA study to account for this is to apply scrap credits to the scrap that comes from all the production processes and end-of-life systems. This is called "value-corrected substitution" and is a method used in LCIA (Life Cycle Impact assessment) which tackles the down cycling issue in LCA when handling products with high scrap ratios.

During production and EOL, large volumes of scrap are produced and recycled. However, the material quality is often lower than that of the virgin material, which means that often the scrap material can't be replaced by the virgin material on a one-by-one basis. The "value-corrected substitution" method uses the price ratio between different grades of scrap (based on their quality) and the virgin material.

Figure 7 provides an example of how this method is used in LCA. In this example the shredded steel from the post-shredding/sorting process is directed to a process called "No. 4 shredded steel-scrap credit". This is the process containing the price ratio of the scrap and the virgin steel. The number (No. 4 in this example) relates to the quality of the scrap material. The second input in this process is the "DE: Stainless steel cold rolled", which is a negative input, which means that the environmental impact of the stainless steel is now environmental savings (negative emissions).

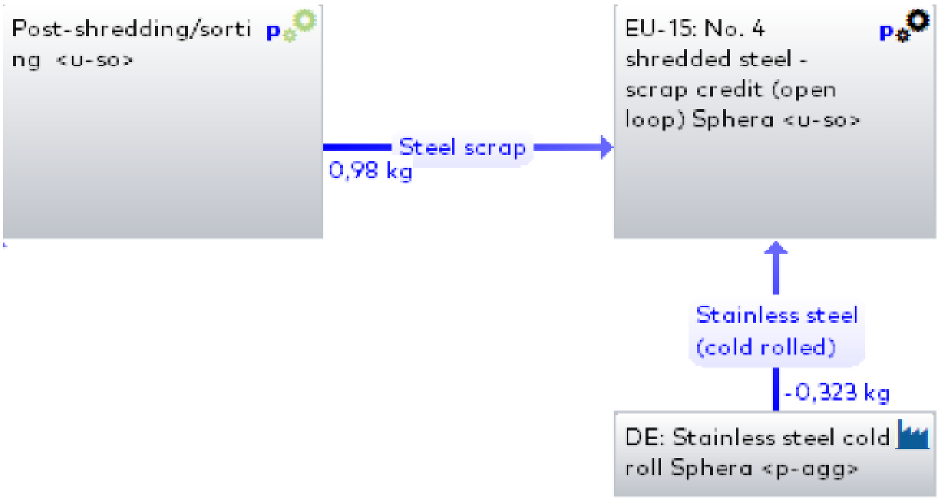

Figure 7 an example of the value-corrected substitution method

Exclusion and cut-off criteria

To keep the scope of the LCA manageable within the available timeframe and focus the analysis on the most impactful elements, some processes and materials will need to be excluded. Processes will be excluded if their mass or energy flows are less than 1% of the total. Mass and energy are used to estimate environmental relevance, as it is not possible to determine the environmental relevance of a flow without conducting an LCA.

Data sources, data collection and assumptions

The data of the database from Sphera GaBi is used for all the background processes of the life cycle of the demonstrators. This includes the production of steel ingots, sheets and plastic granulate, but also the flow inputs as electricity and cooling water. The most representable data regarding the real-life scenario is used to make an as accurate analysis as possible. The processes that are used to fabricate the parts themselves are derived from manufacturing partners and the production area. The difference in use phase emissions of the business-as usual situation versus the demo cases are measured and calculated by the partners of the AeroSolfd project and will serve as the benchmark to compare and evaluate the total life cycle emissions of the demo cases.

As data collection method, templates (see Annex 1: LCA data collection templates) will be used to ensure that the correct data is requested from the partners in a structured way. The templates will be shared with the partners, who will be asked to fill them in and provide it to the environmental analysist. Two templates will be used:

- Bill of Materials (BOM) of all products and components used. The BOM template covers the composition of the product, the raw materials used, and transport distances or purchase location (in which case the distance will be calculated using Google Maps).
- Process flow template. This template is used to identify energy and resource usage and emissions flows for every process in the life cycle. These templates are specifically used for primary data, i.e. directly from the manufacturing partners.

The data collection for the LCA will cover the five life cycle phases (as described in 5.1) of the use-cases as follows:

1. **The extraction of all raw materials.** This data will mostly come from secondary sources (databases and literature). The amount of raw material used will be identified using the BOM templates.
2. **The production and manufacturing of the parts and the product.** This data will be retrieved from the process flow templates provided by the suppliers and manufacturers. If primary data is not available, it is important that the LCA specialist has a good technical understanding of the manufacturing (and assembly) technologies and processes in order to find data that is as close to the specific case as possible. This technical understanding can be gained through meetings and interviews with product-specific suppliers and project partners with this knowledge.
3. **The transportation of materials and parts to the manufacturing sites.** This data will be gathered using the BOM template. Data owners are likely to be person(s) within the product manufacturers who are responsible for the procurement of materials.
4. **The use phase emissions of the business as usual situation and the demo case situation.** Data on the emissions during the use phase of the business-as-usual scenario and the demonstration case scenario will be collected through measurements and calculations during field tests as part of the AeroSolfd project.
5. **The end-of-life of the products themselves**. Data concerning the processes for waste disposal will be gathered using the process flow template provided by the stakeholders responsible for this task.

6. SOCIAL LIFECYCLE ASSESSMENT

6.1. METHODOLOGY USED IN AEROSOLFD

The UNEP/SETAC Life Cycle Initiative developed a methodological framework for developing Social Life Cycle Analysis (S-LCA) which follows the same steps of the environmental LCA, explained I section 5.1; and which is aligned with ISO 14040 and ISO 14044.

An extensive list of indicators for performing S-LCA was developed based on guidelines and standards of Corporate Social Responsibility such as ISO 26000 and Global Reporting Initiative (GRI). But as recently referred by several authors, including Toniolo and colleagues (2020), '*However, the level of methodological development, application, and harmonization of S-LCA is still at a preliminary stage.'* In fact, a list of indicators for performing S-LCA is far from a common accepted one, as the indicators are too high level and lack detail to conveniently address the social impacts of a specific product or service along its life cycle.

Hence, in a first stage, it turned out the need to revisit some guidelines of International Association for Impact Assessment and cross the S-LCA framework with the methodologies and indicators used in Social Impact Assessment of projects, in a way to enlarge and improve the batteries of indicators for performing S-LCA, and for linking midpoints and endpoints (UN SDG). This is then to be revised/complemented with information rising from interviews with operators and other experts, similarly to the work developed by Jasinsky and colleagues (2016).

The following image extracted from RiskGONE Deliverable 3.5 – Guidelines on Societal Acceptance of Nanomaterials, adapted by Factor Social (FS), provides an insight of the steps that will be performed for evaluating the Social impacts of the AeroSolfd solutions, which results from crossing S-LCA and Social Impact Assessment methodologies.

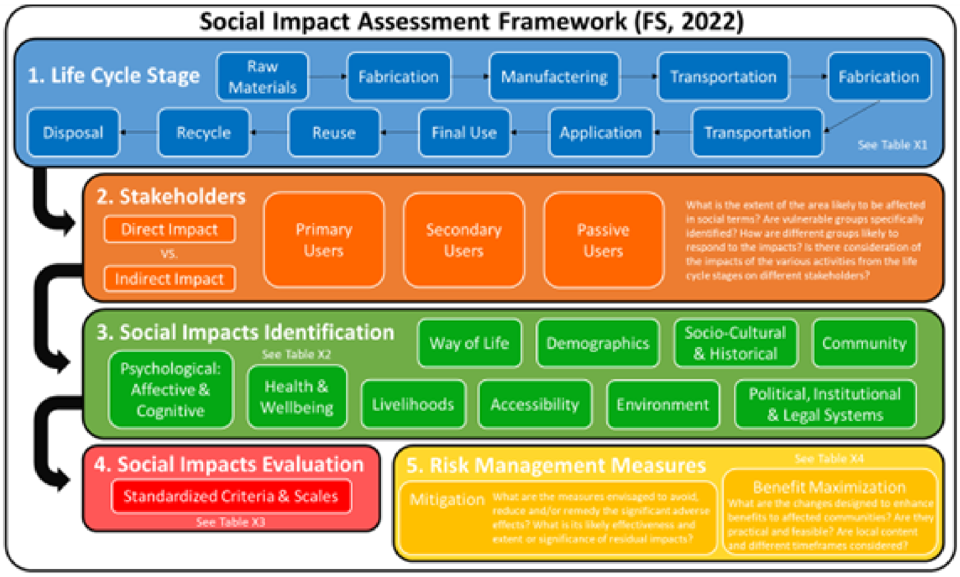

Figure 8 Social Life Cycle Impact Assessment Framework

Selection of Life cycle boundaries

The intended application of S-LCA to AeroSolfd solutions will be:

- learning about the product and identifying positive and/or negative social “hotspots” and the options for reducing the potential negative impacts and risks (or improving positive impacts and risks), through product development and action in the supply chain, or through product use, and handling during operation and/or disposal.
- establishment of improved purchasing procedures or specifications, marketing, reporting and labelling, strategic planning, or development of public policies which can support the reduction of negative impacts or granting positive impacts. (…)

Thus, on a first stage we will be focusing on the manufacturing, operation stages and disposal of materials.

Stakeholders

In order to identify the stakeholders to be considered in S-LCA, one shall screen a wide range of groups such as the ones presented in the following figure.

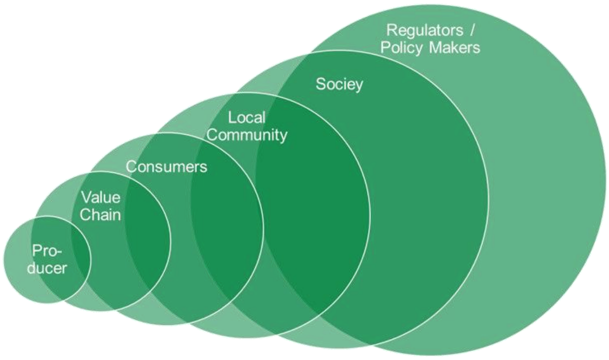

Figure 9 Groups that shall be screened for identifying stakeholders

Following the Social Impact Assessment Framework displayed in RiskGONE Deliverable 3.5 – Guidelines on Societal Acceptance of Nanomaterials, adapted by Factor Social (FS), for fully identifying the social impacts, one needs to consider the different groups of stakeholders, considering the three subset of stakeholders:

- Primary user – direct user of the product; those who manipulate or use the product (product developers, drivers, maintenance…)
- Secondary user – people dealing with remaining or modified parts of the product ; e.g. people dealing with waste materials or those who are reusing products, or people dealing with materials that are part of previous products for instance due to circularity of materials (waste collectors)
- Passive user – Person exposed to the product, or affected by the development or operation of the product (e.g. companies using the product – effect on image; cities where the vehicles operate; citizens...).

The following table provides a first overview of the stakeholders that shall be considered during the Social Impact Assessment.

Table 2 Stakeholders to be considered during the Social Impact Assessment

	Manufacturing	Operation	Disposal

Primary Users	Producer and its workers Suppliers of components/raw materials	Maintenance companies and workers Drivers	Maintenance companies and workers Companies performing waste collection and management and their workers,
Secondary Users	Companies performing waste collection and management and their workers, re-users May require the engagement of policy makers or regulators of waste management in case changes to regulations are required		
Passive Users	Families of the workers, Citizens from communities surrounding the manufacturing areas,	Companies using the products(from companies or individual ones), Municipalities (city managers) Citizens living in areas where transports using the solutions will be running	Municipalities (city managers) citizens exposed to results of product reuses or end-of-life treatment

We can address stakeholders either directly or through their representatives.

Social impacts identification

In order to identify broad categories of social impacts that can be connected with AeroSolfd solutions, the team performed 3 steps in parallel:

- Critical analysis of the hotspots, midpoints and endpoints presented in the Jasinsky paper
- Interviews with stakeholders as complementary information to eventual social impacts of the solutions being developed;
- Critical analysis of the inventory indicators' list provided in the Methodological Sheets for Sub-Categories in Social Life Cycle Assessment (UNEP & SETAC, 2013) which covers most of the indicators presented in S-LCA literature;
- Literature review on $PM_{2.5}$ social impacts.

The critical analysis of the hotspots midpoints and end-points presented in the Jasinsky paper and the critical analysis of the inventor indicators provided by S-LCA literature can be found in the Annex 2.

The following table presents a list of possible social impacts rising from a first screening of literature review on PM2,5 social impacts, and relates them with different types of stakeholders to be considered.

