European Commission

JRC TECHNICAL REPORTS

EU GPP Criteria for Public Spaces Maintenance

Preliminary Report

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2019

EUR 29953 EN

Acknowledgements

This report has been developed in the context of the Administrative Arrangement "Scientific support to Green Public Procurement (GPP 2015)" between DG Environment and DG Joint Research Centre. The project responsibles for DG Environment were: Gianluca Cesarei and Enrico Degiorgis.

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JRC Science Hub
https://ec.europa.eu/jrc

JRC118643

EUR 29953 EN

PDF ISBN 978-92-76-12784-0 ISSN 1831-9424 doi:10.2760/648744

Luxembourg: Publications Office of the European Union, 2019

How to cite this report: Espinosa Martinez, M., Kofoworola, O., De Oliveira Gama Caldas, M., Rodriguez Quintero, R., Wolf, O., Tato, B., Milano, A., Gagliardi, M. and Capeans, J., EU GPP Criteria for Public Spaces Maintenance - Preliminary Report, EUR 29953 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12784-0, doi:10.2760/648744, JRC118643.

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ABSTRACT

Green Public Procurement (GPP), in which public authorities procure goods, services and works that have less environmental impact than comparable contracts, has the potential to accelerate the market introduction and uptake of less environmentally damaging technologies. This report forms the basis to develop the EU GPP criteria for Public Spaces Maintenance. The development of EU GPP criteria requires in-depth information about the technical and environmental performance of this product group as well as about the typical procurement processes. This report gathers the necessary background information for that and presents it in a structured form. The scientific body of evidence gathered will be crosschecked with sector-experienced stakeholders to find the best way to develop the criteria in order to deliver optimum environmental improvements while complying with Public Procurement law and safeguarding the Single Market.

EXECUTIVE SUMMARY

Europe's public authorities are major consumers. By taking into account environmental criteria in its procurement procedures, contracting authorities promote modes of production that are more environmentally friendly and stimulate the supply of 'green' goods and services. Thus, they can make an important contribution to reducing the environmental impact of consumption and production - which is called Green Public Procurement (GPP) or green purchasing.
In order to support GPP, the European Commission has developed a set of common EU GPP criteria for various products and services in order to avoid the distortion of a single market and to reduce administrative burdens. The Commission has developed EU GPP criteria for approximately 20 different product groups. In order to keep the criteria as relevant to public authorities as possible, the Commission both reviews and updates the criteria on a regular basis and develops new criteria when a need for such is determined.

With this in mind, EU GPP criteria for Public Space Maintenance is currently being developed with the aim of lay down a new set of criteria for professional services involved in these activities.

This *Preliminary Report* aims to provide background information with a goal to develop a robust evidence base and prioritize key environmental issues to support the development of the EU GPP criteria. This report includes the results of three Tasks[1], that address:

1) The identification of the scope and overview on existing legislations and ecolabels; GPP experiences and ongoing projects and statistical categories of services and products.
2) Market analysis and cost data
3) Environmental analysis with a description of technical aspects, environmental issues and possible improvement potentials of services and products.

No previous GPP on the subject of Maintenance of Public Space has been developed by the European Commission until now. For this reason, the present study is the first document aiming to define EU GPP Criteria for this product group[2].
Although the maintenance of Public Space is a new product group, part of its proposed scope was previously covered in the EU GPP Criteria for Gardening Products and Services[3].

Part I: identification of the scope.
Since there is no existing EU GPP criteria on Public Space Maintenance, defining a scope is of key importance because it will serve as the basis for the whole study, and for future reviews and updates.
The first Part of this *Preliminary Report* is aimed at giving a response to the need to decide a clear definition of *Public Space Maintenance*.
The subject of maintenance of public spaces is complex because it involves different application fields, such as cleaning services (including winter maintenance), gardening and landscaping. They could interest a multitude of spaces such as urban areas, pedestrian and vehicular areas, man-made green areas, beaches, etc. Furthermore, the maintenance operations are related to the use of specific equipment such as vehicles for street cleaning or machinery both for cleaning or gardening and foresting operations.

The methodology followed for the identification of the scope consists in:

[1] The Documents are available at: http://susproc.jrc.ec.europa.eu/Public_space_maintenance/documents.html
[2] For further information: http://susproc.jrc.ec.europa.eu/Public_space_maintenance/
[3] Information available at: http://ec.europa.eu/environment/gpp/pdf/criteria/gardening.pdf

- **Overview of existing legislation, standards and criteria.** This includes a review of EU legislation, relevant guidelines and ecolabels at the EU and national levels as well as relevant standards, guidelines and initiatives used in the private sector.

In this section, the study focused the research on EU legislation using key words related with different groups found to be involved in Public Space Maintenance, such as:

- cleaning products and services
- gardening and landscaping
- repairing and replacement of public space items
- painting and repainting of public space items
- vehicles used for public space maintenance
- machinery used for public space maintenance

Furthermore, the research on existing relevant national guidelines allowed identifying a wide literature from some very active EU Member States such as Austria, Belgium, Netherland and Italy.
Moreover, the research about the Ecolabels provides insight on the main guideline at European level. In particular European Ecolabel Scheme on different products and services were analysed, as well as national Ecolabels, such as Nordic Swan and Blue Angel.

- **Overview of statistical and technical categories.** The focus of this review was based on the categories that can be used to define the activities and services that might be covered by EU GPP criteria for maintenance of public space.
In this section the main characteristics of different systems of standardization and classification are explained, including: NACE (statistical classification of economic activities in the European Communities); CPA (European Classification of Products by Activity), PRODCOM (classification of goods used for statistics on industrial production in the EU) and finally of CPV (common procurement vocabulary), which establishes a single classification system for public procurement aimed at standardizing the terms used by contracting authorities and entities to describe the subject of contracts.

- **First Stakeholder survey.** The questionnaire is the first step in the development of Public Space Maintenance EU GPP criteria and it aims to help the JRC project team in defining the scope of this product group. It has been designed to identify the views of stakeholders about the topic of maintenance of public space.

The received feedback from different stakeholders allowed a better definition of the scope of this study as also a better limitation of the activities in the scope.
As result, the stakeholder's recommendations allowed to identify activities that should be excluded from the scope, such as:

- Replacement of pavement and urban furniture
- Repairing or replacement of irrigation systems, fountains, street signs, urban furniture and mechanical equipment (e.g., gates)
- Maintenance of sewage
- Painting and repainting activities

- **Proposal of the scope and definition.** As result of the research phase of existing legislation, as well as standards and criteria, of statistical and technical categories, and including the outcomes of stakeholder's reactions to the first scope questionnaire, it has been possible to narrow down the precise scope and definition of EU GPP for Public Space Maintenance.

The four groups identified include:

1) Cleaning products and services
2) Gardening products and services
3) Vehicles for Public Space maintenance
4) Machinery for public space maintenance.

The specific activities covered under the scope are:

- Cleaning, including manual or mechanical sweeping and water jet cleaning, graffiti removal, façade cleaning, litter removal, etc.
- Snow removal
- Pruning, Trimming, Planting, Lawn replacement, irrigation
- Fertilization, Weed control and pesticides use

The specific equipment covered under the scope are:

- Vehicles (human controlled or autonomous) for the transport of workers and equipment, and materials
- Sweepers, Spreaders and street cleaning vehicles for winter operations
- Machinery used for cleaning and gardening (Lawn-mowers, chainsaws, trimmers; leaf collectors, leaf blowers, etc.)

Part II: market analysis and cost data

This Part presents the results of a market research regarding the situation of the Public Spaces Maintenance sector in the European context.
In order to be able to give an accurate and comprehensive overview of the sector, it has been essential to collect key information which enables a quantitative assessment of the economic and environmental relevance of the products and services included within the sector, from a managerial, organizational and functional point of view.
In addition, the market has been characterized according to market segmentation (geographical, technological, target group related), with an overview of the respective products and services, also identifying the key manufacturers/service providers and consumer groups/procurement entities.
Therefore, following the methodology of a market analysis the public space maintenance sector has been described according to the volume of the public procurement purchases in EU 28 (product/service supply and demand) and its market structure.
Finally, an analysis of future trends within the public spaces maintenance sector is provided, among other things, by distinguishing between the advantages and disadvantages between outsourced maintenance services and in-house provisions of public spaces maintenance.

One of the main findings of the market analysis is the fact that the volume and number of cleaning activities and services contracted by the public authorities in each country vary widely between different years, since the rate of purchase depend on the ups and downs based on budget constraints. Therefore, the evolution of the public expenditure in the European cities in the last years, shows the absence of periodicity in the purchase of public spaces maintenance services.

Another essential finding is that there is a large number of local small and medium-sized enterprises and a smaller number of large international companies with a large share of the European market. The latter are specialized in a unique segment and are able to propose a wide and coordinated offer, which generates a high level of competition.

Part III: Environmental analysis

The last Part of this *Preliminary Report* is divided into four chapters representing the four groups of products/services included in the scope of Public Space Maintenance.
Each chapter cover three main topics: the technical analysis of the different products/services; the environmental analysis; and finally, an overview of possible

improvement potential with some first considerations on cost impacts from the use of environmental friendly products and services.

The technical analysis of products/services describes the common practices in use also providing some insight on the different options of products and services available in the market and commonly used.

The sub-sections dedicated to the environmental analysis provide a comparison of the different options of products/services through a literature review on relevant LCA studies or researches. This method has enabled us to identify and compare the performances of the different products/services highlighting the main hotspots during their Life cycle.

The last section represents an overview on possible improvement potentials, providing a useful background information for the development of EU GPP criteria for Public Space Maintenance, including also a first attempt of cost consideration and analysis of market availability concerning environmental friendly alternatives for the purchase of products and services.

List of Abbreviations

AC	Award Criteria
CANs	Contract Award Notices
CCT	Compulsory Competitive Tendering
CH4	Methane
CMA	Calcium Magnesium Acetate
CN	Combined Nomenclature
CNs	Contract Notices
CO2	Carbon dioxide
CPA	Classification of Products by Activity
CPV	Common Procurement Vocabulary
DG	Directorate General
EC	European Commission
EPD	Environmental Product Declaration
ESS	European statistical system
EU	European Union
EV	Electronic Vehicles
FCEV	Fuel Cell Electric Vehicles
FEV	Fuel Efficient Vehicles
GHG	Greenhouse Gas
GPP	Green Public Procurement
GWP	Global Warming Potencial
HEV	Hybrid Electeric Vehicle
HS	Harmonised System
ICEV	Internal Combustion Engine Vehicles
ISIC	International Standard Industrial Classification
ISO	International Organization For Standardization
KF	Potassium Formate
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCV	Light commercial vehicles
LNG	Liquifie natural gas
MDV	Medium duty vehicle
N2O	Nitrous Oxide
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NaCI	Sodium Cloride
NAP	National Action Plans
NOX	Nitrogen Oxide
NPM	New Public Management
NRMM	Non Road Mobile Machine
ODP	Ozone Layer Depletion
OJS	Official Journal Supplement
PCR	Product Category Rules
PEF	Product Environmental Footprintc

PHEV	Plug-In Hybrid Electronic Vehicles
PM	Performance Management
PM10	Particulate Matter
PRC	Preliminary Report For Cleaning services
PRODCOM	PRODuction COMmunautaire
PRT	Preliminary Report For Transport
PVC	Polivinyle Cloride
RDE	Real Drive Emissions
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RTU	Ready To Use
SC	Selection Criteria
SPP	Sustainable Public Procurement
TBC	Technical Background For Cleaning services
TBG	Technical Background For Gardening Services
TBT	Technical Background For Transport
TED	Tenders Electronic Daily
TS	Technical Specifications
TTB	Transilluminated traffic bollards
TTW	Tank To Weel Emissions
VOCs	Volatile Organic Compounds
VMT	Vehicle mile of travel
WTT	Well To Tank

PART I: SCOPE, DEFINITION AND LEGISLATION

Introduction

This section is the first part of the study, and aims:
To provide an overview of existing statistical and technical categories, of existing relevant legislation, standards and other procurement criteria, and to propose on that basis a product/service group scope for the EU GPP criteria. To gather feedback from stakeholders regarding this product/service group scope.

