Questionnaire on ‘Best Available Techniques’ for mobile sources emission reductions in support of a Guidance Document to the Gothenburg Protocol

# Introduction

The European Commission (DG ENV)[[1]](#footnote-1) has assigned IIASA[[2]](#footnote-2) (Austria) and EMISIA[[3]](#footnote-3) (Greece) with the task to identify

*‘Best Available Techniques’ (BAT) in reducing emissions from mobile sources*

(road transport, maritime, rail, non-road mobile machinery, aviation). Collected information on best practice techniques to reduce pollutant emissions from mobile sources will be used for a new guidance document to support the implementation of the Gothenburg Protocol of the UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP)[[4]](#footnote-4).

In principle, the guidance document aims at assisting countries to meet their emission reduction targets, by offering a range of proven measures to reduce emissions from mobile sources. The document should describe options for both improvements of existing, possibly less advanced, technology as well as for new emission control technology. Finally, promising technologies under development should be sketched.

With this questionnaire we would like to collect **your input on technical measures to reduce emissions from new and existing engines and vehicles, mobile machinery, railcars, locomotives, vessels and aircrafts**. The technologies should be proven in practice, effective in emission control, and economical. Please substantiate your input by documents, references to literature and practical examples, own measurements, or any other suitable information. Technologies with best overall performance will be highlighted as ‘best available techniques’ for emission reductions in the guidance document to the countries.

# General guidance for filling in the questionnaire

* Please complete the questionnaire with the following overarching question in mind:

*“What are proven solutions that can be applied on a country level to reduce emissions from mobile sources?”*

* For describing different techniques, feel free to copy the template of the questionnaire as many times as needed. We are looking for successful and practical examples.
* An indicative list of emission reduction technologies and two examples of filling in the questionnaire are provided (one for DPF to control PM from exhaust emissions and one for activated carbon canister to control VOC from fuel evaporation).
* If you think it takes too much time to fill in the questionnaire or that it does not provide the framework of what you would like to respond to, please contact Dr. Leonidas Ntziachristos (leon.n@emisia.com) or Dr. Giannis Papadimitriou (giannis.p@emisia.com) for a direct discussion on best available emission reduction technologies for mobile sources ( +30 2310 473374,  +30 2310 804110).
* Feel free to forward the questionnaire to other relevant experts in your company.
* We would appreciate receiving **your feedback until 25 May 2014**.

# Questions

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| **Q1. General Description** |
| Name of technique |  |
| Pollutants addressed | *“Please also include synergetic effects for some of the pollutants, e.g. an oxidation catalyst used to reduce HC emissions has been shown to also have a positive effect in terms of PM reduction.”* |
| Engine/vehicle/vessel types considered (specify category and other details to the extent possible) |  |
| Limitations in its applicability (e.g. environmental conditions, fuel specifications, technological barriers, behavioural changes, etc.) |  |
| **Q2. Environmental Benefit** |
| Specific claims (% reduction range of pollutants addressed) | *“Please define reduction relative to what base/reference technology, over which duty cycle, engine size/power, etc.”* |
| Successful examples of implementation (please provide literature reference or description or practice examples, to the extent possible) |  |
| **Q3. Environmental Side Effects** |
| Impact on fuel consumption (indicate positive/negative impact and typical % effect) | *“Over the same duty cycles as above – please point out relevant deviations.”* |
| Non-regulated pollutants and trade-offs (e.g. NH3 or N2O emissions, NO2 formation, PM/NOx trade-offs, etc.) |  |
| **Q4. Implementation**  |
| Ease of implementation (technology or expertise required, infrastructural needs, etc.) |  |
| Maintenance and operation (additional maintenance requirements, monitoring requirements, …) |  |
| Durability/lifetime of emission control equipment | *“How effective is the emission control after e.g. 3/5/10 years or many hours of operation...”* |
| Impacts on safety (users, citizens, …) |  |
| Costs for implementation and operation (order-of magnitude estimations per unit, or implementation or any other metric are sufficient) |  |
| **Q5.Other Points** |
| Please provide any other comments or remarks not addressed above |  |
| References for further details |  |
|  |
| **Personal Information** |
| Please state your name, your company and your responsibility, e-mail, telephone number |  |