Table 3 List of possible social impacts

Groups of stakeholders	Pre-assessment of possible social impacts
Competitors for the same raw materials	• How does the competition for the raw product impact on: ○ the price of the materials ○ other activities (e.g. are there activities which cannot afford the price and will be ending, with prejudice for the workers of such activities and their families, and eventually for cultural heritage)
Developers	• Jobs created and families' economy • Work safety – How safe is the maintenance, is there the need for special protective measures? • Economic profitability of the company
Communities surrounding the factory	• Which are the risks associated to the process, accidents on the facility and contamination of environment (air, water or soil), and how can it affect surrounding communities?
Users (companies and drivers)	Interference with: • Driving • Vehicle performance and impact on fuel consumption • Maintenance (changes on maintenance required and economic impact will define if people are lefts with more money or less money on their pockets) • Image (personal/company)
Maintenance	Direct or indirect (i.e.: does it conflict with other parts of the vehicle posing difficulties to their maintenance?) • Work overload - How easy is maintenance, does it imply more hours of work? • Work capability / training – Are there special capabilities required for maintenance? • Work safety – How safe is the maintenance, is there the need for special protective measures?
Citizens	Exposure to noise, air quality, waste and its indirect impact on: • Health ○ Improved Health due to reducing $PM_{2.5}$ effects (premature death in people with heart or lung disease; nonfatal heart attacks; irregular heartbeat; aggravated asthma; decreased lung function; increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing -EPA). ○ Health effects due to other impacts of the technology (e.g. impacts of the technology on noise, waste…) ○ How do Health impacts reflect on health services? ○ How do Health impacts reflect on demographics? • Quality of Life ○ Improving quality of life by reducing $PM_{2.5}$ physiological stress; ○ Impacts on attention, performance, social support and social cohesion, due to other impacts of the technology (e.g. impacts of the technology on noise, waste…)? • Livelihood and socio-cultural heritage ○ Reducing possible impacts on fishing, tourism or other human activities (by reducing lakes and streams acidic and/or changing the

Groups of stakeholders	Pre-assessment of possible social impacts
	nutrient balance in coastal waters and large river basins and consequently in ecosystems biodiversity – EPA) ○ Reducing possible impacts on agriculture and possible local products (economic impact, impact on ways of living and possible cultural impact, depending on how heritage representative are the cultures affected) ○ Other possible impacts on activities due to other impacts of the technology (e.g. impacts of the waste on soil and water; impacts of collecting or competing for raw materials in other human activities)? • Community identity ○ Risk Perception towards $PM_{2.5}$ and values regarding air quality and is relevance
City Managers	• City environmental quality, identity and attractivity (impact of environmental indicators on attracting economic activities – tourism, companies… and increased economy and quality of life) ○ Air quality ○ Noise ○ Waste • Built Heritage ○ Reducing $PM_{2.5}$ will decrease their contribution to acid rain effects on materials such as stain and damage stone and other materials, including culturally important objects such as statues and monuments.
Political, Institutional and Legal	• Social Pressure for Legal/Regulatory change towards improved control of $PM_{2.5}$
Waste collectors and waste treatment / waste reuse	• Work safety – How safe is the maintenance, is there the need for special protective measures? • Work capability / training – Are there special capabilities required for waste treatment or for product reuse or recycling? • Economic profitability of the process and/or company; • Any new jobs created and families' economy?

After merging indicators coming from the 4 sets of sources (Social LCA, Jasinsky paper, stakeholders' interviews and $PM_{2.5}$ impact assessment literature review) a first screening was performed to identify a first version of the list of indicators to be used in AeroSolfd Social LCA.

Social impacts Evaluation

Below we present a table of categories of impacts that are common to use on evaluating impacts of projects (roads, industries…). The challenge is to adapt it to the products and choose what are relevant for evaluating AeroSolfd solutions' social impacts. This selection and adaptation will be performed in a later stage.

Table 4 Evaluation of Impacts

Criteria	Scale
Direct / Indirect	Direct (first order) / Indirect (second order, third order..)

Criteria	**Scale**
Direction	Positive / Neutral / Negative
Significance	Null or Non Significant / Very Low / Low / Medium / High / Very High
Magnitude	Nule (0% - 1%) / Very Low (1% - 5%) / Low (5% - 30%) / Medium (30% - 70%) / High (70% - 95%) / Very High (95% - 99%) / Extreme (99% - 100%)
Geographical Extension	Individual / Household / Neighbourhood / Parish / District Region / Country / International
Duration	Days / Months / Momentary (Less than 1 year) / Short term (1 - 5 years) / Medium term (5 - 10 years, less than project lifespan) / Long term (10 - 20 years, lifespan of the project) / Multiple generations
Reversibility	Reversible / Irreversible
Likelihood	Uncertain / Certain None / Unlikely / Likely / Most Likely / Definite
Confidence	Low / Medium / High
Consequence	Insignificant / Minor / Moderate / Major / Catastrophic
Importance	Low (< 4) / Medium (4 - 5.9) / High (> 6)
Intensity	None / Low / Medium / High / Very High
Reference scale	+2 (Ideal performance) +1 (Progress beyond) 0 (Compliance with local laws) -1 (Non-compliant situation, Improving) -2 (No data, or Noncompliant Situation)

Risk Management Measures

In the end risk management measures will be proposed for the most significant impacts, considering both positive and negative impacts. These will be discussed with the product owners to select which ones to be implemented, by whom and how.

Besides interpretation of results and LCA reporting (which include social impact evaluation and risk management measures, the Life Cycle Interpretation shall also provide.

- Consistency & completeness check,
- Evaluation of the level of stakeholders' engagement
- Contribution, sensitivity and uncertainty analysis.

6.2. FORESEEN INFORMATION REQUIREMENTS AND DATA COLLECTION PLAN

In line with S-LCA, the main steps for data gathering are the following:

a) Identify impact categories and subcategories to be addressed

b) Define the types of impact to be evaluated and the related indicators and methods.

c) Plan the interpretation and identify assumptions, limitations, analyse data quality

d) Primary data; collected by the organisations (e.g. audits of enterprise documentation and documentation of authorities), use of participative methodologies (interviews, focus groups, questionnaires, and surveys)

e) Secondary data; literature, expert interviews, reports, LCI databases

The stages for conducting the first two steps (identification of impact categories and subcategories and definition of indicators) were explained before, in the previous section.

Opposite to Environmental LCA which is already a well-established process with clear categories and indicators data sets which are commonly accepted, the S-LCA is a young process with considerable limitations such as the following, pointed out by several authors including Jacob-Lopes et al (2021):

•*(…) although there are guide categories to date, the indices and subindices of the indicators have not been well established.*

•*(...) a factor of major awareness about the social life cycle assessment, it is the mode of obtaining the data, since this approach uses imprecise and site-specific data determined.*

•*(…) the measurement process can be quantitative, semiquantitative, or qualitative,*

• *(…) incomplete, as it misses non-social phenomena that cause social impacts* (e.g. environmental data)

Because of it, S-LCA is still a very iterative process, moving back and forward, and the interpretation and assumptions, limitations and data quality strongly depend on the information that will be find out during the data gathering process.

Moreover, because AeroSolfd solutions are still being developed and this is an early stage in the process, while reports will be able to provide reliable quantitative indicators on Business as Usual scenario (e.g. number of workers), it will be hard to have concrete quantitative estimations for indicators regarding the AeroSolfd solutions' scenario (e.g. how many workers will be hired for producing 100.000 units of the AeroSolfd solution).

The information requirements directly depend on the categories of social impacts and indicators selected for performing the assessment. The image below, extracted from the Guidelines for Social Life Cycle Assessment of Products (UNEP& SETAC, 2009) presents the reasoning between categories and subcategories of social dimensions to be addressed, and data to be gathered concerning the relevant indicators.

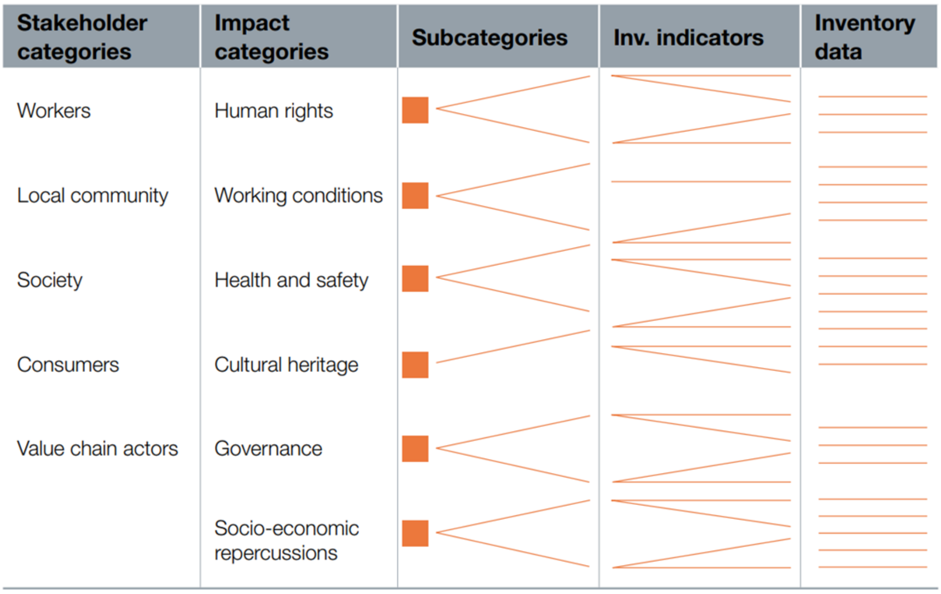

Figure 10 Assessment system from categories to unit of measurement. Adapted from Benoit et al., 2007

In line with those, the main sources of information for data gathering when performing the product social assessment will be:

- **Formal and Legal Reports from the manufacturing companies which** may contain relevant data concerning the social indicators
- **Interviews with stakeholders** which can report how the product affects for instance the producer (e.g. changes in number of workers...), of the operations (e.g. driving, maintenance...) and which allows to establish the difference between the Business as Usual scenario and the demo case scenario – in order to produce reliable data the team will try to find the person within the organisation which can represent the most reliable source for the data;
- **Calculations and conclusions rising from Environmental LCA and from Health assessment** as these provide relevant information for foreseeing social impacts (e.g. environmental impacts concerning acidotic rain (increase or decrease) will define the impact in public outdoor artwork).
- **Social widely accepted data sets** such as EUROSTAT or National Statistics Institutes. The team aims to present the evaluation of social impacts in a semi-quantitative way.

A detailed list of the indicators, the methodology for collecting each of them and the form they will be presented (qualitative, semi-quantitative or quantitative), and their connection with Sustainable Development Goals, is presented in Annex 2.

7. OVERALL SUSTAINABILITY ASSESSMENT

The overall sustainability assessment in AeroSolfd will be based on an integrated analysis of the information obtained as part of the human and environmental risk assessment (HRA and ERA) along the product LC as well as the LCA and S-LCA results and how they contribute to overall sustainability goals. Below we make an overview of the approaches and method considered to be integrated in the framework. These elements include the stage-gate innovation risk governance framework, HRA, ERA, LCA, and S-LCA and existing sustainability frameworks and goals defined by the UN.

Each approach will as well identify the focused impact category and the corresponding midpoint, starting from the identified SDG (Sustainable Development Goal) endpoints and by going backwards (dotted arrows in the figure 11 below). The SDG endpoints and their targets and indicators can as well be used as reference for the midpoint identification in order to align the impacts and harmonize the data collection and inventory contemplating the impacts indicators at different stages and along the cause-effect chain (green arrows in the figure 11 below) before the SDG endpoint is reached.

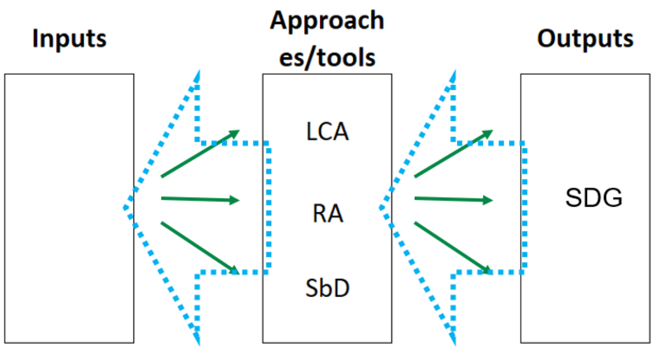

Figure 11 Sketch representing the conceptual framework approach

7.1. UN SUSTAINABILITY GOALS AND RELEVANT SUSTAINABILITY FRAMEWORKS

The retrofit solutions proposed in AeroSolfd will directly contribute to some of the seventeen UN Sustainable Development Goals (SDG) which are presented below through their UN description; and with a graphical presentation (Figure 12) that includes the association with dimensions of sustainability impact of AeroSolfd. The UN SDGs to which AeroSolfd will contribute are:

SDG 3 - Good Health and Well-Being (Ensure healthy lives and promote well-being for all at all ages);

SDG 6 - Clean Water and Sanitation (Ensure availability and sustainable management of water and sanitation for all);

SDG 8 - Decent Work and Economic Growth (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all);

SDG 9 - Industry, Innovation and Infrastructure (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation);

SDG 11 - Sustainable Cities and Communities (Make cities and human settlements inclusive, safe, resilient and sustainable);

SDG 12 - Responsible Consumption and Production (Ensure sustainable consumption and production patterns);

SDG 14 - Life below Water (Conserve and sustainably use the oceans, seas and marine resources for sustainable development);

SDG 15 - Life on Land (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss);

SDG 17 - Partnerships for the Goals (Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development).