The aim of the revision process is to deliver procurement criteria that reflect the latest technological development, while taking into account stakeholder opinions, current legal developments and other GPP initiatives. The criteria need to be ambitious enough to result in the 'greening' of the maintenance of public space sector, while on the other hand, barriers associated with the level of ambition should not hinder the use of the EU GPP criteria.

In the revision of the legal framework in which EU GPP for this product group will be included, mainly European policies and legislation have been considered, although similar initiatives and standards from non-EU countries have also been taken into account[4]

As part of the revision process, the following work has been undertaken:

- **Overview of existing legislation, standards and criteria.** This includes a review of EU legislation, relevant guidelines and ecolabels at the EU and national levels as well as relevant standards, guidelines and initiatives used in the private sector. This is presented in Section 2.

- **Overview of statistical and technical categories.** The focus of this review was based on the categories that can be used to define the activities and services that might be covered by EU GPP criteria for maintenance of public space. This is covered in Section 3.

- **First Stakeholder survey.** The questionnaire is the first step in the development of Public Space Maintenance EU GPP criteria and it aims to help the JRC project team in defining the scope of this product group. It is designed to identify the views of stakeholders about the topic of maintenance of public space. A second questionnaire will be sent during a second phase regarding more specific aspects of the maintenance activities that have been decided to be included in the scope. This is covered in Section 4.

- **Proposal of the scope and definition.** As result of the research phase of existing legislation, as well as standards and criteria, of statistical and technical categories, and including the outcomes of stakeholder's reactions to the first scope questionnaire, it is possible to narrow down the precise scope and definition of EU GPP for Public Space Maintenance. This is covered in Section 5.

[4] Interesting cases of specific policies aiming to regulate the Public Space Maintenance arrive from Australia for instance. In the research phase led to elaborate of this Report, several non-EU policies have been examined, as for instance: "Maintenance of Nature Strips in Urban Areas Policy", elaborated by Development and Economic Growth Department of Narrabri Shire, Australia; or the "Water Quality and Maintenance Costs of Constructed Waterbodies in Urban Areas of South East Queensland", a research conducted by M.L. Bayley and D. Newton in partnership with South East Queensland Healthy Waterways about maintenance activities and cost of artificial lakes.

1 Overview of the approach

Before entering into the details of existing legislations, standards and criteria, it seems relevant to introduce an initial consideration regarding the product group related to the Maintenance of Public Space.

The research done about existing legal, administrative and economic framework showed how complex the subject of maintenance of public space is, since it concerns several application fields, such as cleaning services, gardening and landscaping, painting and repairing, as it will be described in more detail in the following chapters of this document.

As it will be detailed in chapter 3, several policies have been developed and implemented at European and national levels in order to improve the environmental performances of many aspects that could be considered directly related with the maintenance of public space. However, until the present date no document has been specifically conceived and adopted by the European Commission on the specific subject of Maintenance of Public Space.

Both concepts of *Maintenance* and *Public Space* could have multiple definitions and generate different interpretations. For this reason, the proper fulfilment of this Task 1 has a key role in the definition of GPP Criteria for this product group.

In particular, limiting the concept of *public space* for the scope of EU GPP Criteria results to be a hard task since it could embrace a myriad of meanings including application fields such as: urban areas, pedestrian and vehicular areas, manmade green areas, public buildings, natural areas, beaches, lakes, public furniture, etc. As a first attempt to organize the application field of EU GPP for Public Space Maintenance, a precise classification of the different typologies of public spaces considered for the study has been done. These public space categories consist in one of the main points included in the first scoping questionnaire sent to possible stakeholders. For this reason, the results of the first stakeholder questionnaire have a key role in determining the definition of the scope of this EU GPP.

Also, the concept of *maintenance* materializes different interpretations. For instance, one of the focal issues related with the concept of maintenance is the difference between preventive and corrective maintenance. In fact, in some cases it could happen that the distinction between preventive and corrective maintenance is confined to a different nuance of interpretation, and the exact delimitation between them could be more or less evident depending on the fields of application.

Indeed, the possible overlapping between preventive and corrective maintenance, or even reconstruction activities in some cases, could result from an unclear definition of each typology of maintenance.

The subject of *Maintenance* is a recurrent topic in various contexts (urban management, economy, energy and sources supplies, structural behaviour of building, etc.), several definitions are available[5]. It could be particularly interesting at this point having a clear definition of the different categories of maintenance. The publication Reliability Engineering[6] provides the following definitions: *Maintenance can be defined as actions to*

[5] Definition of Collins dictionary: "The maintenance of a building, vehicle, road, or machine is the process of keeping it in good condition by regularly checking it and repairing it when necessary". Moreover, several maintenance typologies are conventionally recognized, as detailed in European Standard BS EN 13306:2010.

[6] Pham, Hoang, ed. 2003. *Handbook of Reliability Engineering.* London: Springer-Verlag. doi:10.1007/b97414. Consulted at: https://books.google.es/books?id=p4f5BwAAQBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

control deterioration process leading to failure of a system, and to restore the system to its operational state through corrective actions after a failure. The former is called Preventive Maintenance, the latter Corrective Maintenance.
Nevertheless, the main European Reference for Maintenance in general is the European Standard EN 13306:2010. The purpose of this European Standard is to define the generic terms used for all types of maintenance and maintenance management irrespective of the type of item considered. This European Standard specifies generic terms and definitions for the technical, administrative and managerial areas of maintenance. See Figure 1.

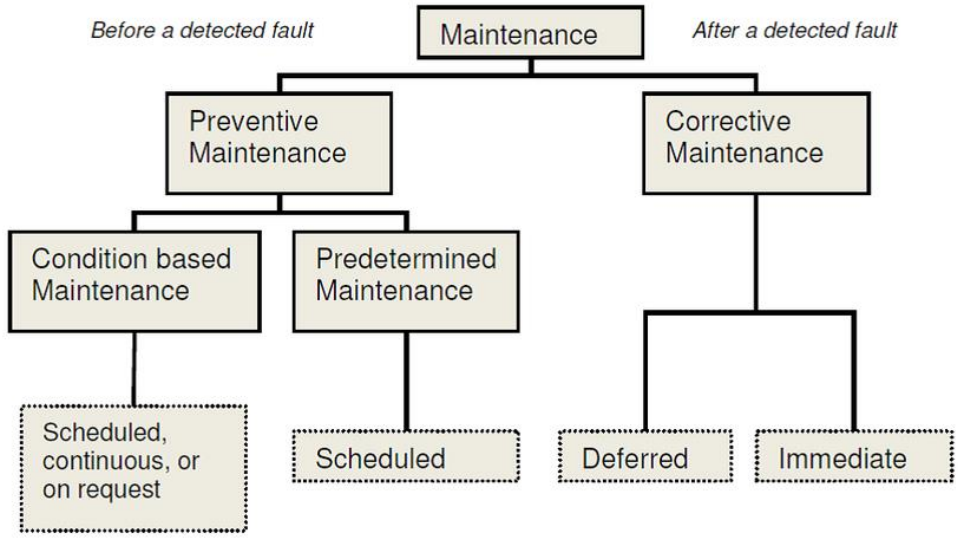


Figure 1: Overview of different type of maintenance according to BS EN 13306:2010.

The EN 13306:2010 results to be useful especially for providing a clear definition of fundamental terms related with maintenance, as follows:

Maintenance: combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function

Maintenance Management: all activities of the management that determine the maintenance objectives, strategies and responsibilities, and implementation of them by such means as maintenance planning, maintenance control, and the improvement of maintenance activities and economics

Corrective Maintenance: Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function

Condition Based Maintenance: Preventive maintenance which include a combination of condition monitoring and/or inspection and/or testing, analysis and the ensuing maintenance actions

Maintainability: Ability of an item under given conditions of use, to be retained in, or restores to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources

Preventive Maintenance: Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item.

Predictive maintenance: Condition based maintenance carried out following a forecast derived from repeated analysis or known characteristics and evaluation of the significant parameters of the degradation of the item. [7]

The maintenance activities, aiming to maintain the public space on usable conditions, which are to be included as scope of this EU GPP are defined chapter 6.

1.1 Overview of other existing GPP

As known, other GPP were previously developed for other product groups. Some of the items considered in other GPP could be possibly considered as Public Space Maintenance products or activities. In order to avoid overlapping between product groups already considered in other GPP and harmonize the Green Public Procurement scopes, a detailed analysis of other GPP scopes has been done. As it results, some of the potential scopes of this GPP for Public Space Maintenance have been discarded because they are already covered in other GPP, while other items previously included in other GPP have been integrated in this scope. In particular, the adopted behaviours are:

- Discard the product groups included in other GPP Criteria, such as:
  - Roads, being part of the scope of EU GPP Criteria of **Road Design, Construction and Maintenance** [8]
  - Street lighting and traffic signals being part of the scope of EU GPP Criteria of **Street lighting and traffic signals**[9]
- Update, adapt and include product groups included in other GPP Criteria, such as:
  - Parks and gardens until present being part of the scope of EU GPP Criteria of **Gardening products and services.**[10] This product group is now converged in the EU GPP Criteria of Maintenance of Public Space.

[7] European Standards " EN 13306:2010" Maintenance - Maintenance terminologie

[8] EU Green Public Procurement Criteria for Road Design, Construction and Maintenance : Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/report_gpp_roads.pdf EU GPP Criteria available at : http://ec.europa.eu/environment/gpp/pdf/GPP%20criteria%20Roads%20(2016)%20203.pdf

[9] EU Green Public Procurement Criteria for Street lighting and traffic signals. Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/street_lighting_tbr.pdf. EU GPP Criteria available at http://ec.europa.eu/environment/gpp/pdf/criteria/street_lighting.pdf

[10] EU Green Public Procurement Criteria for Gardening products and services. Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/garderning_tbr.pdf. EU GPP Criteria available at http://ec.europa.eu/environment/gpp/pdf/criteria/street_lighting.pdf

2 Overview of the existing legislation, standards and criteria

The aim of this section is to provide an overview of existing legislation, standards and other procurement criteria that are of relevance to Public Space Maintenance services. In chapter 2.1, an overview of relevant EU legislation is provided focusing on those Communications, Regulations and Directives important to regulating the different services, activities or products and tools used in relation with public space maintenance. In chapter 2.2 an overview is provided of relevant labelling and green procurement criteria at the national level, including national or international ecolabels. At chapter 2.3 a brief overview of relevant initiatives and best practices in European countries related to the topic of our EU GPP is then provided.