# Indicative emission reduction technologies

1. Powered two-wheelers
* Two-way oxidation catalyst
* Secondary air injection
* Three-way catalyst with oxygen sensor control
* Electronic engine management
* Fuel injection (also relevant for evaporation control)
1. Petrol engines (passenger cars and LCVs)
* Three-way catalyst
* Gasoline Direct Injection (GDI)
* Gasoline Particle Filter (GPF)
* Lean De-NOx catalyst
1. Diesel engines (road/off-road)
* Diesel Oxidation Catalyst (DOC)
* Diesel Particulate Filter (DPF)
* Selective Catalytic Reduction (SCR)
* Combination of DPF+SCR
* Exhaust Gas Recirculation (EGR)
* Lean NOx Catalyst (LNC)
* Closed Crankcase Ventilation (CCV)
1. Rail
* Diesel Particulate Filter (DPF) for rail vehicles, combined with DeNOx and Oxidation System
* Selective Catalytic Reduction (SCR)
* Exhaust Gas Recirculation (EGR)
1. Waterborne
* SOx scrubbers (open/closed loop, hybrid)
* Diesel Particulate Filter (DPF) for inland water vessels
* Diesel Particulate Filter (DPF) for ships and yachts, combined with DeNOx and Oxidation System
* Selective Catalytic Reduction (SCR) – DeNOx systems for commercial ships
1. Aviation
* Low-NOx combustor
* Aircraft design improvements: aerodynamics, weight reduction, and control systems
* CNS/ATM (communication, navigation, surveillance/air traffic management)
1. Off-road spark-ignited equipment
* Three-way catalyst
* Non-Selective Catalytic Reduction system (NSCR)
* Temperature/oxygen sensor
1. Non-exhaust sources
* Activated carbon canister for gasoline light-duty vehicles, mopeds and motorcycles, marine engines, handheld machinery (evaporation control)
* Low-permeability, multi-layer fuel tanks (evaporation control)
* Purging strategy (evaporation control)
* Low-friction tyres (tyre-wear control)
1. Other techniques and emission control strategies
* Repower (replacing an existing engine with a new engine)
* Rebuild (periodic maintenance)
* Refuel (use of alternative fuels, emulsified fuels, biodiesel, hybridization, electrification)
* Replace (retiring higher polluting equipment from service before it would otherwise be retired)