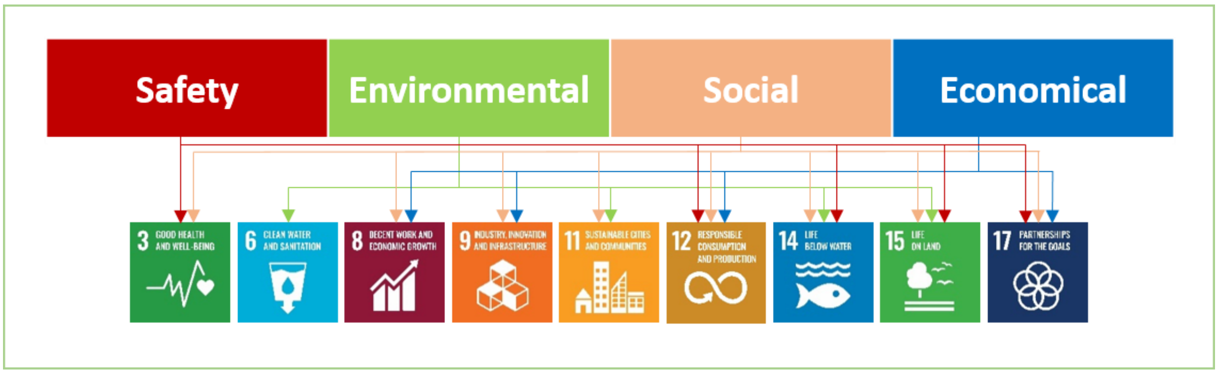

Figure 12 the sustainability impact dimension and UNSDGs in AeroSolfd

Relevant sustainability frameworks and concepts were taken into consideration (i.e: Safe and Sustainable by Design – SSbD; JRC-Safe and Sustainable by Design chemicals and materials; Cefic-Safe-and-Sustainable-by-Design-Guidance; Jasinsky et al. 2016 - A comprehensive framework for automotive sustainability assessment) as well as recent policies; such as the Chemicals Strategy for Sustainability (CSS, 2020); Zero Pollution Action Plan; Circular Economy Action Plan; European Green Deal (2021); EU's 2030 Climate Target on the way to climate neutrality; Materials 2030 Manifesto; Advanced Materials Initiative 2030 (AMI2030); Strategic Research and Innovation Plan for safe and sustainable Chemicals and Materials; and UN Transportation report 2021.

7.2. OVERALL SUSTAINABILITY FRAMEWORK FOR AEROSOLFD

A preliminary *top-down* conceptual sustainability assessment framework was proposed and discussed. The overall framework concept was built on the SDGs, to which the project will contribute, and was inspired by life cycle thinking approach described in "A comprehensive framework for automotive sustainability assessment" by Jasinsky et al. 2016.

The Indicators and Targets envisioned by the UN related to the SDGs to which AeroSolfd aims to contribute were underlined and whether possible integrated with other specific indicators identified by the expert's partners of AeroSolfd project (ANNEX 3). This was done in order to build a tailored overall sustainability assessment framework to the AeroSolfd products and contributions and in line with the SDGs as envisioned by UN.

The overall framework was conceived by starting from the SDGs related to AeroSolfd project, and draw back to the Impact categories, via the approach and tools in order to identify the inputs necessary data needed from external stakeholders and WP leaders for the three AeroSolfd retrofit solutions, as illustrated in Figure 11 presenting the sketch of the conceptual framework approach. A preliminary draft version of the framework was built and shared with the partners for discussion. This first version of the framework was built on life cycle thinking approach proposed in the Jasinsky et al. The framework included a first attempt reflection of the changes expected to be achieved by AeroSolfd retrofit solutions, as well as some qualitative indicator related to these changes and the possible approach for assessing it (e.g.: Governance, LCA, S-LCA, HRA, ERA). The UN SDGs to which AeroSolfd contributes were kept as the End-Points of the framework. An overview of the framework, built in an Excel Spreadsheet, is presented in the ANNEX 4.

The framework was circulated within WP4's Partners and feedback and exchanges of views were gathered in round-table meetings consultations. Which lead to an update of the whole framework concept including the addition of the safety section that was not taken into account in the previous version.

The update version of the framework referred more clearly to the four safety and sustainability dimensions (i.e.: Safety aspects along the value chain; Environmental/Resource aspects; Social criteria aspects [workers, local communities & consumers]; Economic aspects [Market related criteria]) as also described by the JRC Technical report on Safe and Sustainable by Design chemicals and materials.

This new design of the framework included a preliminary data requirements list section, with the aim to be discussed and shaped with stakeholders engaged in providing that data; a section for the identification of potential indicators and aspects that may useful to take into account (as inspired by the JRC Technical Report on Safe and Sustainable by Designs chemical and materials and by the Safe and Sustainable-by-Design report of CEFIC); and a section for identifying the corresponding approach used (i.e.: for the ERA, HRA, LCA, S-LCA).

The overall updated conceptual framework was then built as illustrated in the graphical sketch in Figure 13 below. This version of the framework consist on the basic building block build on the specific case of AeroSolfd which will be expanded and further developed through the stage-gate innovation funnel concept. In fact, AeroSolfd project has higher TRL which corresponds to an advanced step in the innovation funnel process as illustrated in the figure below.

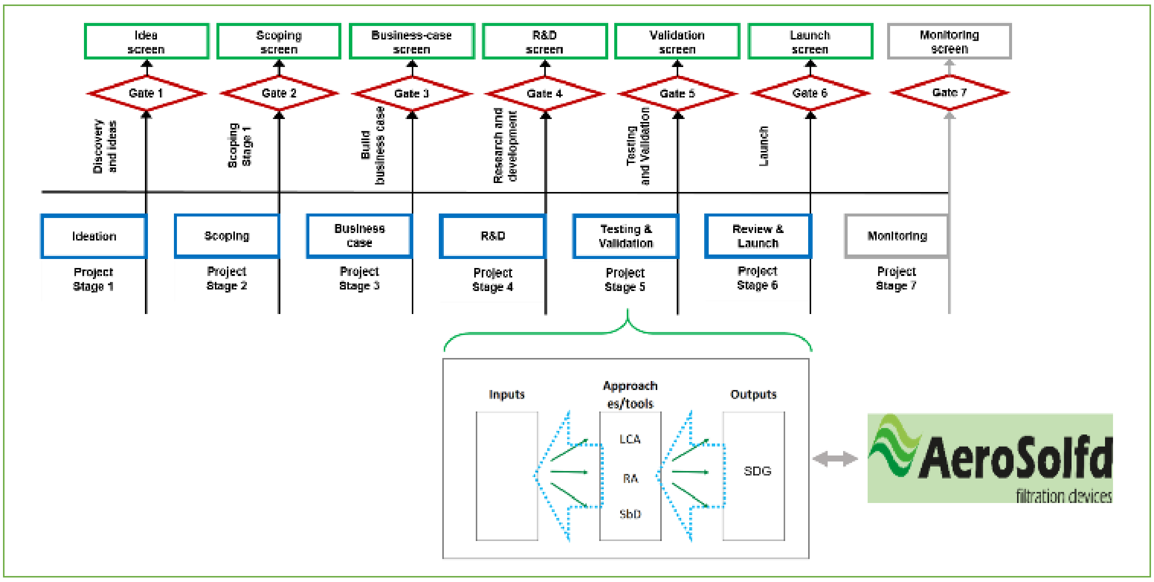

Figure 13 conceptual framework for the sustainability assessment in AeroSolfd

Through a *bottom-up* approach this block of the framework will be further refined based on the scoping and pre-risk assessment scenarios for the three line of the AeroSolfd products and solutions, which were discussed in Chapter 3.

Following the preliminary *top-down* approaches, the *bottom-up* approach was then built on dialogues with the WPs leading partners engaged in the development of the three AeroSolfd products and solutions; namely: 1) Tailpipe Retrofit- Development and Demonstration (WP1), 2) Retrofit Brake Dust particle filter – Development and Demonstration (WP2), 3) Retrofit solutions for closed environments -Product Optimisation and Demonstration (WP3).

The *bottom-up* approach is presented in Chapter 3 and consisted of a Tier 1 qualitative Human and Environmental pre-risk assessment (or categorization) to allow a comparable risk scoping of the human exposure and environmental release of chemicals and particles during the LC phases ((1) the raw materials/intermediates; 2) the manufacturing of item/assembly item; 3) the downstream sales; 4) the in use/maintenance; and 5) the recycling/end-of-life) for each of the three line of the AeroSolfd products and solutions.

The scoping analysis helps us to identify processes and LC phases of potential concern for chemicals and particles exposure and release along the LC and forms the background for dialogue and prioritization for data gathering with the AeroSolfd developers. The final selection of measurements is made after additional dialogue and site visits.

The description of process scenarios will moreover help to further refine the LCA (presented in Chapter 5) and S-LCA (presented in Chapter 6) which can be framed and outlined in accordance with AeroSolfd project specific cases.

For example, understanding the processes involved in manufacturing AeroSolfd products is crucial for establishing process flows. This, in turn, provides guidance on what data needs to be collected in terms of material, energy, and chemical inputs for each phase of the LCA – including Raw Materials, Production, Transport, Use, and Disposal. Additionally, knowing when and where these processes occur helps in defining the temporal and geographical boundaries necessary to select the most relevant dataset for the specific region where these processes are located. Furthermore, assumptions specific to AeroSolfd process scenarios can be made as needed

Understanding the processes of the AeroSolfd products and services helps to refine further the S-LCA study as well. For instance, the information on the process relatively to the manufacturing, operational, use and disposal helps to identify the stakeholders involved which is crucial for a comprehensive assessment of social impacts. Additionally, this information assists in categorizing stakeholders throughout the life cycle phases. This categorization, in turn, refines the identification of categories of social impacts associated with AeroSolfd solutions, as discussed in Chapter 6.

Through a *bottom-up* approach the block below (Figure 14) showing the overall framework will be further refined based on the scoping and pre-risk assessment scenarios for the three line of the AeroSolfd products and solutions, which were discussed in Chapter 3.

The ongoing further improvement of the overall framework will be based on the data collection and measurement from the demonstrations activities. These will as well help to the refinement of the dimensions and aspect contributing to the SDGs to which AeroSolfd aims.

In the overall framework we considered four dimension and specifically addressed the safety. In fact while recognising that safety is an integral part of the three sustainability dimensions (environmental, social and economic) with the discussion and analysis of scoping scenario we identified the potential safety aspects inherent to each of the AeroSolfd solutions. The further improvement of the framework will therefore determine the specific criteria and the essential inputs for the assessment of the safety aspects, and whether they should be primarily based on their intrinsic hazard properties or on hazards combined with exposure in relation to their application or use in line with the ongoing discussions within the scientific community in the context of SSbD.

The improvement of the framework will as well refine the elements of the dimension and aspect considered in the framework that will contribute to the SDGs identified in the AeroSolfd aim. As per within the Safety dimension will contribute to Goal 3, Goal 12, Goal 14, Goal 15 and Goal 17; and within the Environmental dimension will contribute to Goal 6, Goal 11, Goal 14 and Goal 15; and within the Social Dimension will contribute to Goal 3, Goal 8, Goal 9, Goal 11, Goal 12, Goal 14, Goal 15 and Goal 17; while within the Economical dimension will contribute to Goal 8, Goal 9, Goal 12 and Goal 17; (see illustration in Figure 12 the sustainability impact dimension and UNSDGs in AeroSolfd above).

7.2.1. ENVIRONMENTAL IMPACT ON HISTORICAL BUILDINGS

For the environmental impact, the project is set to reduce impact on global warming and detrimental impact on historical buildings by soot and acidic emissions. Numbers concerning these aspects will in part be derived from the LCA approach where mass-flow analysis are completed (Chapter 5). A first tier environmental impact assessment can be made by estimating the effect of changed emission and thereby change in air-pollution levels of e.g., CO_2, NO_x, SO_2, ultrafine particles, $PM_{2.5}$ and PM_{10} as well as BC, EC and OC when implementing retrofit solutions at different scales. To allow an estimate of the positive impact by reducing the concentration of specific air-pollution components, it is necessary to perform a literature study to investigate whether any quantitative links have been made between levels of specific air pollutants and damage to buildings.

The demonstration activities performed within the project will furthermore determine a baseline of the emission before the implementation of the retrofit filtration solutions (i.e.: the tailpipe filter, the brake dust particle filter and the filter squares filters) and the effect of the retrofit solutions in reducing the damage to historic buildings as well as the reduction of the impact on the health and environment will be assessed afterwards comparing in comparison with the data from literature studies.