In this perspective, a crucial role is covered by EU GPP for Public Space Maintenance. It is important to mention that the EU GPP policies, even if they are to remain voluntary tools, are going to acquire a growing importance in the management of Public Procurement. As reported in the General Union Environment Action Programme 2020, *Living well within the limits of our planet*, "*Member States and regions should take further steps to reach the target of applying green procurement criteria to at least 50% of public tenders*."[11]

On the other hand, even an accurate literature review did not show an explicit concern regarding the topic of maintenance of public space; in particular, many topics very related to the maintenance of public space are mentioned and treated in several policies and legislations (water use, reduction of the pollution of transport means, chemical products used in cleaning activities, etc.). However it resulted difficult to find specific documents focused primarily on maintenance. Actually, from the analysis conducted to fulfil Task 1 of the project, the more evident references of certain aspects related to the maintenance of public space are present in the following forms:

- **Chapters dedicated to maintenance** in documents treating about general guidelines of planning, design and realization.
  - Example: Italian legislation UNI/PdR 8:2014 - Guidelines for sustainable development of urban and peri-urban green areas - Planning, design, realization and maintenance[12]
- Research projects and best practices focused on a **specific topic** related to Public Space Maintenance, often reaching the prototyping or implementation phase.
  - Example: Life Project Redust - Best winter maintenance practice to reduce respirable street dust in urban area, implemented in Finland[13]
- **Non-EU legislations on specific topics** related to Public Space Maintenance.
  - Example: The document "Maintenance of Nature Strips in Urban Area Policy" adopted by the city of Narrabri Shire, Australia[14]

As previously mentioned, other EU GPP Criteria, and consequently part of the research done to establish them, will converge in the EU GPP for Public Space Maintenance and in its Technical Background Report. As important sources of information to this report, the following documents have been consulted:

[11] General Union Environment Action Programme 2020, Living well within the limits of our planet. More info at: http://ec.europa.eu/environment/action-programme/

[12] UNI/PdR 8:2014 Linee guida per lo sviluppo sostenibile degli spazi verdi - Pianificazione, progettazione, realizzazione e manutenzione. Available in italian at:http://catalogo.uni.com/pdr/pub/uni_pdr_8_2014.pdf

[13] LIFE Project. More info and dissemination material at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3734

[14] Information available at: http://www.narrabri.nsw.gov.au/index.cfm?page_id=1020

- Green Public Procurement: **Cleaning Products and Services**: Technical Background Report, 2011 [15]
- Green Public Procurement: **Gardening Products and Services**: Technical Background Report, 2011[16]
- Revision of the EU Green Public Procurement Criteria for **Transport:** Preliminary report Task 1 Report: Scope, definitions and legislation, 2016[17]

Note about the research methodology

In order to better organize the research, it has been useful to explore existing legislations, policies or guidelines according to the following structure:

- **Activities** related with Public Space Maintenance, organized around five main services, such as:
  - Cleaning
  - Gardening & landscaping
  - Repairing/Replacement
  - Painting/Repainting
  - Assembly and removal of temporary elements

- **Equipment Items** needed to accomplish Maintenance activities, such as:
  - Vehicles
  - Machinery

[15] EU Green Public Procurement Criteria for Cleaning Products and Services. Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/cleaning_tbr.pdf EU GPP Criteria available at http://ec.europa.eu/environment/gpp/pdf/toolkit/cleaning_product/en.pdf

[16] EU Green Public Procurement Criteria for Gardening Products and Services.

[17] EU Green Public Procurement Criteria for Transport. Technical Background Report available at: http://ec.europa.eu/environment/gpp/pdf/tbr/transport_tbr.pdf.
EU GPP Criteria available at: http://ec.europa.eu/environment/gpp/pdf/criteria/transport.pdf.
Report Task 1 available at: http://susproc.jrc.ec.europa.eu/Transport/docs/EU%20GPP%20Transport%20-%20Task%201%20Report.pdf

2.1 Overview of EU legislation that regulates the environmental performance of maintenance of public space

In order to consider other existing EU legislations that could influence the definition of the present EU GPP Criteria, in this preliminary phase it has been established to focus the research on Public Space in general when needed, rather than specifically to Maintenance of Public Space. By doing so, a larger number of EU legislations have been consulted and taken into consideration. Nevertheless, the following overview focuses only on aspects related to Maintenance, leaving apart the analysis that features related to planning, design and construction of Public Spaces.

2.1.1 Existing EU legislation in terms of cleaning products and services

In the following chapter, considerations about existing EU legislations regarding Cleaning services will be described. In terms of Maintenance of Public Space for this research phase, it has been established to refer to Cleaning Services by including the following activities: Mechanical & manual sweeping, Litter removal, Bins' litter collection and sorting, Mechanical & manual water jet cleaning, Façade/surface cleaning, Graffiti removal, Sidewalks, Bike lanes, Road (asphalt, roadbed) and roadside (shoulders, curbs, green areas) cleaning, Snow removal from sidewalks, Beach cleaning, Water bodies cleaning. Disaster assistance: Debris removal and After event cleaning are also considered for this purpose.

European legislation to be considered for certain of these activities is more related with Transport[18], Machinery[19] and Waste Management[20] (sweeping, litter removal, etc.), while regarding surface cleaning (graffiti removal, road and roadside cleaning, etc.) it is important to consider existing legislations especially with regards to the chemical products used for cleaning operations. For this purpose, the technical report for EU GPP Criteria for Cleaning Products and Services is a vital reference.

European legislation both provides absolute restrictions on the use of substances with certain properties, and rules on the information which producers must provide users with. In past years, the regulatory framework of the chemicals sector has been changed significantly. In particular Regulation (EC) 1907/200612 on the registration, evaluation, authorisation and restrictions of chemicals (commonly known as the REACH Regulation) entered into force on 1 June 2007. It provides a regulatory framework for the collection of information on the properties of substances on the European market, and also for future restrictions on their use. The European Chemicals Agency (known as ECHA), based in Finland, acts as the central point in the REACH system: it runs the databases necessary to operate the system, coordinates the in-depth evaluation of suspicious substances and maintains a public database in which consumers and professionals can find hazard information.
This framework provides not only a rigorous testing and restriction procedure for all substances on the European market, but also provides a highly valuable centralised information source which could be used by public purchasers.

[18]For more detailed information, refer to EU Green Public Procurement Criteria for Transport.
Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/transport_tbr.pdf
Report Task 1 available at http://susproc.jrc.ec.europa.eu/Transport/docs/EU%20GPP%20Transport%20-%20Task%201%20Report.pdf
[19]Included in the chapter 3.1.6 of this document
[20]Detailed information about EU Waste Legislation available at the Official EC Web page: http://ec.europa.eu/environment/waste/legislation/

Regulation (EC) No 1272/200813 (commonly known as the classification, labelling and packaging or CLP Regulation) and Regulation (EC) 1907/2006 (the REACH Regulation), which amend and repeal Directives 67/548/EEC14 and 1999/45/EC15, require producers and suppliers of dangerous substances in EU member states to classify the harmful properties of their substances and to provide industrial and professional users with detailed health, safety and environmental information and advice about their products. All chemical products sold must be accompanied by material safety data sheets (SDS). If the products contain ingredients (above a certain percentage of the weight of the final product) which are classified as dangerous, then this information must be included in the SDS and also on the product label.
The CLP Regulation introduces what is known as the Globally Harmonised System (GHS) for classification and labelling of substances and mixtures into the EU. The GHS is a UN initiative which aims to harmonise the information related to human health and environment provided by manufacturers worldwide, given the global nature of the trade.[21]

The requirements of the CLP Regulation were adopted in 2015. Therefore, before 1st June 2015 two different classification and labelling systems existed and operated in parallel: the recent CLP Regulation and the older systems for classification and labelling of substances (based on Directive 67/548/EEC) and preparations (mixtures) (based on Directive 1999/45/EC).

The CLP Regulation system uses for the classification of hazardous properties a series of Hazard Class and Category Codes and Hazard Statements. In addition, the CLP Regulations establish a new database, known as the classification and labelling inventory, for substances. This database contains classification and labelling information on noted and registered substances received from manufacturers and importers. The database is available on the website of the European Chemicals Agency[22].

Many substances have already been analysed for their properties in this regard, and may be issued with a hazard warning (e.g. T+: Toxic, N: dangerous for the environment), together with a R-Phrase indicating the precise nature of the risk (e.g. R26: very toxic by inhalation, R50: very toxic to aquatic organisms). Under the CLP system Hazard Class and Category Codes (e.g. Acute Tox. 2, Aquatic Acute 1) and Hazard Statements and Codes (e.g. H330 - fatal if inhaled, H400 -Very toxic to aquatic life) are used instead.

2.1.2 Existing EU legislation in terms of gardening and landscaping

In the following chapter considerations of existing EU legislations regarding Gardening Services will be described. In terms of Maintenance of Public Space, for this research phase, it has been established to refer to Gardening Services by including the following activities: Fertilization, Weed control and pesticides use, Manual & automated irrigation, Pruning, Planting, Plant and trees replacement, Green waste composting.
.
Although there are no specific directives or regulations for gardening, there are some related to products (fertilisers, biocides) and machinery used in gardening. Invasive plants are also covered by the relevant national acts but also by European Directive 2000/29/EC and strategies in preparation.

For plant protection products, the European Union has established several Directives: Directive 91/414/EEC of 15 July 1991 concerning the placing of plant protection products (PPPs) on the market; Directive 79/117/EEC of 21 December 1978 prohibiting the placing on the market and use of plant protection products containing certain active substances;

[21] EU Green Public Procurement Criteria for Cleaning Products and Services. Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/cleaning_tbr.pdf
[22] Information available at: https://echa.europa.eu/information-on-chemicals/cl-inventory-database

and Directive 76/769/EEC of 27 July 1976 on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations. They lay down uniform rules on the evaluation, authorisation, placing on the market and control within the European Union of plant protection products and the active substances they contain.
The regulation of such products was first harmonised under Council Directive 91/414/EEC which entered into force on 26th July 1993. This Directive set agreed criteria for considering the safety of active substances in plant protection products and the safety and effectiveness of formulated products. Further, the Directive established a positive list of active substances (Annex I of the Directive) the use of which present an acceptable risk to man or the environment and a mechanism for adding further substances to Annex I, either as new active ingredients or as an existing active ingredient through a review program. The first review of existing active ingredients (these are active ingredients that were on the market on or before 25 July 1993 (or later in newer EU Member States) was completed in March 2009. Active ingredients are included in Annex I for a period of 10 years and have to undergo a second review before the end of the 10-year period in order to take account of new information and to ensure that the plant protection products can still be used safely.
The authorisation of plant protection products themselves is carried out by Member States. Directive 91/414/EEC sets out a harmonised authorisation process for the marketing and use of such products and only active substances included in Annex I can be used in such products (except were certain transitional arrangements applied).

Directive 91/414/EEC was replaced from the 14th June 2011 by Regulation (EC) 1107/2009.
This continues to harmonise the assessment and authorisation of plant protection products across the EU as well as introduces some further requirements such as the introduction of hazard based criteria (for example only active substances that are not PBT (persistent, bioaccumulative and toxic) substances or not vPvB (very persistent and very accumulative) substances can be approved), the assessment of cumulative and synergistic effects, comparative assessment and assessment of endocrine disruption.

Regulation (EC) 1107/2009 introduces for the first time the concept of "low-risk plant protection products". Plant protection products will be authorised as such provided that the meet certain requirements including approval of the low-risk active substances, safeners and synergists contained within it, the product does not contain a substance of concern, the product is sufficiently effective and it does not cause unnecessary pain and suffering to vertebrates to be controlled[23].