# Example of filling in the questionnaire (1)

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| **Q1. General Description** |
| Name of technique | **Diesel Particulate Filter (DPF)** |
| Pollutants addressed | PM (main pollutant addressed), BC, HC, CO |
| Engine/vehicle/vessel types considered (specify category and other details to the extent possible) | Diesel engines and vehicles (both for OEM and retrofit applications): heavy-duty trucks, buses, non-road vehicles (construction and agriculture machineries), marine vessels, trains. |
| Limitations in its applicability (e.g. environmental conditions, fuel specifications, technological barriers, behavioural changes, etc.) | * The system should be properly designed for the particular application to be used.
* DPFs work best on engines built after 1995. Exhaust gas temperature data logging must be performed to determine if the exhaust temperature profile meets DPF-specific requirements.
* Ultra-low-sulfur diesel (ULSD) fuel required (<50ppm).
* Minimum oxygen requirement in exhaust gas: 15% O2 (in some applications).
* Passive filters require operating temperatures high enough to initiate combustion of collected soot. Active regeneration uses other heat sources, such as fuel burning or electric heaters, to raise a DPF temperature sufficiently to combust accumulated PM.
* pDPFs (partial or flow-through filters) are always subject to minimum temperature requirements necessary for periodic regeneration (i.e., combustion of collected PM).
 |
| **Q2. Environmental Benefit** |
| Specific claims (% reduction range of pollutants addressed) | Indicative % reduction range compared to reference technology:\_ Turbocharged compression-ignition engine with high-pressure fuel injection (road/off-road vehicles)\_ Conventional diesel compression ignition engine (marine vessels, trains)* PM (80-95%), HC (85-95%), CO (50-90%)
* PM (30-60%), HC (40-75%), CO (10-60%) (pDPF)
* Allows vehicles as old as Euro II to meet PM standards of Euro IV
 |
| Successful examples of implementation (please provide literature reference or description or practice examples, to the extent possible) | <http://www.dieselretrofit.eu/map.aspx><http://www.epa.gov/cleandiesel/verification/verif-list.htm><http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm> |
| **Q3. Environmental Side Effects** |
| Impact on fuel consumption (indicate positive/negative impact and typical % effect) | * In some situations, installation of a filter system on a vehicle may cause a slight fuel economy penalty (1-2%).
* Soot particulates burn-off forms water and CO2 in small quantity since it is less than 0.05% of the CO2 emitted by the engine.
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| Non-regulated pollutants and trade-offs (e.g. NH3 or N2O emissions, NO2 formation, PM/NOx trade-offs, etc.) | Concerns that catalyzed DPFs may increase the NO2 fraction of total NOx emissions. Some DPFs generate NO2 as a means to help filter regeneration at lower temperatures. The NO2 produced by a DPF is dependent on the catalyst formulation. |
| **Q4. Implementation**  |
| Ease of implementation (technology or expertise required, infrastructural needs, etc.) | Installation: 6-8 hours |
| Maintenance and operation (additional maintenance requirements, monitoring requirements, …) | * Active/passive regeneration and cleaning system needed (filters require periodic maintenance to clean out non-combustible materials, such as ash).
* Since the continuous flow of soot into the filter would eventually block it, it is necessary to ‘regenerate’ the filtration properties of the filter by burning-off the collected particulate on a regular basis.
* pDPF should incorporate electronic back pressure monitoring equipment to signal vehicle and equipment operators when the device needs to be cleaned.
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| Durability/lifetime of emission control equipment | No significant performance degradation if properly maintained. |
| Impacts on safety (users, citizens, …) | --- |
| Costs for implementation and operation (order-of magnitude estimations per unit, or implementation or any other metric are sufficient) | * Material: $8,000–$50,000
* Material: $4,000–$6,000 (pDPF, partial or flow-through)
* Many vehicles can be upgraded for the cost of one new
 |
| **Q5.Other Points** |
| Please provide any other comments or remarks not addressed above | DPF can be combined with Selective Catalytic Reduction (SCR) system or Lean-NOx Catalyst (LNC) technologies for additional emission reductions. |
| References for further details | <http://www.dieselretrofit.eu/Default.aspx><http://www.epa.gov/cleandiesel/technologies/retrofits.htm><http://www.meca.org/diesel-retrofit/what-is-retrofit> |
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| **Personal Information** |
| Please state your name, your company and your responsibility, e-mail, telephone number | Giannis Papadimitriou, Engineer at EMISIA SA, giannis.p@emisia.com, Tel: +30 2310 473374 |