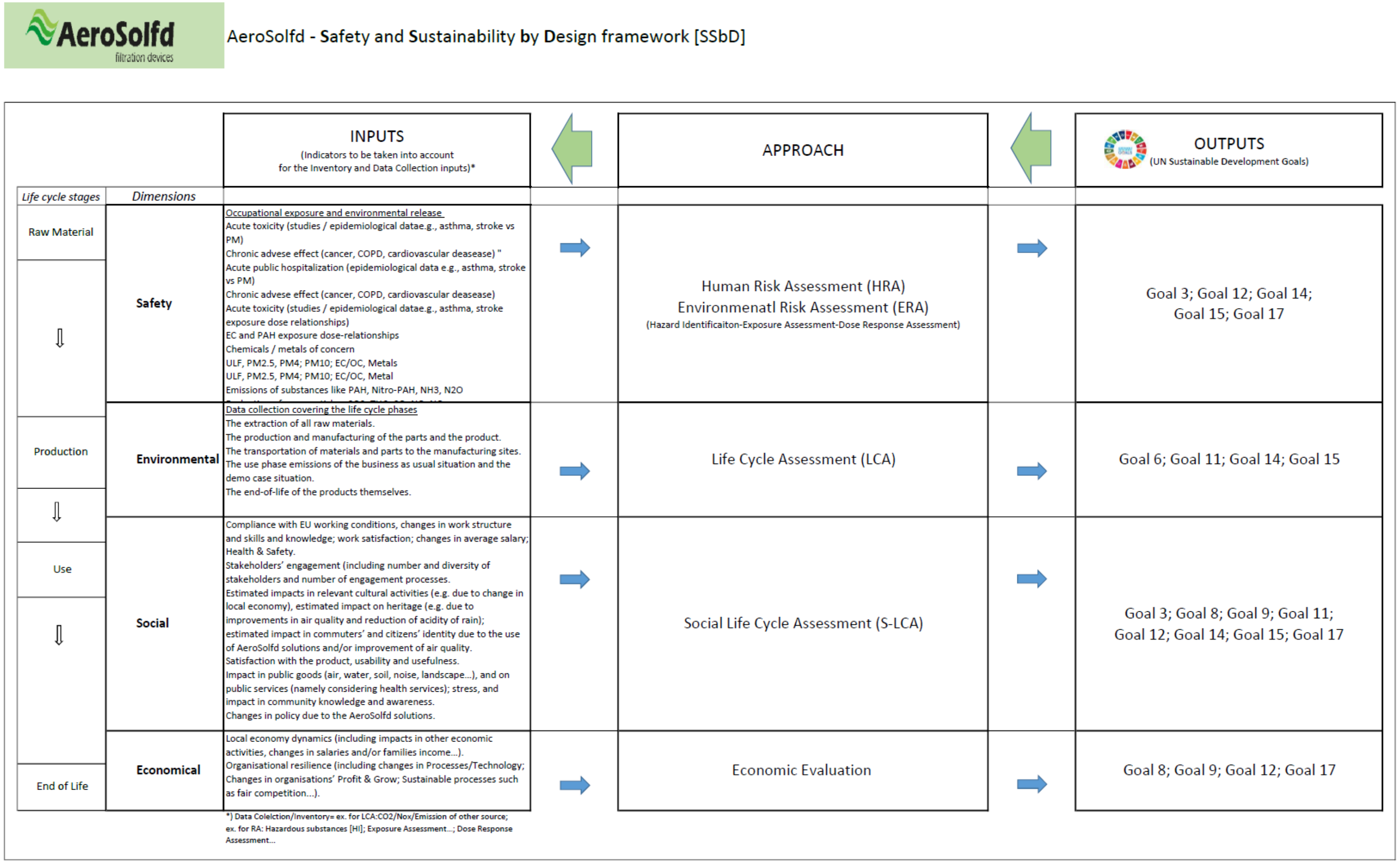

Figure 14 conceptual strategy for the overall sustainability framework and process for identification of information requirements

7.3. DATA COLLECTION PLAN FOR OVERALL SUSTAINABILITY ASSESSMENTY

In this section we introduce the preliminary list of the indicators that have been identified in the *top-down* approach. They were identified for the Data Collection and Inventory (e.g.: Data Collection/Inventory= ex. for LCA: CO2/NOx/Emission of other source; ex. for RA: Hazardous substances identification; Exposure Assessment; Dose Response Assessment) as per the inputs phase.

The list of indicators will be then combined with the specific case/scenario identified in the *bottom-up* approach and the plan for the data collection and the applicable criteria will be determined accordingly.

The data collection process for LCA will employ specialized templates to ensure a structured and precise delivery. The main templates used are:

Bill of Materials (BOM) of all products and components used. The BOM template covers the composition of the product, the raw materials used, and transport distances or purchase location.

Process flow template. This template is used to identify energy and resource usage and emissions flows for every process in the life cycle. These templates are specifically used for primary data.

The data collection for the LCA requires a Life Cycle Inventory, can be classified in the five following phases:

1) Raw materials: Data mostly based on literature and existing databases. Includes Bill of Materials
2) Parts and product manufacturing: Focuses on process flows by suppliers and manufacturers
3) Transportation: Data on the transportation to the manufacturing sites
4) Product use: Data on the use phase of the product in a business-as-usual scenario and the demonstration case scenario
5) End-of-Life: Focuses on process flows for waste disposal

The data provided in the phases above mentioned are needed to evaluate the environmental impact of a product or system over its entire life cycle. For the LCA, the use of specialized software tools (GaBi) is needed. GaBi allows to perform and interpret the results to identify the kye areas to focus on the environmental impact.

The data requirements and their application for the tailpipe, break dust filter and filter square are shown in Tables 1, 2 and 3 respectively.

Table 5 TAILPIPE data collection plan

TAILPIPE	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
Safety (Professionals)	Occupational exposure assessments require information of the specific exposure characteristics and exposure levels during work processes (e.g., handling cordierite, assembly welding, cutting tail-pipe muffler, and demounting, in-use emissions) or emission rates determined from simulated work or handling processes. The data include particle number size-distribution and mass-concentrations in regulatory relevant size-fractions and concentrations of mtals, EC, PAH's and other volatile compounds of potential concern (e.g., COx, NOx). Testing of dustiness or release during handling of the ceramic cordierite filter material and release during handling potential accidents are needed as critical acute exposure risks. Exposures during the proposed recycling approach will be considered. Occupational exposure to on-road workers (e.g., drivers) will be assessed from changed ambient air-pollution assessments. OEL's or toxicological data on the filter material cordierite, chemicals used and process-generated emissions and exposures (e.g., welding fumes; tail-pipe exhaust, as well as exposures expected during recycling). Assessments may be made considering the difference between exposure without and with exhaust filtration.	WP1; WP4	X		X	X
Safety (Public)	The exposure data from occupational exposure measurements and emission rate analysis will be used to estimate exposure from the industrial processes to the public. Tail-pipe exhaust exposure resulting in ambient air-pollution exposure will be assessed from modelling (likely scenario-based scaling) based on WP1 emission measurements.	WP1, WP4	X		X	X

TAILPIPE	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
	Hazard information requirements is similar as the ones for occupational exposure assessment, but the change in tail-pipe emissions is the most important for public risk assessment. Besides hazard assessments on specific exposures, epidemiological data on adverse health effects linked to specific air-pollution levels and compounds will be used as well.					
Environmental	Information relative to the manufacturing processes, materials of all products and components used;	WP1			X	X
	Energy and resource usage for each phase;	WP1			X	
	Emissions flows for every process in each phase; Brake-wear emissions ending up in air, water, and soil.	WP1		X	X	X
Social	Evidence of compliance or of moving beyond, EU working conditions; analysis of the workers' profile and salaries; results of work satisfaction surveys; analysis of the register of accidents and incidents related with the specific product line.	WP1				X
	Evidence on processes of stakeholders' engagement – analysis of number of stakeholders engaged and diversity of groups of stakeholders represented.	WP1				X
	Relevance of materials being used for different types of activities; information from environmental LCA, information on local identity and its connection to environmental quality.	WP1				X
	Analysis of results of surveys or other studies on users' satisfaction with the product.	WP1				X
	Results from environmental LCA, results from the Health Assessment, literature review linking PM2,5 with stress, evidence of awareness raising campaigns.	Literature…				X
	Analysis of evidence relating policy change with the AeroSolfd solutions.					

TAILPIPE	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
Economical	Induced changes in price of raw materials and its impact in activities using them, suppliers' income, country in which suppliers' operate, terms of contracts with suppliers (e.g. requirements concerning standard certification, payment time), diversification of processes and of products, number of patents registered, income to the developer/manufacturer companies.	WP1				X
	Processes/Technology; information on business plans and product investment and profits predicted.	WP1				X
	Evidences on the implementation of good practices (e.g practices of sustainability, fair competition; Non-Bribery/Anti-Corruption; life-work balance...).	WP1				X
	Reports/studies on the impact of the use of the AeroSolfd technologies in the companies' image; complaints registers.	WP1				X
		WP1				X

*) Source of Data

Table 6 BRAKE DUST FILTER data collection plan

BRAKE DUST FILTER	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
Safety (Professionals)	Occupational exposure measurements of particles and dust during manufacturing processes (steel laser welding expected),		X		X	X

BRAKE DUST FILTER	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
	mounting (metal drilling expected) and service (brake-wear particles). Used filter cages will be tested for potential release during accidental dropping the filter. Particles and fume exposures during anticipated recycling processes will be assessed considering the most likely recycling route(s). A large part of the manufacturing process is upstream and cannot be assessed directly. Occupational exposure to on-road workers (e.g., drivers) will be assessed from changed ambient air-pollution assessments. OELs and hazard information is on laser welding, steel drilling dust and brake-wear particles. As specific toxicological data may not be available on brake-wear particles, assessments require collection of information the physicochemical exposure characteristics (size-distribution, chemical composition, and additional data on toxicologically relevant hazard indicators).					
Safety (Public)	The exposure data from occupational exposure measurements during manufacturing processes (laser welding expected), mounting (metal drilling) and service (brake-wear particles) will be used to estimate exposure from the industrial processes to the public. The change in brake-wear emissions is the key exposure to the public and will be assessed from modelling (likely scenario-based scaling) based on WP2 emission measurements. Hazard information requirements is similar as the ones for occupational exposure assessment, but the change in brake-wear particle emissions is the most important for public risk assessment. Besides derived hazard data on in particular brake-wear particles, epidemiological data on adverse health effects		X		X	X

BRAKE DUST FILTER	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
	linked to $PM_{2.5}$ and PM_{10} as well as specific metals (if possible) will be used as well.					
Environmental	Information relative to the manufacturing processes, materials of all products and components used;	WP2			X	X
	Energy and resource usage for each phase;	WP2			X	
	Emissions flows for every process and in each phase; Brake-wear emissions ending up in air, water, and soil.	WP2		X	X	X
Social	Evidence of compliance or of moving beyond, EU working conditions; analysis of the workers' profile and salaries; results of work satisfaction surveys; analysis of the register of accidents and incidents related with the specific product line.	WP2				X
	Evidence on processes of stakeholders' engagement – analysis of number of stakeholders engaged and diversity of groups of stakeholders represented.	WP2				X
	Relevance of materials being used for different types of activities; information from environmental LCA, information on local identity and its connection to environmental quality.	WP2				X
	Analysis of results of surveys or other studies on users' satisfaction with the product.	WP2				X
	Results from environmental LCA, results from the Health Assessment, literature review linking $PM_{2.5}$ with stress, evidence of awareness raising campaigns.	Literature…				X
	Analysis of evidence relating policy change with the AeroSolfd solutions.					
Economical	Induced changes in price of raw materials and its impact in activities using them, suppliers' income, country in which suppliers' operate, terms of contracts with suppliers (e.g. requirements concerning standard certification, payment time),	WP2				X

BRAKE DUST FILTER	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
	diversification of processes and of products, number of patents registered, income to the developer/manufacturer companies.					
	Processes/Technology; information on business plans and product investment and profits predicted.	WP2				X
	Evidences on the implementation of good practices (e.g practices of sustainability, fair competition; Non-Bribery/Anti-Corruption; life-work balance...).	WP2				X
	Reports/studies on the impact of the use of the AeroSolfd technologies in the companies' image; complaints registers.	WP2				X
		WP2				X

*) Source of Data

Table 7 FILTER SQUARES data collection plan

FILTER SQUARES	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
Safety (Professionals)	Potential risk of exposures during assembly of filter squares are currently considered negligible, because most production is upstream. Exposures related to handling of filter materials may occur and requires confirmation. Exposure or handling release test measurements will be	WP3, WP4	X		X	X

FILTER SQUARES	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
	made on filter materials. Dust (ultrafine particles, EC/OC, PAH, PM_4 and total dust) release (filter cake of collected air-pollution particles) during changing of used filters and potential handling accidents dropping the filter is needed as critical acute exposures. Exposures during the proposed recycling approach will be considered. Occupational exposures at the bus depot and metro station platforms, will be assessed from concentrations in area air-pollution (ultrafine particles, EC/OC, BC, PAH, metals, PM_4, PM_{10}) and may be further modelled based on measured air-pollution concentrations and filtration efficacies of the filter boxes. Exposures during recycling will be assessed based on proposed route for recycling. OELs and hazard data on work process emissions and filter material. For the bus depot and metro station exposures where the filter squares will be tested, the hazard of ultrafine particles, EC/OC, PAH, PM_4 and PM_{10} air-pollution and further considerations of specific exposure characteristics of metro platform exposures where brakes and track will play an important role. Assessments may be made considering the difference between exposure without and with filter boxes.					
Safety (Public)	The results from occupational exposure assessments will be used to estimate exposure public exposure from industrial processes. The concentration and change in ambient air-pollution (ultrafine particles, EC/OC, BC, PAH, metals, $PM_{2.5}$ and PM_{10}) on metro platforms and released	WP3, WP4	X		X	X

FILTER SQUARES	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
	from metro stations will be estimated from measurements and measured filtration efficacies of the filter boxes. Hazard information requirements is similar as the ones for occupational exposure assessment. The change in ambient ultrafine, $PM_{2.5}$ and PM_{10} air-pollution on metro platforms and released from metro stations is the most important for public risk assessment in this case.					
Environmental	Information relative to the manufacturing processes, materials of all products and components used;	WP3			X	X
	Energy and resource usage for each phase;	WP3			X	X
	Emissions flows for every process in each phase;	WP3		X	X	X
Social	Evidence of compliance or of moving beyond, EU working conditions; analysis of the workers' profile and salaries; results of work satisfaction surveys; analysis of the register of accidents and incidents related with the specific product line.	WP3				X
	Evidence on processes of stakeholders' engagement – analysis of number of stakeholders engaged and diversity of groups of stakeholders represented.	WP3				X
	Relevance of materials being used for different types of activities; information from environmental LCA, information on local identity and its connection to environmental quality.	WP3				X
	Analysis of results of surveys or other studies on users' satisfaction with the product.	WP3				X

FILTER SQUARES	Information requirements (*What*)	WPs/Task* (*How*)	Application (*Where is used/Destinations*)			
			HRA	ERA	LCA	S-LCA
	Results from environmental LCA, results from the Health Assessment, literature review linking PM2,5 with stress, evidence of awareness raising campaigns.	Literature…				X
	Analysis of evidence relating policy change with the AeroSolfd solutions.					
Economical	Induced changes in price of raw materials and its impact in activities using them, suppliers' income, country in which suppliers' operate, terms of contracts with suppliers (e.g. requirements concerning standard certification, payment time), diversification of processes and of products, number of patents registered, income to the developer/manufacturer companies.	WP3				X
	Processes/Technology; information on business plans and product investment and profits predicted.	WP3				X
	Evidences on the implementation of good practices (e.g practices of sustainability, fair competition; Non-Bribery/Anti-Corruption; life-work balance...).	WP3				X
	Reports/studies on the impact of the use of the AeroSolfd technologies in the companies' image; complaints registers.	WP3				X
		WP3				X

*) Source of Data

8. DEVIATIONS FROM THE PLAN

In case of deviation of submission / completion of Deliverable: reasons and justifications, description of interdependencies with other affected tasks / WPs
D4.1 was delayed 6 months as compared to the plan in the description of action. The process for developing the overall framework was complex and required several iterations across WP4 to align the information and approaches in the different principle methods (risk innovation governance, risk assessment, LCA, S-LCA, and sustainability assessment) with partially overlapping topics. Further, developing a workable framework for AeroSolfd and the data collection plan required deeper interaction with WP1, 2 and 3 than first planned.