Directive 2009/128/EC introduces a framework for sustainable use of pesticides, including plant protection products. This aims to reduce the risks and impacts of such plant protection products on human health and the environment and promotes the use of integrated pest management and of non-chemical alternative approaches or techniques. The Directive includes a number of measures to achieve this aim, including the following:

- *Training of professional users, distributors and advisors, including (by 14 December 2013) the establishment of a certification system.*
- *Restriction of sale of pesticides authorised for professional use to persons holding the relevant certificate.*
- *Inspection of pesticide application equipment.*
- *Prohibition of aerial spraying (with certain exceptions).*
- *Reduction of pesticide use or risks in specific areas including use of appropriate risk management measures and the use of low-risk plant protection products and biological control measures. The specific areas include areas used by the general*

[23]The active substances that are approved for use in the EU can be found at: http://ec.europa.eu/food/plant/protection/evaluation/database_act_subs_en.htm.

public (e.g. parks and gardens, sports and recreation grounds, school grounds, children's playgrounds and in the close vicinity of healthcare facilities).

- *Ensuring that professional users do not endanger human health or the environment during operations such as:*
  - *storage, handling, dilution and mixing of pesticides before application.*
  - *handling of packaging and remnants of pesticides.*
  - *disposal of tank mixtures remaining after application.*
  - *cleaning of equipment used after application.*
  - *recovery or disposal of pesticide remnants and their packaging in accordance with Community legislation on waste.*
  - *Promotion of low-pesticide-input pest management, giving priority where possible to nonchemical methods.*

Council Regulation (EC) No 834/2007 on organic production and labelling of organic products is helpful in stipulating the arrangements for organic production.

For mineral fertilisers there is also EU Regulation No 2003/2003 of the European Parliament and of the Council of 13 October 2003 (as amended). It defines, in particular, the provisions relating to the placing of fertilisers on the market, i.e. the conditions for designating "EC fertilisers", as well as provisions on their labelling and packaging. The Regulation aims to simplify harmonised Community legislation in the field of fertilisers by bringing all the existing provisions in this field under one instrument. The objective is to ensure the free movement of these products within the European Union. [24]

This last regulation is currently under revision. As previously described, it ensures free movement within the single market primarily for conventional, non-organic fertilisers, typically extracted from mines or produced chemically. Innovative fertilising products produced from organic materials are outside the scope of the current Fertilisers Regulation. Their access to the single market is therefore dependent on mutual recognition between Member States, and due to diverging national rules, this is often difficult. In 2016, a draft Regulation has been sent to the European Parliament and Council for adoption. This revised version will set out common rules on converting bio-waste into raw materials that can be used to manufacture fertilising products. It defines safety, quality and labelling requirements that all fertilising products need to comply with to be traded freely across the EU. Producers will have to demonstrate that their products meet those requirements, as well as limits for organic contaminants, microbial contaminants and physical impurities before affixing the CE-mark.[25]

2.1.3 Existing EU legislation in terms of repairing and replacement of public space items

In the following chapter, considerations about existing EU legislations regarding the Repairing and Replacement of public space items will be described. In terms of Maintenance of Public Space, for this research phase, it has been established to refer to the public items that could be object of Repairing and Replacement by including the following: sidewalk/bike lane/road pavement, urban furniture element, playground element, signage and wayfinding element (excl. street lights), drinking fountains, ornamental fountains, irrigation/pumping systems, plant and trees replacement, lawn replacement, manhole cover replacement.

[24] EU Green Public Procurement Criteria for Gardening products and services. Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/garderning_tbr.pdf.

For the research purpose, it has been useful to further divide this public space maintenance activity into two main groups:

- Repairing and Replacement of Sidewalk/bike lane/road pavement
- Repairing and Replacement of public furniture items, including: urban furniture element, playground element, signage and wayfinding element (excl. street lights), drinking fountains, Ornamental fountains and Manhole cover replacement.
- Repairing and Replacement of gardening items, including: Irrigation/pumping systems, plant and trees replacement, Lawn replacement

In relation with the Repairing and Replacement of sidewalk/bike lane/road pavement detailed information about existing European legislations could be found in the Technical Background Report of Road Design, Construction and Maintenance.[26]

On the subject of Gardening items, the Technical Background Report for EU GPP Criteria for Gardening Products and Services is again an important reference.

No previous background research from any existent GPP was available for the topic of repairing and replacement of public furniture items, so different sources have been consulted to describe the legislative scenario of this public space maintenance activity. After reviewing the existing literature related to the topic of design and maintenance of public furniture, it emerged that this kind of subject is mainly taken into account by National policies and regulations, rather than European legislation. In particular, it is has been noticed that there is not an unique European legislation referring to the whole product group of public furniture, while several European Standards regulate some smaller product groups contained in what is commonly defined as public furniture.

Nevertheless, several studies and pilot projects have been conducted on the subject of public furniture at the European level. In particular, a LIFE PROJECT very closely related to the scope of the EU GPP for Public Space Maintenance has been identified: LIFE FUTURE project, Sustainable Urban FUrniTURE: Tool design to perform environmental assessments in the green procurement framework (LIFE14 ENV/ES/000703). The project started on October 2015 for a total duration of 30 months; updated information about the project are available on the webpage. Further details about the project are reported in the chapter 1.3.3 Other projects and ongoing initiatives

The sector study carried out in the first phase of the LIFE FUTURE project can be considered as an interesting reference for the elaboration of this chapter. Indeed, some reports elaborated in the framework of the LIFE FUTURE project have been consulted [27], since they provide a quite complete overview of:

- Legal framework, Procedures, tools and methodologies and other environmental information about urban furniture, described in the document:
  - D1.1 Report on the current situation of the urban furniture sector related to GPP
- Characterization of urban furniture and technical and environmental classification, described in the document:
  - D1.2 Report on the selected products and their specifications (technical description)

The following categorization used in the LIFE FUTURE project looks appropriate also for the analysis of maintenance activities related to public space items, in particular focusing on their repairing and replacement.

[26] EU Green Public Procurement Criteria for Road Design, Construction and Maintenance. Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/report_gpp_roads.pdf

[27] Dissemination material of the project LIFE14 ENV/ES/000703 available at: http://www.life-future-project.eu/dissemination.php?op=4

Urban furniture categories	Urban furniture products
Street furniture products	Benches, seats and chairs Bicycle parking Canopies and kiosks Bins and containers Hydrants Advertising and information panels Planters and pots Tree pits, manholes and lids
Recreational and leisure products	Playgrounds Sports courts Showers and footbaths Fountains and hydrants
Traffic management products	Traffic signs Guardrails, barriers and parapets Milestones and bollards Speed reducers

Table 1:Urban furniture categories and products as reported in the project LIFE14 ENV/ES/000703

From the studies conducted to investigate the existing technical and quality standards for public space furniture at European level, it emerged that the following Standards should be considered according to product categories.

Urban furniture categories	Technical and quality standards
Street furniture products	EN 581-1 Outdoor furniture - Seating and tables for camping, domestic and contract use - Part 1: General safety requirements. EN 581-2 Outdoor furniture - Seating and tables for camping, domestic and contract use - Part 2: Mechanical safety requirements and test methods for seating. EN 581-3 Outdoor furniture - Seating and tables for camping, domestic and contract use - Part 3: Mechanical safety requirements and test methods for tables.
Recreational and leisure products	EN 16630 Permanently installed outdoor fitness equipment - Safety requirements and test methods. EN 14877 Synthetic surfaces for outdoor sports areas – Specification. EN 14904 Surfaces for sports areas - Indoor surfaces for multi-sports use – Specification. EN 15330-1 Surfaces for sports areas - Synthetic turf and

	needle-punched surfaces primarily designed for outdoor use - Part 1: Specification for synthetic turf surfaces for football, hockey, rugby union training, tennis and multi-sports use. EN 15330-2 Surfaces for sports areas - Synthetic turf and needle-punched surfaces primarily designed for outdoor use - Part 2: Specification for needle-punched surfaces. EN 14384 Pillar fire hydrants.
Traffic management products	EN 12966 Road vertical signs - Variable message traffic signs. EN 12899-1 Fixed, vertical road traffic signs - Part 1: Fixed signs. EN 12899-3 Fixed, vertical road traffic signs - Part 3: Delineator posts and retroreflectors. EN 12899-4 Fixed, vertical road traffic signs - Part 4: Factory production control. EN 12899-5 Fixed, vertical road traffic signs - Part 5: Initial type testing. EN 13422 Vertical road signs - Portable deformable warning devices and delineators - Portable road traffic signs - Cones and cylinders. EN 1790 Road marking materials - Preformed road markings. EN 12899-2 Fixed, vertical road traffic signs - Part 2: Transilluminated traffic bollards (TTB).

Table 2: Urban furniture categories and related technical and quality standards as reported in the project LIFE14 ENV/ES/000703

For further details please refer to the Standards above mentioned.

2.1.4 Existing EU legislation in terms of painting and repainting of public space items

In the following chapter considerations about existing EU legislations regarding the Painting and Repainting of public space items will be described. In particular, for this research phase, activities of Painting and Repainting are considered part of Public Space maintenance when applied to façades or surfaces of outdoor elements or to urban furniture items.

In relation to this specific product category no EU GPP has been developed, but a very detailed Legislation at European level is available. In particular, since the 21st of April 2004 the 2004/42/EC Directive regulates the use of paints and varnishes in relation to the maximum allowed levels of volatile organic compounds. The directive refers to the limitation of emissions of volatile organic compound due to the use of organic solvents in decorative paints and varnishes and vehicle refinishing products[28].

[28]Further information about this topic are available at the following webpage: http://ec.europa.eu/environment/air/pollutants/stationary/paints/paints_legis.htm

The Directive, based on Article 114 of the Treaty on the Functioning of the European Union (formerly: Article 95 of the EC Treaty), is a harmonisation directive which aims to ensure the free circulation of goods within the Internal Market.

The products covered by the Paints Directive are paints for use on buildings, their trims and fittings and structures associated to buildings and products for vehicle refinishing. The specific sub-categories of products covered are listed in Annex I of the Paints Directive.
For the decorative paints and varnishes, Annex II A to the Directive sets out two sets of limit values for the maximum contents of VOCs (in grammes per litre of the product ready for use). The first set of limit values applied from 1 January 2007 on. The second, and stricter, set of limit values apply since 1 January 2010.
For the purpose of the EU GPP Criteria of Public Space Maintenance only regulation related with paints used for construction, their trims and fittings and structures associated to buildings should be considered. Moreover, it could be considered that, excluding particular cases, the totality of paints and varnishes to be considered for Public Space Maintenance are exclusively for outdoor application.

The scope of Directive 2004/42/EC covers paints and varnishes products. In particular, some of the subcategories mentioned in the Directive that may be taken into consideration in order to inform the scope of EU GPP for Public Space Maintenance are:

- *'coatings for exterior walls of mineral substrate' means coatings designed for application to outdoor walls of masonry, brick or stucco;*
- *'interior/exterior trim and cladding paints for wood, metal or plastic' means coatings designed for application to trim and cladding which produce an opaque film. These coatings are designed for either a wood, metal or a plastic substrate.*
- *'interior/exterior trim varnishes and wood stains' means coatings designed for application to trim which produce a transparent or semi-transparent film for decoration and protection of wood, metal and plastics.*
- *'multicoloured coatings' means coatings designed to give a two-tone or multiple-colour effect, directly from the primary application;*
- *'decorative effect coatings' means coatings designed to give special aesthetic effects over specially prepared pre-painted substrates or base coats and subsequently treated with various tools during the drying period.*[29]

The values of maximum VOCs allowed for each subcategory are described in the Annex II of the directive.