# Example of filling in the questionnaire (2)

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| **Q1. General Description** |
| Name of technique | **Activated Carbon Canister** |
| Pollutants addressed | VOC (from fuel evaporation) |
| Engine/vehicle/vessel types considered (specify category and other details to the extent possible) | * All petrol vehicles (passenger cars, light commercial vehicles, mopeds and motorcycles), marine engines, and small handheld machinery (e.g. in lawn and garden applications)
* Can be installed in uncontrolled vehicles/equipment (retrofitting) or as replacement of smaller canisters (e.g. for meeting stricter limits)
 |
| Limitations in its applicability (e.g. environmental conditions, fuel specifications, technological barriers, behavioural changes, etc.) | * Canister has to be properly purged for maintaining its working capacity
* For correct dimensioning a number of parameters should be taken into consideration: fuel tank size, fuel specifications, climatic conditions, type of application (on-road, off-road)
* Adsorption efficiency may decrease with ethanol content
 |
| **Q2. Environmental Benefit** |
| Specific claims (% reduction range of pollutants addressed) | * Up to 99% of breathing losses depending on carbon quality, age, purging strategy, ambient temperature
* No effect on other evaporation losses (due to permeation, leakages and refuelling)
 |
| Successful examples of implementation (please provide literature reference or description or practice examples, to the extent possible) | [http://www.meca.org/galleries/files/MECA\_Evap\_](http://www.meca.org/galleries/files/MECA_Evap_White_Paper_Final.pdf)[White\_Paper\_Final.pdf](http://www.meca.org/galleries/files/MECA_Evap_White_Paper_Final.pdf) |
| **Q3. Environmental Side Effects** |
| Impact on fuel consumption (indicate positive/negative impact and typical % effect) | No significant impact on fuel consumption (only small amounts of fuel saved) |
| Non-regulated pollutants and trade-offs (e.g. NH3 or N2O emissions, NO2 formation, PM/NOx trade-offs, etc.) | --- |
| **Q4. Implementation**  |
| Ease of implementation (technology or expertise required, infrastructural needs, etc.) | Easy to install when properly designed |
| Maintenance and operation (additional maintenance requirements, monitoring requirements, …) | * No additional maintenance required
* Malfunctioning purge valve (venting fuel vapour to the engine), and leaks in vent and vacuum hoses may be detected by OBD (where applicable)
* Evap-related problems/failures do not have any impact on vehicle driveability
 |
| Durability/lifetime of emission control equipment | Deterioration of canister performance with mileage |
| Impacts on safety (users, citizens, …) | --- |
| Costs for implementation and operation (order-of magnitude estimations per unit, or implementation or any other metric are sufficient) | Cost of materials for vehicle manufacturers: 10 – 20 €- Including carbon canister, hoses, purge valve- Excluding engine calibration |
| **Q5.Other Points** |
| Please provide any other comments or remarks not addressed above | * For an effective control of evaporative emissions, an activated carbon canister should be combined with low-permeability fuel tank and hoses
* In addition to the quantity of carbon contained in the canister, carbon quality is also important. There are typically two classes of durability of carbons:
* Low Degradation Carbons: these carbons lose about 4% to 9% of their capacity over the lifetime of the vehicle, due to repeated cycling with gasoline.
* High Degradation Carbons: these carbons lose about 12% to 20% of their capacity over the lifetime of the vehicle, due to repeated cycling with gasoline.
 |
| References for further details | * Estimating the Costs and Benefits of Introducing a New European Evaporative Emissions Test Procedure. JRC Scientific and technical Reports, EUR 26057 EN, 2013.
* Joint EUCAR/JRC/CONCAWE Programme on: Effects of gasoline vapour pressure and ethanol content on evaporative emissions from modern cars. Final report to DG Joint Research Centre. EUR 22713 EN, Luxembourg: Office for Official Publications of the European Communities, 2007.
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| **Personal Information** |
| Please state your name, your company and your responsibility, e-mail, telephone number | Giorgos Mellios, Managing Director of EMISIA SA, giorgos.m@emisia.com, Tel: +30 2310 473352 |

1. European Commission, Directorate General Environment, DG ENV.SRD.2, B-1049 Brussels, Belgium. Contact person: Mr Thomas Verheye, Unit C3, DG ENV, Office: BU9 05/147. [↑](#footnote-ref-1)
2. [http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionand](http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/CLRTAP---EMEP---CIAM.en.html) [Greenhousegases/CLRTAP---EMEP---CIAM.en.html](http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/CLRTAP---EMEP---CIAM.en.html) (International Institute for Applied Systems Analysis) [↑](#footnote-ref-2)
3. <http://www.emisia.com/> (Emission inventorying and modelling, impact assessment studies of environmental policies) [↑](#footnote-ref-3)
4. <http://www.unece.org/index.php?id=29858> [↑](#footnote-ref-4)