There are no deviations from the plan.

9. LINKS WITH OTHER WPS

This deliverable is feeding into subsequent tasks in WP4 as depicted in Figure 1. WP4 is depending on substantial data from WP1, WP2, and WP3 in the upcoming work as indicated in the description of action.

10. CONCLUSIONS AND RECOMMENDATIONS

The sustainability framework was build integrating considerations and procedures for human and environmental risk assessment, as well as the environmental life cycle assessment, and the social life cycle assessment. The case-specific risk scoping analysis was performed in order to identify the perceivable foreseen risks and relevant data needs (including knowledge gaps and priorities for possible tests and measurements) to perform the overall sustainability assessments.

The information requirements for the assessments were identified and data will be a mixture of qualitative and quantities data as well as read-across data due to the innovation stage and practical limitations to map the entire value chain for each product as part of the AeroSolfd project.

Qualitative and quantitative data will be collected (measured, literature review, derived, or modelled)

Results from the human and environmental risk assessment will be used as input for the final LCA and overall sustainability assessment.

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Glossary-Definitions

Criteria

An aspect with an assessment method and a minimum threshold or target values (on which a decision may be based)

Endpoint (Risk Assessment)

An observable or measurable inherent property of a chemical substance. It can for example refer to a physical-chemical property like vapour pressure or to degradability or a biological effect that a given substance has on human health or the environment, e.g. carcinogenicity, irritation, aquatic toxicity.

EU (2006). Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (OJ L 396 30.12.2006). https://echa-term.echa.europa.eu/
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Endpoint method-model and indicator (LCA)

The category endpoint is an attribute or aspect of the environment, human health, or resources, identifying an environmental issue giving cause for concern. Hence, endpoint method (or damage approach)/model) is a characterisation method/model that provides indicators at the level of Areas of Protection (natural ecosystems, human health, resource availability) or at a level close to the Areas of Protection level.

ISO (2006). ISO 14040:2006 Environmental Management - Life Cycle Assessment - Principles and Framework

Indicator

A parameter, or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon, with a significance extending beyond that directly associated with its value (OECD 2003). The indicator could be quantitative or semi- quantitative or qualitative derived from a model, often trough a tool or direct measurement

Adapted from OECD, OECD. 2021. Glossary of statistical terms. Retrieved November 16, 2021 (https://stats.oecd.org/glossary/detail.asp?ID=830)

Midpoint method and indicator (LCA)

In LCA, the midpoint method is a characterisation method that provides indicators for comparing environmental interventions at the level of a cause-effect chain between emissions/resource consumption and the endpoint level (where effects and damage are assessed)

Sustainability dimensions

Refers to the four dimensions of sustainability addressed in this study: safety, environmental, social and economic

12. ANNEX

ANNEX 1

LCA data collection templates

BILL OF MATERIALS (BOM)

Demo X	Production			Manufacturing			Transport		Quantity
	Material composition			Manufacturing process	Coating	Heat treatment	Transport means	Transport distance	
	Component	Material	Mass (kg)						
Benchmark product (total weight: kg)									

PROCESSES INVENTORY

Process	*This sheet can be copied for every process in the products life cycle*		
Process identification			
Process application			
Process operator			
Location			
Quantitative reference and unit		Date of completion	
Contact person		Time period	
Process Flowsheet			→
General comment			
Technology representativeness			

Inputs	Amount	Unit	Datasource	Data quality	Origin	Comments
Energy source incl. efficiency						
Material inputs						
Service inputs						

Outputs	Amount	Unit	Datasource	Data quality	Origin	Comments
Products						
Emissions to air						
Emissions to water						
Emissions to soil						

Waste						
Process waste	Amount	Unit	Datasource	Data quality	Origin	Comments

Packaging					
Product per unit/box		Comments			
Unit					
Components/materials	Amount	Unit	Data Quality	Destination	Comments

Transport					
Materials, Supplies and Waste	Distance (km)	Means of tranport	Capacity (kg)	Actual load (kg)	Empty return (Yes/No)

ANNEX 2

THE CRITICAL ANALYSIS OF THE HOTSPOTS

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
COMMUNITY / RAW MATERIALS			8	How does the competition for the raw product impacts on the price of the materials?	semi-quantitative	survey / interview
			8	How does the competition for the raw product impacts on other activities (e.g. are there activities which cannot afford the price and will be ending, with prejudice for the workers of such activities and their families, and eventually for cultural heritage)	qualitative	survey / interview
SUPPLIERS		PROFIT & GROW	8, 17	representativeness of the income for the supplier (% of profits)	quantitative	survey / interview
	Fair Competition(UN-SETAC)	COMPLIANCE WITH EU WORK REGULATIONS AND WORKING CONDITIONS	12, 17	Where do the suppliers providing parts of the product have their premisses/facilities?	semi-quantitative	survey / interview
			8, 12, 17	Where are their suppliers t from?		

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
			3; 8; 12; 17	Does your ToR / contract with suppliers include the need of suppliers to perform accordingly with specific Social Responsibilities? If yes indicate which CSR are identified in the contract		
	Corruption (UN-SETAC)	**NON-BRIBERY / ANTI-CORRUPTION**	**12, 17**	Does your ToR / contract with suppliers include non-bribery / anti-corruption requirements?	qualitative / semi-quantitative	survey / interview
		FAIR COMPETITION	**8; 12, 17**	Does your ToR / contract with suppliers include requirements concerning their payments to their raw material suppliers? (Length of payment - before expedition of the product, at time of product arrives, up to 30 days after, up to 90 days after, up to 6 months, up to 1 year, more than 1 year)	semi-quantitative	survey / interview
	Promoting Social Responsibility (UN-SETAC)		**all the above, 12**	PERCENTAGE OF SUPPLIERS THE ENTERPRISE HAS AUDITED WITH REGARD TO THE ELEMENTS IN TOR, AND COMPLIANCE LEVELS?	(works as an additional point to previous indicators)	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
ORGANISATION / CONTEXT (to be applied to product developers and users which are companies)	**Relationship with Suppliers (UN-SETAC) (only to be applied to product developers)**	**PRODUCT CONTRIBUTION TO THE BROADER ECONOMY**	**8, 11, 12, 17**	Are payments to suppliers performed on time? (Length of payment - before expedition of the product, at time of product arrives, up to 30 days after, up to 90 days after, up to 6 months, up to 1 year, more than 1 year)	semi-quantitative	survey / interview
	Economic Development (UN-SETAC)	**PRODUCT CONTRIBUTION TO THE COMPANY ECONOMIC SUSTAINABILITY**	**9**	% of change in number of products and/or services?	semi-quantitative / quantitative	survey / interview
			8	% of change in sales/income?	semi-quantitative / quantitative	survey / interview
				% of change in expenses (services, products or materials)?	semi-quantitative / quantitative	survey / interview
	Technology Development (UN-SETAC)	**CHANGES IN PROCESSES / TECHNOLOGY**	**9**	changes in technology? •% of change in processes? •% of increased time /frequency/money in processes (e.g. maintenance)	semi-quantitative / quantitative	survey / interview
		COMPANY IMAGE	**12**	% of improvement in company sustainability image?	semi-quantitative / quantitative	survey / interview
		ENGAGMENT WITH STAKEHOLDERS	**17**	Change on diversity and number of stakeholders that the organisation is working with? Why and what impact? •% change in number •% change in diversity	semi-quantitative / quantitative	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
WORKERS / HUMAN RESOURCES (to be applied to product developers and users which are companies)	**Workers (UN-SETAC) Product Based Employment (Jasinsky et al)**	**WORK STRUCTURE**	**8, 9**	Changes in work being performed?	qualitative	survey / interview
			8	changes in responsibility?	qualitative / semi-quantitative	survey / interview
			8	Change in number of workers (increase in which number and percentage)?	quantitative	survey / interview
			8	What type of staff - think for all sectors, procurement, production, maintenance? (% of highly skilled, medium skilled and unskilled?)	qualitative / quantitative	survey / interview
		WORKERS' SKILLS	**8**	Changes in staff knowledge and capability • will you need to provide training to staff? • % of staff being trained? • In which areas of expertise? • Are you opening the training to other organisations/people in the community?	qualitative / quantitative	survey / interview
	Fair Salary (UN-SETAC)	**SALARY**	**8**	average salary of each type of new workers * workers affected •change in mean salary of company worker •% above mean at national level	quantitative	survey / interview
	Hours of Work (UN-SETAC)	**WORKING HOURS**	**8**	Change in working hours (increase in which percentage?)	qualitative / semi-quantitative	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
			8	Changes in shifts	qualitative / semi-quantitative	survey / interview
			8	changes in working hours flexibility	qualitative / semi-quantitative	survey / interview
		LIFE-WORK BALANCE	8	changes in work-life balance	qualitative / semi-quantitative	survey / interview
		WORK SATISFACTION	8	Changes in satisfaction with work?	qualitative / semi-quantitative	survey / interview
	Health & Safety (UN/SETAC)	POTENTIAL RISKS (JASINSKY et al)	3, 8	• changes in work risks due to changes in exposure to hazardous materials, reduced or improved environmental quality) •new Individual protective equipment required and provided; •specific H&S training required and provided?	quantitative	gathered from Health Assessment
		ACCIDENTS AND INCIDENTS (UN/SETAC)	3, 8	•Total number of accidents and of incidents of non-compliance with regulations and voluntary codes concerning health and safety impacts of products and services and type of outcomes (UN/SETAC; GRI) •Occupational health and safety performance - injury and illness rate (Jasinsky et al)	quantitative	gathered from Health Assessment

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
		HEALTH & SAFETY COMPLAINTS (UN/SETAC)	**3, 8, 17**	What are the Health & Safety complaints? / perceived disadvantages about the product?	qualitative	complaints register
DIRECT PRODUCT CONSUMERS (drivers/bus	**Product Experience (UN-SETAC)**	**PRODUCT OVERALL SATISFACTION (UN/SETAC)**	**17**	Satisfaction with the product/service? Perceived benefits about the product?	qualitative / semi-quantitative	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
drivers/maintenance/ company CEO)		**PRODUCT USABILITY (new - AeroSolfd)**	**17**	Perceived evaluation of the product/service on functionality - usability? (e.g. Impact in driving, maintenance.../ general impact) Interference with: • Driving • Vehicle performance and impact on diesel consumption • Maintenance (changes on maintenance required and economic impact will define if people are left with more money or less money on their pockets) • Direct and Indirect impacts on Maintenance (i.e.: does it conflict with other parts of the vehicle posing difficulties to their maintenance?) •Work overload - How easy is maintenance, does it imply more hours of work? •Work capability / training – Are there special capabilities required for maintenance?	qualitative / semi-quantitative	survey / interview
		PRODUCT USEFULNESS (new - AeroSolfd)	**17**	Perceived evaluation of the usefulness of the product/service? • Image (personal/company)	qualitative / semi-quantitative	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
		COMPLAINTS (UN/SETAC)	**17**	What are the complaints / perceived disadvantages about the product?	qualitative	interview / survey
	Health & Safety (UN/SETAC)	**POTENTIAL RISKS (JASINSKY et al)**	**3**	•Interference with level of safety of vehicles (i.e. Euro NCAP rating) •The whole-body vibration impact on the driver's health, such as musculoskeletal and lumbar spine disorders •How safe is the maintenance, is there the need for special protective measures?	quantitative	gathered from Health Assessment
		ACCIDENTS AND INCIDENTS (UN/SETAC)	**3**	•Total number of accidents and of incidents of non-compliance with regulations and voluntary codes concerning health and safety impacts of products and services and type of outcomes (UN/SETAC; GRI) •Occupational health and safety performance - injury and illness rate (Jasinsky et al)	quantitative	gathered from Health Assessment
		HEALTH & SAFETY COMPLAINTS (UN/SETAC)	**3, 17,**	What are the Health & Safety complaints? / perceived disadvantages about the product?	qualitative	complaints register
		PRODUCT CONTRIBUTION TO THE	**8**	% of change in number of products and/or services?	quantitative	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
WASTE Managers / Reusers -cicularity /Recyclers	**Economic Development (UN-SETAC)**	**COMPANY ECONOMIC SUSTAINABILITY**	**8**	represetativeness of the income for the waste user: •% of change in sales/income? •% of reduced spending s	quantitative	survey / interview
	Technology Development (UN-SETAC)	**CHANGES IN PROCESSES / TECHNOLOGY**	**9**	changes in technology? •% of change in processes? •% of increased time /frequency/money in processes (e.g. maintenance)	quantitative	survey / interview
		WORK STRUCTURE	**9**	changes in work being performed?	qualitative / semi-quantitative	survey / interview
		WORKERS' SKILLS	**8**	Changes in staff knowledge and capability - will you need to provide training to staff? • % of staff being trained? • In which areas of expertise? • Are you opening the training to other organisations/people in the community?	qualitative / quantitative	survey / interview
	Health & Safety (UN/SETAC)	**POTENTIAL RISKS (JASINSKY et al)**	**3, 8**	•Interference with level of safety of vehicles (i.e. Euro NCAP rating) •How safe is the dismantling, is there the need for special protective measures?	qualitative / quantitative	gathered from Health Assessment