[29] Directive 2004/42/CE on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC. Available at this link: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32004L0042

2.1.5 Existing EU legislation in terms of vehicles used for public space maintenance

In the following chapter considerations about existing EU legislations regarding the Vehicles used for public space maintenance will be described.
In particular, for this research phase, it has been established to refer to vehicles used for Public Space Maintenance activities by including the following items: Human-controlled vehicles, Remote controlled, autonomous or robotic vehicles, Sweepers and street cleaning vehicles (e.g., mechanical brooms).

As known, several actions and guidelines have been implemented by the European Commission to reduce the environmental impact of this sector. Moreover, ad hoc EU GPP Criteria for Transport have been published and are currently under revision.

The importance of taking action in the transport sector to reduce its environmental impacts, particularly in relation to its emission of greenhouse gases (GHGs), air pollutants and noise, has been highlighted in various EU strategic documents, including the seventh Environment Action Programme[30]. The broader transport policy framework is set by the 2011 Transport White Paper[31], which underlines the need for, and a number of initiatives that will contribute to, improving the environmental performance of road transport vehicles and the way that they are used (European Commission, 2011a).[32]

The main legislation areas related with vehicles concern the following points:

Reducing GHG emissions from vehicles
The main legislation to improve the GHG emissions performance of road transport focuses on reducing carbon dioxide (CO2) emissions from new cars and light commercial vehicles (LCVs).
Some of most relevant existing legislations on this topic:

- *Regulation (EC) No 443/2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light duty vehicles*
- *Regulation (EU) No 510/2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from light duty vehicles*
- *Directive 98/79/EC relating to the quality of petrol and diesel fuels, as amended by Directive 2009/30/EC*
- *Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles*

Reducing the air pollutant emissions from vehicles
Separate legislation limits the emissions of air pollutants from light duty vehicles (LDVs, i.e. cars and LCVs) and from HDVs.[30]
Some of most relevant existing legislations on this topic:

[30] General Union Environment Action Programme 2020, Living well within the limits of our planet. More info at: http://ec.europa.eu/environment/action-programme/
[31] Transport White Paper, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system
[32] EU Green Public Procurement Criteria for Transport. Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/transport_tbr.pdf.

- *Regulation 715/2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information*
- *Regulation 595/2009 on type approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information, as amended by Commission Regulation (EU) No 582/2011*

Reducing the noise from vehicles
European legislation also directly regulates the noise levels of vehicles.
Some of most relevant existing legislations on this topic:
- *Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems*

For more detailed information, please refer to EU Background Technical Report of Green Public Procurement Criteria for Transport.

2.1.6 Existing EU legislation in terms of machinery used for public space maintenance

In the following chapter considerations about existing EU legislations regarding the Machinery used for public space maintenance will be described.
In particular, for this research phase, it has been established to refer to machinery used for Public Space Maintenance by including the following items: lawn-mowers (including lawn tractors) and scarifiers, chainsaws, brush saws, strimmers, hedge trimmers, pruners and similar hand-operated machines, leaf collectors and leaf blowers, auto-hoes, rotary cultivators, compost shredders, high pressure cleaning machines (water/sand).

Machineries included in the product group of Public Space Maintenance are mainly related with gardening activities. For this reason, a good reference also in this case is the research made for the Background Technical Report of the EU-GPP for Gardening and Landscaping.

Machinery used for Public Space Maintenance activities are part of so called **Non-Road Mobile Machinery** (NRMM). As reported on European Commission webpage[33], NRMM covers a very wide variety of machinery typically used off the road in many ways. It comprises, for example:
- *small gardening and handheld equipment (lawn mowers, chainsaws, etc.)*
- *construction machinery (excavators, loaders, bulldozers, etc.)*
- *agricultural & farming machinery (harvesters, cultivators, etc.)*
- *even railcars, locomotives and inland waterway vessels.*

For machinery, it is important to mention:
- *Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors. The aim of the Directive is to promote the smooth functioning of the internal market and to improve the health and well being of the population by reducing the noise emitted by the equipment used outdoors.*[34]

[33]Information available at: https://ec.europa.eu/growth/sectors/automotive/environment-protection/non-road-mobile-machinery_en
[34]EU Green Public Procurement Criteria for Gardening products and services.

- *Regulation (EU) 2016/1628*[35] *of the European Parliament and of the Council of 14 September 2016 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery, amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC.*

2.2 Overview of relevant national guidelines and labels

Environmental labels and national guidelines on green public buying are valuable tools for implementing green procurement, as they bridge the competency gap existing between procurement practitioners and environmental experts. One of the consequences of the increasing attention paid to environmental issues is the multiplication of environmental labelling schemes and different national guidelines. Environmental labelling schemes are numerous and multifaceted throughout many European countries. It is necessary to distinguish between several environmental labels. According to the International Standards Organisation (ISO) there are three environmental labels typologies: Type I (eco-labels), Type II (green claims) and Type III (environmental impact labels).[36] .

Furthermore, over the years several EU Member States have developed multiple national and trans-national tools aiming to guarantee the sustainability of products and services produced, bought and consumed in their countries. This section aims to review national guidelines that are in place for activities attributable to Public Space Maintenance, with a focus on most active EU Member States.

2.2.1 National guidelines

At the national level, most EU Member States have now published GPP National Action Plans (NAPs) which outline a variety of actions and support measures for green public procurement[37]. In 2003, the European Commission in its *Communication on Integrated Product Policy* (IPP)[38] encouraged Member States to draw up publicly available National Action Plans (NAPs) for greening their public procurement. Many have set targets for GPP or SPP, either in terms of overall procurement, or for individual product and service groups. A number of countries and regions have also developed GPP or SPP criteria sets. In many cases these are similar to the EU GPP criteria, with adjustments to reflect the particular circumstances or priorities of the authorities developing them. Most of the criteria sets rely upon life-cycle assessment (LCA) where it is available, together with eco-labels and the evidence which these are based upon[39], such as the Final Report of Assessment and Comparison of National Green Public Procurement Criteria and Underlying Schemes[40].

Technical Background Report available at http://ec.europa.eu/environment/gpp/pdf/tbr/garderning_tbr.pdf.

[35] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R1628

[36] Standard Catalogues for Ecolabelling: ISO 14024:1999, Environmental labels and declarations – Type I environmental labelling – Principles and procedures; ISO 14021:1999, Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling); ISO 14025:2006, Environmental labels and declarations – Type III environmental declarations – Principles and procedures

[37] Official Web page of EC http://ec.europa.eu/environment/gpp/action_plan_en.htm

[38] Communication from the Commission to the Council and the European Parliament, Integrated Product Policy Building on Environmental Life-Cycle Thinking, 2003. Available at: http://ec.europa.eu/environment/ipp/ippcommunication.htm

[39] : Buying Green! A handbook on green public procurement. 3rd edition, 2016. Available at this link: http://ec.europa.eu/environment/gpp/buying_handbook_en.htm

[40] Assessment and Comparison of National GPP/SPP Criteria and Underlying Schemes, Report to the European Commission, ENV.G.2/SER/2009/0059r, 2010. Available at: http://regi.kozbeszerzes.hu/static/uploaded/document/A%20nemzeti%20z%C3%B6ld%20%C3%A9s%20fenntarthat%C3%B3%20k%C3%B6zbeszerz%C3%A9si%20k%C3%B6vetelm%C3%A9nyek.pdf

The document *National GPP Action Plans policies and guidelines*[41] contains a comprehensive overview of the state of affairs in the 28 EU Member States (last updated in November 2016).

A Member State that showed to be very active in terms of National Guidelines for Sustainable Public Procurement is the **Netherlands**. Since 2014, the web platform PIANOo[42] (available in Dutch and English), is the main contact point for Sustainable Public Procurement for Dutch procurers. The Netherlands defined their National GPP around six thematic areas: Energy and climate, Materials and raw materials, Water and soil, Quality of life (disruption, air and noise), Natural environment, biodiversity and space, Health and welfare (working conditions, human health, animal welfare). Dutch National Guidelines are particularly interesting because they treat subjects and topics that are not yet considered by the EU GPP tool. Indeed, particularly related with the topic of Public Space Maintenance the following environmental criteria have been developed:

Environmental Criteria for Sustainable Public Procurement of Green Spaces[43]
An interesting aspect is included in this document, pointing out the importance of making a distinction between the procurement criteria that are related to products and materials and procurement criteria that are related to services. This is due to the fact that some authorities have their own green space services, and they purchase only plant material, machines and tools, while other authorities outsource green space management and purchase both labour-hours and products for this. The Dutch criteria are developed following the Sustainable Groundwork, Road and Hydraulic Engineering Approach[44] and are classified according to the three different levels of the Ambition Web[45.] For Green Spaces Public Procurement only the first two levels of the Ambition Web are considered: Level 1, including Selection criteria (SC) Technical specifications (ME) Contract provisions (CB) and Level 2, including Award criteria (AC). The Criteria consider services and products for 3 phases: design, completion and management and maintenance. For our research purpose only criteria related with the third phase will be considered.

Technical Specifications:
1. Acquiring nursery products and flower bulbs
2. Acquiring plant material of genetic quality (rural areas)
3. Use of fertilisers/soil improvers
4. Controlling unwanted weeds, diseases and pests

Award criteria (optional for Management and Maintenance):
1. Acquiring nursery products and flower bulbs
2. Acquiring plant material of genetic quality (rural areas)
3. Sustainable plant containers
4. Green space design where plant and soil fit in with each other
5. Sustainability action plan

Contract provisions:
1. Planning and reporting on fertilisation, soil improvement and control

Detailed descriptions about the technical specifications and the awards criteria are reported in the above-mentioned document.

[41] Complete list of National GPP for each member state updated in November 2016. Available at: http://ec.europa.eu/environment/gpp/pdf/national_gpp_strategies_en.pdf
[42] https://www.pianoo.nl/public-procurement-in-the-netherlands
[43] Environmental criteria for SPP of Green spaces, Version 7 May 2015. Available at: https://www.pianoo.nl/sites/default/files/documents/documents/greenspaces-environmentalcriteria.pdf
[44] The Sustainable Groundwork, Road and Hydraulic Engineering Approach offers practical tools for the implementation of sustainability in civil engineering projects and linking it to organisational objectives. More info at: https://www.pianoo.nl/sites/default/files/documents/documents/sustainablepublicprocurementthisishowitsdone.pdf
[45] The Ambition Web is a tool that helps organisations identify their ambitions, draw up criteria and monitor their progress in working towards achieving those ambitions

Environmental Criteria for Sustainable Public Procurement of Public Space Cleaning Services [46]

From an analysis of the 28 State Members, the Netherlands seems to be one of the few countries provided with Environmental Criteria centred in Public Space Cleaning Services. For this product group the Dutch Environmental Criteria consider the following aspects:

Technical Specifications:

1. Weed control on paved surfaces
2. Removal of graffiti

Award criteria:

1. Use of pest management (Integrated Pest Management) to prevent pest nuisance

In order to establish precise criteria for this national SPP, the legislations taken into account are mainly national.

Environmental Criteria for Sustainable Public Procurement of Preservation Works [47]

Even if the scope of the Dutch Environmental Criteria for Preservation Works does not exactly correspond with what we described Public Space Maintenance as meant in this document, it represents an interesting reference for the scenario of National guidelines available for this product group. In fact, although it is stated in the document that *Preservation Works mainly apply to the completion, management and maintenance of civil engineering constructions such as bridges, locks, viaducts, hydraulic engineering constructions and pumping stations, ships and other systems*, many of the services included in the scope, could be also referred to Public Space elements. In a Dutch Public Procurement, the aspects influencing the result are the following:

Technical Specifications:

1. Application of low-solvent preservation systems
2. Prevention of products with lead or chromate-containing pigments
3. Processing/removal of waste arising

Environmental Criteria for Sustainable Public Procurement of Winter Maintenance[48]

Besides the Netherlands, other European countries such as **Austria** have developed their National GPP Strategies following the scheme of existing EU GPP. Some of the product groups that are touched by Austrian GPP Criteria and can be considered as references for EU GPP for Public Space Maintenance are: cleaning products and services, furniture, gardening products and services[49].