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
		ACCIDENTS AND INCIDENTS (UN/SETAC)	**3, 8**	•Total number of accidents and of incidents of non-compliance with regulations and voluntary codes concerning health and safety impacts of products and services and type of outcomes (UN/SETAC; GRI) •Occupational health and safety performance - injury and illness rate (Jasinsky et al)	quantitative	gathered from Health Assessment
		HEALTH & SAFETY COMPLAINTS (UN/SETAC)	**3, 8, 17**	What are the Health & Safety complaints / perceived disadvantages about the product?	qualitative	complaints register
COMMUNITY (to be applied to local community surrounding the production facility and communities where the product			**17**	number of places of production facilities	quantitative (works as a multiplier of impacts)	survey / interview
			17	number of places where the product reaches the market	quantitative (works as a multiplier of impacts)	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
will be used - markets)	**Access to basic needs for human dignity (healthcare, sanitation & clean water, healthy food, shelter, education) (UN-SETAC) Nuisance (UN-SETAC)**	**PUBLIC GOODS**	**3**	Changes in air - evaluating consequences in •health (effects as a result of VOCs, particulates, ozone, polycyclic aromatic hydrocarbons, heavy metals emission; $PM_{2.5}$ impact on: premature death in people with heart or lung disease; nonfatal heart attacks; irregular heartbeat; aggravated asthma; decreased lung function; increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing -EPA; + physiological stress) , •nuisance and performance (cognitive and emotional) •Livelihood and socio-cultural heritage (economic or leisure activities)	qualitative /semi-quantitative (change*number of people affected)	environmental data + health data + literature

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
			3; 6; 14	Changes in water (quality or consumption) -evaluating consequences in •water availability •health, •nuisance and performance (cognitive and emotional) •Livelihood and socio-cultural heritage (economic or leisure activities, e.g. possible impacts on fishing, tourism or other human activities by reducing lakes and streams acidic and/or changing the nutrient balance in coastal waters and large river basins and consequently in ecosystems biodiversity (EPA); reducing possible impacts on agriculture and possible local products with economic impact, impact on ways of living and possible cultural impact, depending on how heritage representative are the cultures affected)	qualitative /semi-quantitative (change*number of people affected)	environmental data + health data + literature
			3, 15	Impacts in soil - evaluating consequences in •health, •nuisance and performance (cognitive and emotional) •Livelihood and socio-cultural heritage(economic or leisure activites)	qualitative /semi-quantitative (change*number of people affected)	environmental data + health data + literature

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
			3	Impacts noise (the social impact of sound, sound pressure level from engine, exhaust and rolling noise), evaluating consequences in: •health •nuisance and performance (cognitive and emotional, e.g. attention, performance, social support and social cohesion) •Livelihood and socio-cultural heritage (economic or leisure activities)	qualitative /semi-quantitative (change*number of people affected)	environmental data + health data + literature
			3	Impacts in landscape - evaluating consequences in: •health, •nuisance and performance (cognitive and emotional) •Livelihood and socio-cultural heritage (economic or leisure activities, e.g. due to reduction of sun exposure...)	qualitative /semi-quantitative (change*number of people affected)	environmental data + health data + literature
		POTENTIAL ACCIDENTS	**3**	types of possible accidents with impacts to the environment and/or local communities	qualitative /semi-quantitative (change*number of people affected)	Environmental Assessment
		STRESS	**3**	Reduction of anxiety or stress due to Risk Perception towards $PM_{2.5}$ and values regarding air quality and is relevance	qualitative / semi-quantitative (change*number of people affected)	environmental data + health data + literature

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STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
			3	•stress (overal nuisance and performance - cognitive and emotional) * people affected	qualitative / semi-quantitative (change*number of people affected)	use information used for public goods
		PUBLIC SERVICES	3, 11	Impact in Health services (% of increase or decrease in use)	qualitative / semi-quantitative (change*number of people affected)	health data + literature
			8, 11	Impact in Employment services (% of increase or decrease in use)	quantitative (%change in number of people unemployed localy)	interview + local data
			11	Impact on demographics due to increased/reduced health	qualitative / semi-quantitative	health data + literature
	Job Creation (UN-SETAC)	LOCAL ECONOMY DYNAMICS	8, 17	Are you recruiting from any specific source (geographical place or school)? •How many workers (% in the community)? •Average salary (% above the local salary)	quantitative	interview + local data
			9	number of patents registered	quantitative	survey / interview
			17	% of change in spending/buying in local economy (due to the product, suppliers or services related with it)	quantitative	survey / interview

STAKEHOLDERS CATEGORIES	ASPECTS AS IN SOURCE	INDICATORS	SDG	INFORMATION TO BE COLLECTED	TYPE OF INDICATOR	METHOD FOR DATA COLLECTION
			17	knowledge shared with other companies/industries/research/academic organisations	qualitative	survey / interview
	Promotion of skills & knowledge (UN-SETAC)	**SKILLS & KNOWLEDGE**	**11, 17**	increased awareness and knowledge about $PM_{2.5}$ and their impacts	semi-quantitative	survey
	Culture / Heritage	**CULTURE / HERITAGE**	**11**	Impact of environmental changes in cultural heritage (e.g. Impacts of acidotic rains?), based on Cultural Heritage in Urgent Need of Safeguarding	qualitative / semi-quantitative	environmental data + literature
			11	Impacts in livelihoods due to change of public resources (raw materials, environmental quality..)	qualitative	environmental data + health data + literature
		IDENTITY	**11**	Change in local/city identity due to environmental quality change	qualitative / semi-quantitative	survey
	Policy	**CHANGES IN POLICY**	**11, 17**	% of city managers / politicians committed with change towards reducing $PM_{2.5}$	quantitative	gather data from AeroSolfd partners
			11, 17	Social Pressure (measured in social events and number of people engaged) for Legal/Regulatory change towards improved control of $PM_{2.5}$	quantitative	literature (benchmark)

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ANNEX 3

UN SDGS INDICATORS AND TARGETS IN AEROSOLFD

Indicators for the SDG and targets to which AeroSolfd expects to contribute		
UN Sustainable Development Goals (SDGs)		**AeroSolfd**
Goals and targets (from the 2030 Agenda for Sustainable Development)	*Indicators*	
Group 1		
Goal 6. Ensure availability and sustainable management of water and sanitation for all		
6.1By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1Proportion of population using safely managed drinking water services	
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1Proportion of population using (*a*) safely managed sanitation services and (*b*) a hand-washing facility with soap and water	
6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	6.3.1Proportion of domestic and industrial wastewater flows safely treated	
	6.3.2 Proportion of bodies of water with good ambient water quality	X
6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1Change in water-use efficiency over time	
	6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	
6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1Degree of integrated water resources management	
	6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation	
6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1Change in the extent of water-related ecosystems over time	X
6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	6.a.1Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	
6.b Support and strengthen the participation of local communities in improving water and sanitation management	6.b.1Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable		
11.1By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	11.1.1Proportion of urban population living in slums, informal settlements or inadequate housing	
11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons	11.2.1Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities	
11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	11.3.1Ratio of land consumption rate to population growth rate	
	11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically	
11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage	11.4.1Total per capita expenditure on the preservation, protection and conservation of all cultural and natural heritage, by source of funding (public, private), type of heritage (cultural, natural) and level of government (national, regional, and local/municipal)	
11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	11.5.1Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population	
	11.5.2 Direct economic loss attributed to disasters in relation to global gross domestic product (GDP)	
	11.5.3 (*a*) Damage to critical infrastructure and (*b*) number of disruptions to basic services, attributed to disasters	
11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	11.6.1Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities	
	11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	X
11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	11.7.1Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities	
	11.7.2 Proportion of persons victim of physical or sexual harassment, by sex, age, disability status and place of occurrence, in the previous 12 months	
11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	11.a.1Number of countries that have national urban policies or regional development plans that (*a*) respond to population dynamics; (*b*) ensure balanced territorial development; and (*c*) increase local fiscal space	
11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk	11.b.1Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030	
	11.b.2 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction	
11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials	*No suitable replacement indicator was proposed. The global statistical community is encouraged to work to develop an indicator that could be proposed for the 2025 comprehensive review. See E/CN.3/2020/2.*	

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development		
14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and	14.1.1 (a) Index of coastal eutrophication; and (b) plastic debris density	
14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order	14.2.1 Number of countries using ecosystem-based approaches to managing marine areas	
14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations	X
14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological	14.4.1 Proportion of fish stocks within biologically sustainable levels	
14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best	14.5.1 Coverage of protected areas in relation to marine areas	
14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries	14.6.1 Degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing	
14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries,	14.7.1 Sustainable fisheries as a proportion of GDP in small island developing States, least developed countries and all countries	
14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed	14.a.1 Proportion of total research budget allocated to research in the field of marine technology	
14.b Provide access for small-scale artisanal fishers to marine resources and markets	14.b.1 Degree of application of a legal/regulatory/ policy/institutional framework which recognizes and protects access rights for small-scale fisheries	
14.c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"	14.c.1 Number of countries making progress in ratifying, accepting and implementing through legal, policy and institutional frameworks, ocean-related instruments that implement international law, as reflected in the United Nations Convention on the Law of the Sea, for the conservation and sustainable use of the oceans and their resources	
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss		
15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.1 Forest area as a proportion of total land area	
	15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type	
15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	15.2.1 Progress towards sustainable forest management	
15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.1 Proportion of land that is degraded over total land area	
15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	15.4.1 Coverage by protected areas of important sites for mountain biodiversity	
	15.4.2 Mountain Green Cover Index	
15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1 Red List Index	
15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed	15.6.1 Number of countries that have adopted legislative, administrative and policy frameworks to ensure fair and equitable sharing of benefits	
15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal	15.7.1 Proportion of traded wildlife that was poached or illicitly trafficked	
15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species	15.8.1 Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species	
15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	15.9.1 (a) Number of countries that have established national targets in accordance with or similar to Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011–2020 in their national biodiversity strategy and action plans and the progress reported towards these targets; and (b) integration of biodiversity into national accounting and reporting systems, defined as implementation of the System of Environmental-	
15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	15.a.1 (a) Official development assistance on conservation and sustainable use of biodiversity; and (b) revenue generated and finance mobilized from biodiversity-relevant economic instruments	
15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for	15.b.1 (a) Official development assistance on conservation and sustainable use of biodiversity; and (b) revenue generated and finance mobilized from biodiversity-relevant economic instruments	
15.c Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities	15.c.1 Proportion of traded wildlife that was poached or illicitly trafficked	

Group 2		
Goal 3. Ensure healthy lives and promote well-being for all at all ages		
3.1 By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births	3.1.1 Maternal mortality ratio	
	3.1.2 Proportion of births attended by skilled health personnel	
3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births	3.2.1 Under-5 mortality rate	X
	3.2.2 Neonatal mortality rate	
3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases	3.3.1 Number of new HIV infections per 1,000 uninfected population, by sex, age and key populations	
	3.3.2 Tuberculosis incidence per 100,000 population	
	3.3.3 Malaria incidence per 1,000 population	
	3.3.4 Hepatitis B incidence per 100,000 population	
	3.3.5 Number of people requiring interventions against neglected tropical diseases	
3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being	3.4.1 Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease	X
	3.4.2 Suicide mortality rate	
3.5 Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol	3.5.1 Coverage of treatment interventions (pharmacological, psychosocial and rehabilitation and aftercare services) for substance use disorders	
	3.5.2 Alcohol per capita consumption (aged 15 years and older) within a calendar year in litres of pure alcohol	
3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents	3.6.1 Death rate due to road traffic injuries	
3.7 By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes	3.7.1 Proportion of women of reproductive age (aged 15–49 years) who have their need for family planning satisfied with modern methods	
	3.7.2 Adolescent birth rate (aged 10–14 years; aged 15–19 years) per 1,000 women in that age group	
3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all	3.8.1 Coverage of essential health services	X
	3.8.2 Proportion of population with large household expenditures on health as a share of total household expenditure or income	
3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	3.9.1 Mortality rate attributed to household and ambient air pollution	X
	3.9.2 Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services)	
	3.9.3 Mortality rate attributed to unintentional poisoning	
3.a Strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate	3.a.1 Age-standardized prevalence of current tobacco use among persons aged 15 years and older	
3.b Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade-Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all	3.b.1 Proportion of the target population covered by all vaccines included in their national programme	
	3.b.2 Total net official development assistance to medical research and basic health sectors	
	3.b.3 Proportion of health facilities that have a core set of relevant essential medicines available and affordable on a sustainable basis	X
3.c Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States	3.c.1 Health worker density and distribution	
3.d Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks	3.d.1 International Health Regulations (IHR) capacity and health emergency preparedness	
	3.d.2 Percentage of bloodstream infections due to selected antimicrobial-resistant organisms	