Belgium is another country that shows a concrete engagement towards the implementation of National Guidelines for Green Public Procurement. For instance, GPP target for Brussels Capital Region by 2017 is to cover the 20% of financial volume of public procurements and 20% of the (number of) public procurement with environmental clauses.[50] In most of the cases the EU GPP criteria are the start of discussion at national

[46] Environmental criteria for SPP of Public Space Cleaning Services, Version 7 May 2015. Available at: https://www.pianoo.nl/sites/default/files/documents/documents/publicspacecleaningservices-environmentalcriteria.pdf

[47] Environmental criteria for SPP of Preservation Works, Version 7 May 2015. Available at: https://www.pianoo.nl/sites/default/files/documents/documents/preservationworks-environmentalcriteria.pdf

[48] Environmental criteria for SPP for Winter Maintenance, Version 7 May 2015. Available at: https://www.pianoo.nl/sites/default/files/documents/documents/wintermaintenance-environmentalcriteria.pdf

[49] Further information is available at http://www.nachhaltigebeschaffung.at/

[50] : Source: Complete list of National GPP for each member state updated in November 2016. Available at: http://ec.europa.eu/environment/gpp/pdf/national_gpp_strategies_en.pdf

level with stakeholders. Currently, sustainable criteria for about 70 product and service groups are available, and GPP for Construction materials, Food and catering services, Paints and varnishes are at the moment under development[51].

Italy is also a EU Member actively engaged in supporting GPP at the national level; since 2008 a national action plan on GPP has been adopted by Ministerial Decree[52], then updated in 2013. 17 product groups have been included in the Italian GPP[53]. Particularly interesting for the EU GPP for Public Space Maintenance is the GPP for Urban Furniture (Arredo Urbano)[54]. The document mainly focuses on design and installation of new urban furniture items, but a concise reference to maintenance is also included, specifying that paints and surface cleaning products should respect EU Ecolabel requirements.

2.2.2 Labels

Some countries have extensive ecolabel programmes at the national level. Very well-known ecolabels at the European level are: the European Ecolabel (the Flower), the Nordic Swan and the Blue Angel. There are many other ecolabel schemes in developed countries. Procurers may consider the following list of reliable ecolabels:

- Good Environmental Choice (Australia)
- Environmental Label (Croatia)
- Green Mark (Taiwan)
- Ecologo/Environmental Choice (Canada)
- Korean Ecolabel (South Korea)
- Ecomark (Japan)
- Green Seal (United States)

However, this overabundance of label schemes can be an obstacle for procurers, who may not know which scheme is more suitable for their needs.

2.2.2.1 EU Ecolabel

As aforementioned, many environmental labels exist all over Europe and elsewhere. Some of them focus on particular environmental concerns such as recyclability, biodegradability or energy efficiency. Others are valid and recognized in specific countries only. The European Ecolabel Scheme is a voluntary tool that promotes environmentally sound goods and services by awarding them with a distinctive symbol of environmental quality (a green flower). The label goes only to the most environmentally friendly brands in each product group. The Flower is a valuable tool to public purchasers, as it helps them identify green products. Alone among similar initiatives, the European Eco-label Scheme meet the following features:

- is recognized throughout the European Union, Norway, Liechtenstein and Iceland;
- requires product screening by an independent party; and
- assesses a product's total environmental impact, from extraction of the raw materials to eventual disposal (the "cradle to grave" approach)

[51] An overview on all product groups is available at https://overheid.vlaanderen.be/productgroepen
[52] Available at: http://www.minambiente.it/pagina/il-piano-dazione-nazionale-il-gpp-pan-gpp
[53] Complete list at: http://www.minambiente.it/pagina/criteri-vigore
[54] Criteri ambientali minimi per l'acquisto di articoli per l'arredo urbano. Available at: http://www.minambiente.it/sites/default/files/archivio/allegati/GPP/2017/allegato_arredo_urbanopdf.pdf

Categories considered for product groups of EU Ecolabel do not exactly match with the categories used in this document for this research phase. The complete list of EU Ecolabel categories is available at the following link: http://ec.europa.eu/environment/ecolabel/products-groups-and-criteria.html. Among those product groups included within the framework of EU Ecolabels relevant for the scope of this study, it is necessary to quote:

EU Ecolabel Cleaning Up / All purpose cleaners and cleaners for sanitary facilities

Further information http://ec.europa.eu/ecat/category/en/1/all-purpose-cleaners-and- :

For more information about this product group:

- Full criteria document, including product group definition (Article 1): Commission Decision 2014/893/EU
- Summary of the criteria document: Factsheet
- Technical background reports, calculation sheets, application forms, User Manuals and more: Under the product group tab on the Product Group and Criteria page

EU Ecolabel Furniture / Wooden furniture.

Further information: http://ec.europa.eu/ecat/category/en/34/wooden-furniture

For more information about this product group:

- Full criteria document, including product group definition (Article 1): Commission Decision 2009/894/EC
- Summary of the criteria document: Factsheet
- Technical background reports, calculation sheets, application forms, User Manuals and more: Under the product group tab on the Product Group and Criteria page

EU Ecolabel Gardening / Growing Media, soil improvers and mulch

Further information: http://ec.europa.eu/ecat/category/en/23/growing-media

For more information about this product group:

- Full criteria document, including product group definition (Article 1): Commission Decision 2015/2099/EC
- Summary of the criteria document: Factsheet
- Technical background reports, calculation sheets, application forms, User Manuals and more: Under the product group tab on the Product Group and Criteria page

EU Ecolabel Do-It-Yourself / Indoor and outdoor paints and varnishes

Further information: http://ec.europa.eu/ecat/category/en/44/indoor-and-outdoor-paints

For more information about this product group:

- Full criteria document, including product group definition (Article 1): Commission Decision 2014/312/EU
- Summary of the criteria document: Factsheet
- Technical background reports, calculation sheets, application forms, User Manuals and more: Under the product group tab on the Product Group and Criteria page

EU Ecolabel Lubricants / Chainsaw oils, concrete release agents, wire rope lubricants, stern tube oils and other total loss lubricants

Further information: http://ec.europa.eu/ecat/category/en/49/chainsaw-oils--concrete-r

For more information about this product group:

- Full criteria document, including product group definition (Article 1): Commission Decision 2011/381/EU
- Summary of the criteria document: Factsheet
- Technical background reports, calculation sheets, application forms, User Manuals and more: Under the product group tab on the Product Group and Criteria page

2.2.2.2 Nordic Swan – Denmark, Finland, Iceland, Norway and Sweden

The Nordic Swan Ecolabel is the official Nordic Ecolabel since 1989. It is administered on consignment of the Swedish government by the non-profit state-owned company Ecolabelling Sweden. The Nordic Swan Ecolabel is a tool to help consumers choose environmentally-sound products. Today there are 63 product groups that can receive the Nordic Swan Ecolabel. The Nordic Swan Ecolabel is a voluntary, positive ecolabelling of products and services with a common Nordic registered trademark, the Nordic Swan Ecolabel. Its purpose is to give consumers a clear and concise environmental product information, as well as promoting the development of products that are environmentally-sound.

To decide which products can be Nordic Swan Ecolabelled, they do environmental analyses to determine which product groups to develop criteria for. Products that are chosen are judged from a lifecycle perspective. Among several factors taken into account are the following: environmental problem of the product group, opportunity for product development, and potential influences of the product's development.

As happens with EU Ecolabel, categories considered for product groups of the Nordic Swan Ecolabel do not exactly match with the categories used in this document. The complete list of Nordic Swan Ecolabel categories is available at the following link: http://www.svanen.se/en/Find-products/ Among those product groups and services included within the framework of Nordic Swan relevant for the scope of this study, it is necessary to quote the criteria for the following categories:

Nordic Ecolabelling of Cleaning products
Nordic Ecolabelled cleaning products are amongst the least environmentally harmful products within their category, the substances they contain have the lowest impact on the environment possible, and strict requirements are imposed with regard to the chemicals used in the products. The environmental requirements include strict requirements as to the content of environmentally harmful substances and substances not readily degradable in aquatic environments. Account is also taken of health factors; for example, the content of fragrance and other allergenic substances is restricted. The products are discharged into water after use. Properties such as biodegradability, bioaccumuability and toxicity to aquatic organisms are accordingly key considerations with regard to all constituent components. The effect of the products on the environment will also depend on the way in which they are used.

Accordingly, the consumer must be provided with dosage information. The required performance testing must demonstrate that the specified dose of the product has a cleaning effect that is satisfactory.

Furthermore, packaging requirements are imposed in order to reduce the quantity of packaging used and to increase recycling and re-use.

Further information:
http://www.svanen.se/en/Criteria/Nordic-Ecolabel-criteria/Criteria/?productGroupID=15

For more information about this product group:

- Nordic Ecolabelling of Cleaning Products Background to ecolabelling. Background document
- Nordic Ecolabelling of Cleaning products. Criteria

Nordic Ecolabelling of Cleaning services

A Nordic Ecolabelled cleaning service provider offers its customers environmentally-friendly cleaning. The Nordic Ecolabelled cleaning service has a low consumption of chemicals and uses a high proportion of environmentally-friendly chemicals. The environmental impacts of greenhouse gases are minimised by means of stringent requirements as to transport and the use of refuse bags. All of this is combined with high cleaning quality and well trained staff.

Further information:
http://www.svanen.se/en/Criteria/Nordic-Ecolabel-criteria/Criteria/?productGroupID=43

Additional information on this product service:

- Nordic Ecolabelling of cleaning services. Criteria
- Nordic Ecolabelling of Cleaning Services background to ecolabelling. Background document

Nordic Ecolabelling of Compost bins

Criteria for awarding an environmental labelling licence for compost bins have been drawn up for containers intended to compost organic household waste and garden waste. Both year-round compost bins (group A) and bins which can only operate during the warmer part of the year (group B) are included in the criteria document. The central objective of the criteria is to ensure satisfactory performance of the compost bins. The year-round compost bins must undergo a thorough performance test over a three month period in temperatures down to - 3°C. Chemicals which are particularly hazardous to the environment may not be used during the manufacturing of the container. The requirement to use recycled materials for compost bins with frames of plastic will increase the utilization of available recycled raw material. Comprehensive user instructions make it easier to control the biological process taking place in the container, thus minimizing adverse effects on the performance while in use. Material descriptions will make it easier to recycle or dispose of the materials of the composting container at the end of its life cycle. A warranty and a spare part service can extend the working life of compost bins.

Further information:
http://www.svanen.se/en/Criteria/Nordic-Ecolabel-criteria/Criteria/?productGroupID=11

Additional information on this product service:

- Nordic Ecolabelling of Compost bins. Criteria

Nordic Ecolabelling of Durable/resistant wood for outdoor use

Nordic Ecolabelled durable wood is an alternative to conventionally impregnated wood and is recognized by:

- no heavy metals or biocides are added
- problem-free as waste
- produced from sustainable forestry wood
- has sufficient biological durability

Further information:
http://www.svanen.se/en/Criteria/Nordic-Ecolabel-criteria/Criteria/?productGroupID=49

Additional information on this product group:
- Nordic Ecolabelling of Durable/resistant wood for outdoor use. Criteria
- Nordic Ecolabelling of Durable/resistant wood for outdoor use background to ecolabelling. Background documents

Nordic Ecolabelling of Machines for parks and gardens
Nordic Ecolabelling of Machines for parks and gardens includes requirements on manufacturing, operation and end-of-life. The purpose is to identify the most environmentally friendly options in this field. Both personal and professional machines can be Nordic Ecolabelled.