Group 3		
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all		
8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	8.1.1 Annual growth rate of real GDP per capita	
8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	8.2.1 Annual growth rate of real GDP per employed person	
8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services	8.3.1 Proportion of informal employment in total employment, by sector and sex	X
8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	8.4.1 Material footprint, material footprint per capita, and material footprint per GDP	
	8.4.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP	
8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	8.5.1 Average hourly earnings of employees, by sex, age, occupation and persons with disabilities	X
	8.5.2 Unemployment rate, by sex, age and persons with disabilities	X
8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training	8.6.1 Proportion of youth (aged 15–24 years) not in education, employment or training	X
8.7 Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms	8.7.1 Proportion and number of children aged 5–17 years engaged in child labour, by sex and age	X
8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	8.8.1 Fatal and non-fatal occupational injuries per 100,000 workers, by sex and migrant status	X
	8.8.2 Level of national compliance with labour rights (freedom of association and collective bargaining) based on International Labour Organization (ILO) textual sources and national legislation, by sex and migrant status	X
8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products	8.9.1 Tourism direct GDP as a proportion of total GDP and in growth rate	
8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all	8.10.1 (*a*) Number of commercial bank branches per 100,000 adults and (*b*) number of automated teller machines (ATMs) per 100,000 adults	
	8.10.2 Proportion of adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider	
8.a Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-related Technical Assistance to Least Developed Countries	8.a.1 Aid for Trade commitments and disbursements	
8.b By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization	8.b.1 Existence of a developed and operationalized national strategy for youth employment, as a distinct strategy or as part of a national employment strategy	
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation		
9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	9.1.1 Proportion of the rural population who live within 2 km of an all-season road	
	9.1.2 Passenger and freight volumes, by mode of transport	
9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries	9.2.1 Manufacturing value added as a proportion of GDP and per capita	
	9.2.2 Manufacturing employment as a proportion of total employment	
9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets	9.3.1 Proportion of small-scale industries in total industry value added	X
	9.3.2 Proportion of small-scale industries with a loan or line of credit	X
9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	9.4.1 CO_2 emission per unit of value added	
9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending	9.5.1 Research and development expenditure as a proportion of GDP	X
	9.5.2 Researchers (in full-time equivalent) per million inhabitants	X
9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States	9.a.1 Total official international support (official development assistance plus other official flows) to infrastructure	
9.b Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities	9.b.1 Proportion of medium and high-tech industry value added in total value added	
9.c Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020	9.c.1 Proportion of population covered by a mobile network, by technology	

Goal 12. Ensure sustainable consumption and production patterns		
12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	12.1.1 Number of countries developing, adopting or implementing policy instruments aimed at supporting the shift to sustainable consumption and production	X
12.2 By 2030, achieve the sustainable management and efficient use of natural resources	12.2.1 Material footprint, material footprint per capita, and material footprint per GDP	X
	12.2.2 Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP	X
12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	12.3.1 (*a*) Food loss index and (*b*) food waste index	
12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	12.4.1 Number of parties to international multilateral environmental agreements on hazardous waste, and other chemicals that meet their commitments and obligations in transmitting information as required by each relevant agreement	
	12.4.2 (*a*) Hazardous waste generated per capita; and (*b*) proportion of hazardous waste treated, by type of treatment	
12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	12.5.1 National recycling rate, tons of material recycled	X
12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	12.6.1 Number of companies publishing sustainability reports	X
12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities	12.7.1 Number of countries implementing sustainable public procurement policies and action plans[3]	X
12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	12.8.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (*a*) national education policies; (*b*) curricula; (*c*) teacher education; and (*d*) student assessment	
12.a Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production	12.a.1 Installed renewable energy-generating capacity in developing countries (in watts per capita)	
12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local	12.b.1 Implementation of standard accounting tools to monitor the economic and environmental aspects of tourism sustainability	X
12.c Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected	12.c.1 Amount of fossil-fuel subsidies (production and consumption) per unit of GDP	
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development		
Finance		
17.1 Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection	17.1.1 Total government revenue as a proportion of GDP, by source	
	17.1.2 Proportion of domestic budget funded by domestic taxes	
17.2 Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of gross national income for official development assistance (ODA/GNI) to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries	17.2.1 Net official development assistance, total and to least developed countries, as a proportion of the Organization for Economic Cooperation and Development (OECD) Development Assistance Committee donors' gross national income (GNI)	
17.3 Mobilize additional financial resources for developing countries from multiple sources	17.3.1 Additional financial resources mobilized for developing countries from multiple sources	
	17.3.2 Volume of remittances (in United States dollars) as a proportion of total GDP	
17.4 Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress	17.4.1 Debt service as a proportion of exports of goods and services	
17.5 Adopt and implement investment promotion regimes for least developed countries	17.5.1 Number of countries that adopt and implement investment promotion regimes for developing countries, including the least developed countries	
Technology		
17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms,	17.6.1 Fixed Internet broadband subscriptions per 100 inhabitants, by speed[4]	
17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually	17.7.1 Total amount of funding for developing countries to promote the development, transfer, dissemination and diffusion of environmentally sound technologies	
17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology	17.8.1 Proportion of individuals using the Internet	
Capacity-building		
17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the Sustainable Development Goals, including through North-South, South-South and triangular cooperation	17.9.1 Dollar value of financial and technical assistance (including through North-South, South-South and triangular cooperation) committed to developing countries	

[illegible]		
Trade		
17.10 Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda	17.10.1 Worldwide weighted tariff-average	
17.11 Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of [illegible]	17.11.1 Developing countries' and least developed countries' share of global exports	
17.12 Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market [illegible]	17.12.1 Weighted average tariffs faced by developing countries, least developed countries and small island developing States	
Systemic issues		
Policy and institutional coherence		
17.13 Enhance global macroeconomic stability, including through policy coordination and policy coherence	17.13.1 Macroeconomic Dashboard	
17.14 Enhance policy coherence for sustainable development	17.14.1 Number of countries with mechanisms in place to enhance policy coherence of sustainable development	
17.15 Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development	17.15.1 Extent of use of country-owned results frameworks and planning tools by providers of development cooperation	
Multi-stakeholder partnerships		
17.16 Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in [illegible]	17.16.1 Number of countries reporting progress in multi-stakeholder development effectiveness monitoring frameworks that support the achievement of the sustainable development goals	
17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies [illegible]	17.17.1 Amount in United States dollars committed to public-private partnerships for infrastructure	
Data, monitoring and accountability		
17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts	17.18.1 Statistical capacity indicator for Sustainable Development Goal [illegible]	
	17.18.2 Number of countries that have national statistical legislation that complies with the Fundamental Principles of Official Statistics	
	17.18.3 Number of countries with a national statistical plan that is fully funded and under implementation, by source of funding	
17.19 By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries	17.19.1 Dollar value of all resources made available to strengthen statistical capacity in developing countries	
	17.19.2 Proportion of countries that (*a*) have conducted at least one population and housing census in the last 10 years; and (*b*) have achieved 100 per cent birth registration and 80 per cent death registration	

ANNEX 4

SUSTAINABILITY FRAMEWORK OVERVIEW

Retrofit solutions for

1 - Tailpipe

2 - Brake

3 - Closed environment emissions


1 - Tailpipe


2 - Brake


3 - Closed

Retrofit solutions for

1 - Tailpipe
2 - Brake
3 - Closed environment emissions

1 - Tailpipe

TABLE A-1

	Impact category	Expected change due to AeroSolfd	Qualitative indicator (pos/static/neg/?)	Lead Partner	Approach (how the midpoint (Governance, SLCA, RA..) can be assessed)	MIDPOINTS (Final framework in Jasinsky et al. adjusted) *b) From Jasinski et al. Fig. 2*	
		A net change may occur. Ultrafine particles contributes to cloud formation and cooling.	static/neg		Environmental impact assessment (LCA)	Global warming potential	
		No change is expected	static		Environmental impact assessment (LCA)	Stratospheric ozone depletion	
		net NOX release to air is expected to be reduced	pos		Environmental impact assessment (LCA)	Photochemical ozone creation potential	
	Environmental impact	Improved air-quality is expected, including reduced formation of secondary aerosols (needs assessment along Life-cycle)	static / pos		Environmental impact assessment (LCA)	Acidification potential (terrestrial and aquatic)	
		Improved air-quality is expected, including reduced formation of secondary aerosols	pos		Environmental impact assessment (LCA)	Particulate matter formation	
LIFE CYCLE STAGES		No change is expected	static		Environmental impact assessment (LCA)	Eutrophication potential (terrestrial and aquatic)	
		A postive change is expected	pos		Ecotoxic assessment (e.g., SSWD approach) (LCA)	Ecotoxicity (terrestrial and aquatic)	
						Human toxicity	
Design		An increase is expected for production, use and disposal	neg		Energy budget (LCA)	Energy consumption	
		more ressources will be needed (i.e. net waste)	neg		Materials budget (LCA)	Resource and minerals consumption (net of renewable, reused and recycled materials)	
	Resource impact	more ressources will be needed (i.e. net waste)	neg		water use assessment (LCA)	Water consumption	
		more ressources will be needed (i.e. mining, energy, space for use, and net waste)	neg		Assessment of land use (LCA)	Land use	
Raw materials							
		A change could occur due to impact on car by retrofit solution	?		Euro NCAP rating, qualitative safety assessment/inspection,	Vehicle safety (accident avoidance)	
		No change; Potentially increased traffic due to more E-freindly	?		Traffic measurement	Congestion	
Manufacturing		A change could occur due to impact on car by retrofit solution; and noise from filtration units	?		Noise and vibrational measurements in site; per vehicle/filtersystem	Noise and vibration	
		A change is expected due to reduced emissions and filtration.	pos		chemical measurements / release tests (e.g., FLEC)	Vehicle interior air quality	
	Social impact	No change	static		Capacity per vehicle unit; disability-friendliness;	Mobility capability	
Use		A change is expected; increased employment	pos		Estimation of employments associated with the retrofit solution	Employment (quantity)	
		A change is expected , but can vary depending on life-cycle stage (production, use, waste..)	?		Occupational risk assessment (qualitative and quantitative) (SLCA)	Occupational health and safety	[Employment quality]
		No change is expected	static		No assessment needed	Labour rights	
		No change is expected	static		No assessment needed	Human rights (including conflict minerals)	
End of Life			pos		Risk assessment for the public (commuters and general) (SLCA)	General public health and safety	
		A change is expected; increased cost due to addition of new product	neg		Financial cost-benefit (LCA)	Money to contractors	
		A change is expected; increased cost due to addition of new product	neg		Financial cost-benefit (LCA)	Production cost	[Gross profit from selling a car, materials, components and from product maintenances and finance]
	Economic impact	A change is expected; increased cost for consumer due to addition of new product; gain for producers	neg/pos		Financial cost-benefit (LCA)	Acquisition cost	
		A change is expected; increased cost (fuel and electricity, service) due to addition of new product	neg		Financial cost-benefit (LCA)	Operating and maintenance cost	
		A change is expected; residual value should be assessed and included	neg		Financial cost-benefit (LCA)	End-of-life cost (value)	

1A - Tailpipe

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1B - Tailpipe

b) From Jasinski et al. Fig. 2 MIDPOINTS (Final framework in Jasinsky et al. adjusted)		UN Sustainable Development Goals in proposal: UN Goal 6	UN Goal 11	UN Goal 14	UN Goal 15	UN Goal 3	UN Goal 8	UN Goal 9	UN Goal 12	UN Goal 17	*b) From Jasinski et al. Fig. 2* END POINTS	*in the proposal* UN Sustainable Development Goals in proposal
Global warming potential		√		√								
Stratospheric ozone depletion			√	√		√						
Photochemical ozone creation potential			√			√						
Acidification potential (terrestrial and aquatic)			√	√							Group1	
Particulate matter formation				√		√					Climate Change	Clean water and sanitation [UN Goal 6]
Eutrophication potential (terrestrial and aquatic)			√								Ecosystem quality (air, water and soil quality)	Sustainable cities [UN Goal 11]
Ecotoxicity (terrestrial and aquatic)			√	√							Impact on biodiversity	Life below water [UN Goal 14]
Human toxicity						√					Resource depletion	Life on land [UN Goal 15]
Energy consumption			√	√	√							
Resource and minerals consumption (net of renewable, reused and recycled materials)			√	√	√							
Water consumption			√	√	√							
Land use			√	√	√							
											Group 2	
Vehicle safety (accident avoidance)						√	√				Human health	Good health and well-being [UN Goal 3]
Congestion			√			√	√				Quality of life (Human wellbeing)	
Noise and vibration				√		√						
Vehicle interior air quality						√						
Mobility capability						√	√					
Employment (quantity)						√	√			√	Group 3	
Occupational health and safety	[Employment quality]					√	√				Gross Value Added	Economic growth [UN Goal 8]
Labour rights						√	√				Dividends	Industry, innovation & infras. [UN Goal 9]
Human rights (including conflict minerals)						√	√					Responsible production [UN Goal 12]
General public health and safety											Taxes (profit, people, production, environmental and road tax)	Partnerships for the goals [UN Goal 17]
Money to contractors							√		√	√		
Production cost	[Gross profit from selling a car, materials, components and from product maintenances and finance]						√		√	√		
Acquisition cost							√		√	√		
Operating and maintenance cost							√		√	√		
End-of-life cost (value)							√		√	√		

Retrofit solutions for

1 - Tailpipe

2 - Brake

3 - Closed environment emissions

1 - Tailpipe

2 - Brake

TABLE A-2

	Impact category	Expected change due to AeroSolfd	Qualitative indicator (pos/static/neg/?)	Lead Partner	Approach (how the midpoint (Governance, SLCA, RA..) can be assessed)	MIDPOINTS (Final framework in Jasinsky et al. adjusted) *b) From Jasinski et al. Fig. 2*	
	Environmental impact	A net change may occur. Ultrafine particles contributes to cloud formation and cooling.	static/neg		Environmental impact assessment (LCA)	Global warming potential	
		No change is expected	static		Environmental impact assessment (LCA)	Stratospheric ozone depletion	
		net NOX release to air is expected to be reduced	pos		Environmental impact assessment (LCA)	Photochemical ozone creation potential	
		Improved air-quality is expected, including reduced formation of secondary aerosols (needs assessment along Life-cycle)	static / pos		Environmental impact assessment (LCA)	Acidification potential (terrestrial and aquatic)	
		Improved air-quality is expected, including reduced formation of secondary aerosols	pos		Environmental impact assessment (LCA)	Particulate matter formation	
LIFE CYCLE STAGES		No change is expected	static		Environmental impact assessment (LCA)	Eutrophication potential (terrestrial and aquatic)	
		A postive change is expected	pos		Ecotoxic assessment (e.g., SSWD approach) (LCA)	Ecotoxicity (terrestrial and aquatic)	
						Human toxicity	
Design	Resource impact	An increase is expected for production, use and disposal	neg		Energy budget (LCA)	Energy consumption	
		more ressources will be needed (i.e. net waste)	neg		Materials budget (LCA)	Resource and minerals consumption (net of renewable, reused and recycled materials)	
		more ressources will be needed (i.e. net waste)	neg		water use assessment (LCA)	Water consumption	
		more ressources will be needed (i.e. mining, energy, space for use, and net waste)	neg		Assessment of land use (LCA)	Land use	
Raw materials							
	Social impact	A change could occur due to impact on car by retrofit solution	?		Euro NCAP rating, qualitative safety assessment/inspection,	Vehicle safety (accident avoidance)	
		No change; Potentially increased traffic due to more E-freindly	?		Traffic measurement	Congestion	
Manufacturing		A change could occur due to impact on car by retrofit solution; and noise from filtration units	?		Noise and vibrational measurements in site; per vehicle/filtersystem	Noise and vibration	
		A change is expected due to reduced emissions and filtration.	pos		chemical measurements / release tests (e.g., FLEC)	Vehicle interior air quality	
		No change	static		Capacity per vehicle unit; disability-friendliness;	Mobility capability	
Use		A change is expected; increased employment	pos		Estimation of employments associated with the retrofit solution	Employment (quantity)	
		A change is expected , but can vary depending on life-cycle stage (production, use, waste..)	?		Occupational risk assessment (qualitative and quantitative) (SLCA)	Occupational health and safety	**[Employment quality]**
		No change is expected	static		No assessment needed	Labour rights	
		No change is expected	static		No assessment needed	Human rights (including conflict minerals)	
End of Life			pos		Risk assessment for the public (commuters and general) (SLCA)	General public health and safety	
	Economic impact	A change is expected; increased cost due to addition of new product	neg		Financial cost-benefit (LCA)	Money to contractors	**[Gross profit from selling a car, materials, components and from product maintenances and finance]**
		A change is expected; increased cost due to addition of new product	neg		Financial cost-benefit (LCA)	Production cost	
		A change is expected; increased cost for consumer due to addition of new product; gain for producers	neg/pos		Financial cost-benefit (LCA)	Acquisition cost	
		A change is expected; increased cost (fuel and electricity, service) due to addition of new product	neg		Financial cost-benefit (LCA)	Operating and maintenance cost	
		A change is expected; residual value should be assessed and included	neg		Financial cost-benefit (LCA)	End-of-life cost (value)	

2A - Brake

2B - Brake

	b) From Jasinski et al. Fig. 2											*b) From Jasinski et al. Fig. 2*	*in the proposal*
	MIDPOINTS (Final framework in Jasinsky et al. adjusted)		**UN Sustainable Development Goals in proposal**									**END POINTS**	**UN Sustainable Development Goals in proposal**
			UN Goal 6	UN Goal 11	UN Goal 14	UN Goal 15	UN Goal 3	UN Goal 8	UN Goal 9	UN Goal 12	UN Goal 17		
	Global warming potential		√		√								
	Stratospheric ozone depletion			√	√		√						
	Photochemical ozone creation potential			√			√						
	Acidification potential (terrestrial and aquatic)			√	√							Group1	
	Particulate matter formation				√		√					**Climate Change**	Clean water and sanitation [UN Goal 6]
	Eutrophication potential (terrestrial and aquatic)			√								**Ecosystem quality (air, water and soil quality)**	Sustainable cities [UN Goal 11]
	Ecotoxicity (terrestrial and aquatic)			√	√							**Impact on biodiversity**	Life below water [UN Goal 14]
	Human toxicity						√					**Resource depletion**	Life on land [UN Goal 15]
	Energy consumption			√	√	√							
	Resource and minerals consumption (net of renewable, reused and recycled materials)			√	√	√							
	Water consumption			√	√	√							
	Land use			√	√	√							
												Group 2	
	Vehicle safety (accident avoidance)						√	√				**Human health**	Good health and well-being [UN Goal 3]
	Congestion			√			√	√				**Quality of life (Human wellbeing)**	
	Noise and vibration				√		√						
	Vehicle interior air quality						√						
	Mobility capability						√	√					
on	Employment (quantity)						√	√			√	Group 3	
LCA)	Occupational health and safety	**[Employment quality]**					√	√				**Gross Value Added**	Economic growth [UN Goal 8]
	Labour rights						√	√				**Dividends**	Industry, innovation & infras. [UN Goal 9]
	Human rights (including conflict minerals)						√	√					Responsible production [UN Goal 12]
)	General public health and safety											**Taxes (profit, people, production, environmental and road tax)**	Partnerships for the goals [UN Goal 17]
	Money to contractors	**[Gross profit from selling a car, materials, components and from product maintenances and finance]**						√		√	√		
	Production cost							√		√	√		
	Acquisition cost							√		√	√		
	Operating and maintenance cost							√		√	√		
	End-of-life cost (value)							√		√	√		

Retrofit solutions for

1 - Tailpipe

2 - Brake

3 - Closed environment emissions

1 - Tailpipe

2 - Brake

3 - Closed

TABLE A-3

	Impact category	Expected change due to AeroSolfd	Qualitative indicator (pos/static/neg/?)	Lead Partner	Approach (how the midpoint (Governance, SLCA, RA..) can be assessed)	b) From Jasinski et al. Fig. 2 MIDPOINTS (Final framework in Jasinsky et al. adjusted)	
	Environmental impact	A net change may occur. Ultrafine particles contributes to cloud formation and cooling.	static/neg		Environmental impact assessment (LCA)	Global warming potential	
		No change is expected	static		Environmental impact assessment (LCA)	Stratospheric ozone depletion	
		net NOX release to air is expected to be reduced	pos		Environmental impact assessment (LCA)	Photochemical ozone creation potential	
		Improved air-quality is expected, including reduced formation of secondary aerosols (needs assessment along Life-cycle)	static / pos		Environmental impact assessment (LCA)	Acidification potential (terrestrial and aquatic)	
		Improved air-quality is expected, including reduced formation of secondary aerosols	pos		Environmental impact assessment (LCA)	Particulate matter formation	
LIFE CYCLE STAGES		No change is expected	static		Environmental impact assessment (LCA)	Eutrophication potential (terrestrial and aquatic)	
		A postive change is expected	pos		Ecotoxic assessment (e.g., SSWD approach) (LCA)	Ecotoxicity (terrestrial and aquatic)	
						Human toxicity	
Design	Resource impact	An increase is expected for production, use and disposal	neg		Energy budget (LCA)	Energy consumption	
		more ressources will be needed (i.e. net waste)	neg		Materials budget (LCA)	Resource and minerals consumption (net of renewable, reused and recycled materials)	
		more ressources will be needed (i.e. net waste)	neg		water use assessment (LCA)	Water consumption	
		more ressources will be needed (i.e. mining, energy, space for use, and net waste)	neg		Assessment of land use (LCA)	Land use	
Raw materials							
	Social impact	A change could occur due to impact on car by retrofit solution	?		Euro NCAP rating, qualitative safety assessment/inspection,	Vehicle safety (accident avoidance)	
		No change; Potentially increased traffic due to more E-freindly	?		Traffic measurement	Congestion	
Manufacturing		A change could occur due to impact on car by retrofit solution; and noise from filtration units	?		Noise and vibrational measurements in site; per vehicle/filtersystem	Noise and vibration	
		A change is expected due to reduced emissions and filtration.	pos		chemical measurements / release tests (e.g., FLEC)	Vehicle interior air quality	
		No change	static		Capacity per vehicle unit; disability-friendliness;	Mobility capability	
Use		A change is expected; increased employment	pos		Estimation of employments associated with the retrofit solution	Employment (quantity)	
		A change is expected , but can vary depending on life-cycle stage (production, use, waste..)	?		Occupational risk assessment (qualitative and quantitative) (SLCA)	Occupational health and safety	[Employment quality]
		No change is expected	static		No assessment needed	Labour rights	
		No change is expected	static		No assessment needed	Human rights (including conflict minerals)	
End of Life			pos		Risk assessment for the public (commuters and general) (SLCA)	General public health and safety	
	Economic impact	A change is expected; increased cost due to addition of new product	neg		Financial cost-benefit (LCA)	Money to contractors	
		A change is expected; increased cost due to addition of new product	neg		Financial cost-benefit (LCA)	Production cost	[Gross profit from selling a car, materials, components and from product maintenances and finance]
		A change is expected; increased cost for consumer due to addition of new product; gain for producers	neg/pos		Financial cost-benefit (LCA)	Acquisition cost	
		A change is expected; increased cost (fuel and electricity, service) due to addition of new product	neg		Financial cost-benefit (LCA)	Operating and maintenance cost	
		A change is expected; residual value should be assessed and included	neg		Financial cost-benefit (LCA)	End-of-life cost (value)	

3A - Closed

3B – Closed

b) From Jasinski et al. Fig. 2 MIDPOINTS (Final framework in Jasinsky et al. adjusted)		UN Sustainable Development Goals in proposal UN Goal 6	UN Goal 11	UN Goal 14	UN Goal 15	UN Goal 3	UN Goal 8	UN Goal 9	UN Goal 12	UN Goal 17	b) From Jasinski et al. Fig. 2 END POINTS	in the proposal UN Sustainable Development Goals in proposal
Global warming potential		v		v								
Stratospheric ozone depletion			v	v		v						
Photochemical ozone creation potential			v			v						
Acidification potential (terrestrial and aquatic)			v	v							Group1	
Particulate matter formation				v		v					Climate Change	Clean water and sanitation [UN Goal 6]
Eutrophication potential (terrestrial and aquatic)			v								Ecosystem quality (air, water and soil quality)	Sustainable cities [UN Goal 11]
Ecotoxicity (terrestrial and aquatic)			v	v							Impact on biodiversity	Life below water [UN Goal 14]
Human toxicity						v					Resource depletion	Life on land [UN Goal 15]
Energy consumption			v	v	v							
Resource and minerals consumption (net of renewable, reused and recycled materials)			v	v	v							
Water consumption			v	v	v							
Land use			v	v	v							
											Group 2	
Vehicle safety (accident avoidance)						v	v				Human health	Good health and well-being [UN Goal 3]
Congestion			v			v	v				Quality of life (Human wellbeing)	
Noise and vibration				v		v						
Vehicle interior air quality						v						
Mobility capability						v	v					
Employment (quantity)						v	v			v	Group 3	
A) Occupational health and safety	[Employment quality]					v	v				Gross Value Added	Economic growth [UN Goal 8]
Labour rights						v	v				Dividends	Industry, innovation & infras. [UN Goal 9]
Human rights (including conflict minerals)						v	v					Responsible production [UN Goal 12]
General public health and safety											Taxes (profit, people, production, environmental and road tax)	Partnerships for the goals [UN Goal 17]
Money to contractors							v		v	v		
Production cost	[Gross profit from selling a car, materials, components and from product maintenances and finance]						v		v	v		
Acquisition cost							v		v	v		
Operating and maintenance cost							v		v	v		
End-of-life cost (value)							v		v	v		