A Nordic Ecolabelled Machine for parks and gardens is energy efficient and generates only minimal emissions of substances that are harmful to health and the environment. It should also contribute less to the greenhouse effect and the spread of hazardous substances than a non-Nordic Ecolabelled machine.

Further information:
http://www.svanen.se/en/Criteria/Nordic-Ecolabel-criteria/Criteria/?productGroupID=21

Additional information on this product group:
- Nordic Ecolabelling of Machines for parks and gardens. Criteria
- Nordic Ecolabelling of Machines for parks and gardens background to ecolabelling. Background document

Nordic Ecolabelling of Outdoor furniture and playground equipment
The purpose of the criteria is to secure low environmental impact in the production and use of outdoor furniture and playground equipment. The environmental requirements have been drawn up from a life cycle perspective and have been formulated to ensure minimum environmental impact during production, use and in the waste phase. Requirements have accordingly been primarily imposed with respect to the following:
- Wood raw materials from sustainable forestry operations.
- The use of recycled plastic and metal raw materials and a design that permits the re-use of plastic and metal.
- The use of chemicals with a lower environmental impact.
- Good performance properties (safety, strength and stability).

The Nordic Ecolabelled product must be accompanied by information on how to maintain the product and recommended maintenance of products. This information must also include instructions on how to proceed when the product comes to the end of its useful life.

Further information:
http://www.svanen.se/en/Criteria/Nordic-Ecolabel-criteria/Criteria/?productGroupID=40

Additional information on this product group:
- Nordic Ecolabelling of Outdoor furniture and playground equipment. Criteria
- Nordic Ecolabelling of Outdoor furniture and playground equipment background to ecolabelling. Background document

2.2.2.3 Blue Angel – Germany

The Blue Angel was used as the role model for the ISO 14024 standard (so-called Type-1 ecolabels), an international standard upon which many global environmental labels are based. It is a Type-1 ecolabel in addition to the EU Ecolabel and the Nordic Swan. This environmental label was created in 1978 on the initiative of the German Federal Minister of the Interior and approved by the Ministers of the Environment for the German federal states. The Blue Angel is a market-based, voluntary instrument of environmental policy. It was created with a scientific and holistic approach, involving in its creation many professional and commercial groups and the Environmental Label Jury. The standards set by the Blue Angel provide guidance for manufacturers and commercial companies when they want to improve the environmental performance of their products and services. Consumers can base their purchasing decisions on the Blue Angel and consciously choose the more environmentally-friendly alternative. The Blue Angel has achieved several successes within Germany, in fact it has become a recognised label delivering a high level of guidance: 92% of those surveyed were aware of the Blue Angel. 37% of those surveyed stated that the environmental label influences their purchase decision (Study on Environmental Awareness in Germany 2014).

Products and services awarded with the Blue Angel cause less damage to the environment and, at the same time, protect people's health by e.g.:

- Saving resources during their production
- Being manufactured from sustainably produced raw materials
- Using less resources during their use or disposal because they are, for example, particularly energy efficient
- Avoiding dangerous substances for the environment and/or people's health or limiting them to a minimum
- Being especially durable and easy to repair
- Being easy to recycle
- Causing low emissions to the soil, water and air, as well as low noise emissions
- Nevertheless fulfilling their intended function (fitness for use) to a high level of quality

As happens with the EU Ecolabel and the Nordic Swan Ecolabel, categories considered for product groups of Blue Angel do not exactly match with the categories used in this document. Complete list of Blue Angel Ecolabel categories is available at the following link: https://www.blauer-engel.de/en/products
Among those product groups and services included within the framework of Blue Angel relevant for the scope of this study, it is necessary to quote the criteria for two following categories:

Blue Angel for Garden and Leisure products
The Blue Angel identifies garden equipment with especially low noise emissions. This includes:

- lawnmowers,
- lawn trimmers,
- lawn edge trimmers,
- brush cutters,
- chain saws,
- grass trimmers,
- hedge trimmers,
- scarifiers and compost shredders.

In addition, the Blue Angel Ecolabel for garden and leisure products also focus on mobile toilets being used increasing frequently – in camping vehicles and sport boats, as well as at construction sites, motorway service areas and major events or in tour buses, aircraft, passenger trains and passenger ships. The alternative to standard products promoted by Blue Angel criteria are sanitary additives and flushing-water additives compatible with clarification plants that have been awarded the Blue Angel Ecolabel. It is not permitted for them to contain, for example, any biocidal properties against microorganisms in clarification plants or to have any other negative effects when disposed of in clarification plants.

Further information: https://www.blauer-engel.de/en/products/garden-leisure

Blue Angel for Construction products
The products labelled by Blue Angel include within the category of construction products the environmentally-friendly painting product group,

Further information: https://www.blauer-engel.de/en/products/construction

2.2.2.4 MPS Environmental Programme for Horticulture

MPS https://www.my-mps.com/en/ (Milieu Programma Sierteelt or 'Environmental Programme Floriculture' in English) is an international organisation created in 1993 which develops and manages certificates that allow employees in the horticulture sector to implement sustainability in their companies. The MPS standards are internationally accepted and serve as a guide in the horticultural sector. The product certificates MPS (Environmental Programme for Horticulture) with sustainability certificate are assumed to satisfy all components of the technical specification "Acquiring nursery products and flower bulbs" for Dutch Public Procurements of Green Spaces.

2.3 Other projects and ongoing initiatives

By reviewing the available information primarily through the Internet, the existence of several national and international initiatives aiming to pursue similar objectives as the EU GPP for Public Space Maintenance have been noted. Particularly interesting initiatives are represented by projects developed under the framework of European Union LIFE Programme. LIFE is the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU. Since 1992, LIFE has co-financed 4306 projects.[55] Two LIFE projects considered the most interesting for the scope of this EU GPP are described in this section.

2.3.1 LIFE FUTURE - Sustainable Urban FUrniTURE

One of the analysed projects that present many common points with the EU GPP for Public Space Maintenance is the previously mentioned ongoing *LIFE FUTURE: Sustainable Urban FUrniTURE.* On the project's website http://www.life-future-project.eu/ detailed information about the aims of the project and other background studies are available.[56] Partners of the project are from Spain (AIMPLAS, Plastics Technology Centre, AIJU Instituto Tecnológico de producto infantil y ocio, Las Naves, Universitat Jaume I), Belgium (Association of Cities and Regions for Recycling and sustainable Resource management (ACR+)) and Croatia (City of Koprivnica). Detailed information below:

[55] More detailed information about LIFE Projects available at: http://ec.europa.eu/environment/life/
[56] More detailed information and project documents available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=5297

The main objective of the LIFE FUTURE project is to develop a tool – the Green Urban Furniture (GUF) Tool – to perform an accurate and simplified environmental analysis of urban furniture to facilitate Green Public Procurement (GPP). The GUF Tool will be based on the methodology of Life Cycle Assessment (LCA). The project will study different elements of urban furniture, focusing on two categories selected to validate the functionality of the tool. Moreover, the tool will be used by public bodies for real-life procurement processes to demonstrate its effectiveness and practical applicability for GPP, with at least 200 urban furniture items being acquired using the GUF Tool. The use of the tool will help ensure a range of environmental benefits, for example, in terms of climate change, eco-toxicity and resource depletion. In particular, the project will:

- *Help users to understand GPP criteria;*
- *Aid in the selection of the best solutions in terms of GPP; and*
- *Encourage public bodies to include green procurement clauses, based on GUF Tool results, in their tenders*.

Expected results:

- *Updated analysis of GPP for urban furniture in the EU, in particular focusing on Spain and Croatia;*
- *Validation and demonstration of the economic advantages of the proposed system for analysis and evaluation (GUF Tool); and*
- *Reduction of the environmental impacts of urban furniture using the GUF Tool. The average environmental impact benefits of urban furniture after applying eco-design criteria are predicted as follows: - Global warming: 26.5% (reduction of 1 870 kg CO2 equivalent per urban furniture item); - Acidification: 28.7% (reduction of 51 kg SO2 equivalent per urban furniture item); - Eutrophication: 25.5% (reduction of 0.9 kg PO4 equivalent per urban furniture item); - Energy consumption: 15.5% (reduction of 27 000 MJ per urban furniture item); and - Amount of waste: 10.8% (reduction of 116 kg of waste per urban furniture item).*

2.3.2 REDUST - Winter Maintenance Strategy with feasible additional measures

The REDUST Life project (LIFE09 ENV/FI/000579) developed by the City of Helsinki Environment Centre in partnership with other Finnish entities (City of Espoo, City of Vantaa, Nordic Envicon Oy, Helsinki Metropolia University of Applied Sciences, Helsinki Region Environmental Services Authority) aimed to:

- find best winter practices in the fields of traction control, dust suppression and street cleaning, and accelerate their implementation in order to reduce levels of respirable street dust (PM10) in urban areas and to
- develop and implement a strategy to reduce levels of respirable (PM10) street dust by means of better winter maintenance practices in urban areas in Finland.

The project started in January 2011 and was finished in 2014. Due to the detailed studies conducted in order to analyse the existing winter maintenance services and products, and the research developed to improve their environmental performances, this best practice could represent a precious source to develop EU GPP Criteria related with the aspect of Public Space Maintenance.[57]

[57] Further information about the project and technical reports available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3734#RM

3 Overview of statistical and technical categories

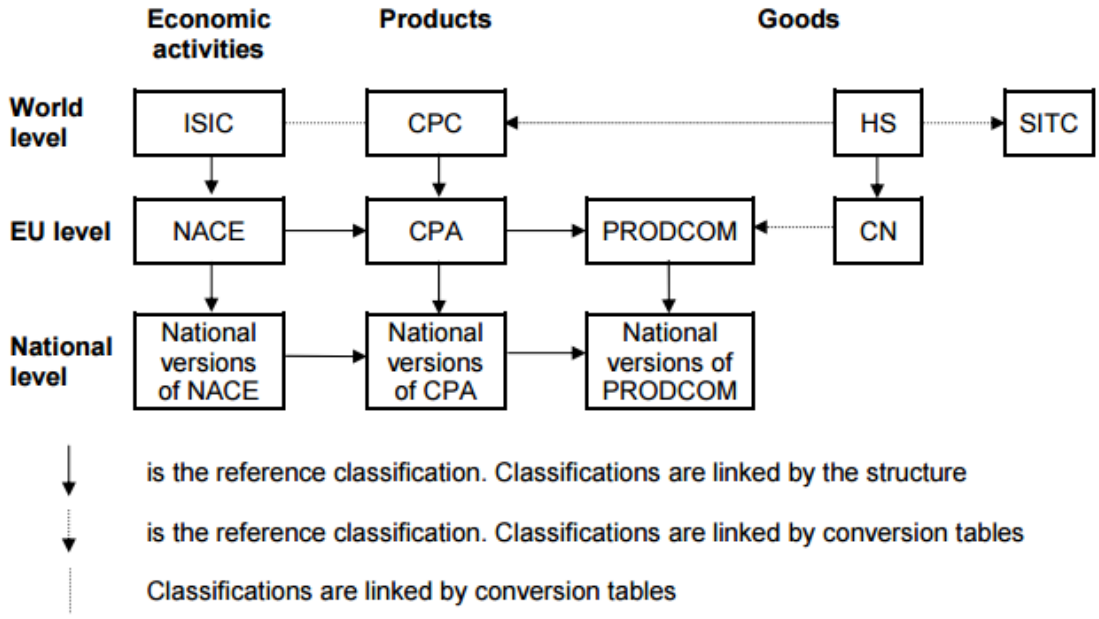
The main purpose of this section is to provide an overview of existing statistical and technical categories that could be used to define categories of product service and groups for the revised EU GPP criteria. Hence, this section investigates agreed definitions of potentially relevant services for the maintenance of public spaces that could be applied EU-wide for the purpose of defining the EU GPP criteria.

3.1 The need for statistical and technical categories

One of the basic requirements for statistical work is the existence of a recognised framework which can accommodate the vast range of statistical data available so that they can be presented and analysed in a meaningful way. Classifications provide that common language for both the compilation and the presentation of statistics. To achieve an effective single market, it is essential, for both macro- and microeconomic analysis and for commercial marketing, to have a single, up-to-date classification system that can be used in all Member states and by the Community institutions.

Economic statistics require different classifications for different purposes. Hence, international classifications have been developed on this basis. These range from the branch classification that is embodied in the System of National Accounts (SNA) to the International Standard Industrial Classification of All Economic Activities (ISIC) and the very detailed commodity classification of the Harmonised System (HS).

Under the auspices of the United Nations Statistical Division, an integrated system of statistical classifications has been developed. This system makes it possible to compare statistics produced in different statistical domains. From the European point of view, the system can be represented as follows:



Where:

- ISIC is the United Nations International Standard Industrial Classification of all Economic Activities.
- NACE is the statistical classification of economic activities in the European Communities.
- CPC is the United Nations Central Product Classification.

CPA is the European Classification of Products by Activity.

- HS is the Harmonized Commodity Description and Coding System, managed by the World Customs Organisation.
- CN is the Combined Nomenclature, a European classification of goods used for foreign trade statistics.
- SITC is the United Nations Standard International Trade Classification, an international classification of goods used for foreign trade statistics.
- PRODCOM is the classification of goods used for statistics on industrial production in the EU.

In order to study the different European classifications more in detail we will focus on the following: NACE, CPA, PRODCOM and finally the Common Procurement Vocabulary; not included as part of the European statistical system (ESS) but essential for the public procurement of goods and services within the European context.

3.1.1 NACE

NACE is the acronym used to designate the various statistical classifications of economic activities developed since 1970 in the European Union. The word NACE derives from the French Nomenclature statistique des activités économiques dans la Communauté Européenne. NACE is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activity in the fields of economic statistics (e.g. production, employment and national accounts) and in other statistical domains developed within the European statistical system (ESS).

NACE consists of a hierarchical structure described in the NACE Regulation as follows:

- a first level consisting of headings identified by an alphabetical code (sections),
- a second level consisting of headings identified by a two-digit numerical code (divisions),
- a third level consisting of headings identified by a three-digit numerical code (groups),
- a fourth level consisting of headings identified by a four-digit numerical code (classes).

Hence, statistics produced on the basis of NACE are comparable at European and, in general, at world level. The use of NACE is mandatory within the European statistical system. The latest version adopted by Eurostat, NACE Rev. 2, is to be used for statistics referring to economic activities performed from 1 January 2008 onwards.

3.1.2 CPA

The Statistical classification of products by activity, abbreviated as CPA, is the classification of products (goods as well as services) at the European Union level. CPA product categories are related to activities as defined by the Statistical classification of economic activities in the European Community (NACE). Each CPA product - whether a transportable or non-transportable good or a service - is assigned to one single NACE activity. This linkage to NACE activities gives the CPA a structure parallel to that of NACE at all levels.

As stated, the CPA is part of an integrated system of statistical classifications, developed under the auspices of the United Nations Statistical Division. As NACE, CPA has a hierarchical structure but, instead of four levels, CPA has six levels, each of them identified with a specific code.

- first level: 21 sections (alphabetical code);
- second level: 88 divisions (two-digit numerical code);

- third level: 261 groups (three-digit numerical code);
- fourth level: 575 classes (four-digit numerical code);
- fifth level: 1 342 categories (five-digit numerical code);
- sixth level: 3 142 subcategories (six-digit numerical code).

3.1.3 PRODCOM

PRODCOM is the abbreviation for the EU system of production statistics for mining and manufacturing (i.e. excluding services, other than "industrial services"). The product classification (PRODCOM list), upon which production statistics are based, is drawn up each year by the PRODCOM committee. The headings of the PRODCOM list are derived from the Combined Nomenclature, but their code is a further breakdown of the European Classification of Products by Activity (CPA) code. PRODCOM headings are coded using an eight-digit numerical code, the first six digits of which are identical to those of the CPA code. The PRODCOM list is therefore linked to, and therefore consistent with, CPA. The link with CPA emphasises the link with NACE, enabling the enterprises producing the products to be identified, while the link with the CN allows comparisons between production statistics and foreign trade statistics

3.1.4 CPV

The common procurement vocabulary (CPV) establishes a single classification system for public procurement aimed at standardising, by means of a single classification system for public procurement, the terms used by contracting authorities and entities to describe the subject of contracts, by offering an appropriate tool to potential users (contracting entities/authorities, candidates or tenderers in contract award procedure). Thus, this classification tool consists of a main vocabulary for defining the subject of a contract, and a supplementary vocabulary for adding further qualitative information. The main vocabulary is based on a tree structure comprising codes of up to 9 digits (an 8-digit code plus a check digit) associated with a wording that describes the type of supplies, works or services forming the subject of the contract.

- The first two digits identify the divisions (XX000000-Y);
- The first three digits identify the groups (XXX00000-Y);
- The first four digits identify the classes (XXXX0000-Y);
- The first five digits identify the categories (XXXXX000-Y);

Each of the last three digits gives a greater degree of precision within each category. The supplementary vocabulary may be used to expand the description of the subject of a contract. The correspondence between the CPV and the Statistical Classification of Products by Activity (CPA), the General Industrial Classification of Economic Activities within the European Communities (NACE Rev. 1) and the Combined Nomenclature (CN) could be found in the Official Journal of the European Communities (COMMON POSITION (EC) No 60/2002 adopted by the Council on 7 June 2002)

The use of the CPV is mandatory in the European Union as from 1 February 2006. The CPV version 2008 is the current CPV version to:

- Fill the notices of calls for competition
- Search business opportunities in TED
- Find contract notices in the archive of TED

3.2 Overview per maintenance of public spaces

Regarding the maintenance of Public Spaces, after a comprehensive analysis of the several technical categories included within the European statistical system, we conclude that the most appropriate system to analyse the features of the maintenance of public spaces sector seems to be the Common Procurement Vocabulary (CPV). In addition to the recommendation of the European Commission inviting the contracting entities and authorities to use it, this classification might help to measure more accurately the size and characteristics of the maintenance of public spaces sector than the remainder technical categories more focused on commercial transactions. By contrast, the CPV classification enables the gathering with greater exactitude all of the information registered on public procurement, by which public authorities, such as government departments or local authorities, purchase work, goods or services from companies.

Thus, the previous section described the various classification systems existing within the European context and their structure and correspondence with other classification systems. This section focuses on the relevant statistical definitions for those categories which could potentially be included in the EU GPP criteria, i.e.:

- **Activities.** Organized around main services, such as:
  1. Cleaning
  2. Gardening & landscaping
  3. Repairing/Replacement
  4. Painting/Repainting
  5. Assembly and removal of temporary elements

- Equipment Items, such as:
  6. Vehicles
  7. Machinery

3.2.1 Cleaning Activities

The relevant CPV-codes for cleaning activities are mostly listed in: *Division 90 Sewage, refuse, cleaning and environmental services.* Specifically, under the group *9060 Cleaning and sanitation services in urban or rural areas, and related services,* within which are included the following categories:

- 90610000, Street-cleaning and sweeping services
- 90620000, Snow-clearing services
- 90630000, Ice-clearing services
- 90640000, Gully cleaning and emptying services
- 90650000, Asbestos removal services
- 90660000, Deleading services
- 90670000, Disinfecting and exterminating services in urban or rural areas
- 90680000, Beach cleaning services
- 90690000, Graffiti removal services

In addition, three classes of the group *9091 Cleaning services* could be included within the cleaning activities for the maintenance of public spaces:

- 90911300, Window-cleaning services
- 90914000, Car park cleaning services
- 90918000, Bin-cleaning services

Moreover for Winter Maintenance the following categories should be considered:

- 34144420-8, Salt spreaders
- 34144710-8, Shovel loaders
- 43313000-0, Snow ploughs and snow blowers
- 44113910-7, Material for winter maintenance
- 90620000-9, Snow clearing services
- 90630000-2, De-icing services
- 34927100-2, Purchase of salt Spreading salt

NACE cleaning services fall under division *81 Services to buildings and landscape facilities*. This division includes the provision of a number of general support services, such as the exterior cleaning of buildings of all types, cleaning of industrial machinery, cleaning of trains, buses, etc., cleaning of the inside of roads, disinfecting and exterminating activities for buildings, street sweeping, and snow and ice removal. PRODCOM is not relevant for this category, because it only covers the classification of products and not of services.

3.2.2 Gardening and landscaping activities

Regarding the gardening and landscaping activities, the relevant CPV-codes are listed under three main divisions: *Division 77 Agricultural, forestry, horticultural, aquacultural and apicultural services, Division 03 Agricultural, farming, fishing, forestry and related products* and *Division 45, Construction work.* Specifically, under the *groups 7731 Planting and maintenance services of green areas, 7734 Tree pruning and hedge trimming, 0345 Tree-nursery products and 4511 Building demolition and wrecking work and earthmoving work.* Within these divisions are included the following categories:

- 77341000, Tree pruning
- 77342000, Hedge trimming
- 77313000, Parks maintenance services
- 77314000, Grounds maintenance services
- 45236230, Flatwork for gardens
- 45236250, Flatwork for parks
- 77311000, Ornamental and pleasure gardens maintenance services
- 77330000, Floral display services
- 77312000, Weed-clearance services
- 03121100. Live plants, bulbs, roots, cuttings and slips
- 03440000, Forestry products
- 03441000. Ornamental plants, grasses, mosses or lichens
- 03451000, Plants
- 03451100, Bedding Plants
- 03451200, Flower bulbs
- 03451300, Shrubs
- 03452000, Trees
- 77314100, Grassing services
- 77315000, Seeding services
- 45112710, Landscaping works for green areas
- 45112711, Landscaping work for parks

- 45112712, Landscaping work for gardens
- 45112713, Landscaping work for roof gardens
- 45112714, Landscaping work for cemeteries

Besides these three divisions, all of these services can also be classified as gardening and landscaping activities:

- Landscape gardening services, which are found in class 7142 *Urban planning and landscape architectural services*
- Miscellaneous gardening equipment, found in group 1610 *Agricultural and forestry machinery for soil preparation or cultivation*

NACE gardening services fall under division *81 Services to buildings and landscape facilities*. This division includes the provision of a number of general support services, such as the provision of gardening care and maintenance services and provision of these services along with the design of landscape plans and/or the construction (i.e. installation) of walkways, retaining walls, decks, fences, ponds, and similar structures. Within PRODCOM, category *28.30 Manufacture of agricultural and forestry machinery* represents forestry products, but no specific definition of gardening and landscaping activities is included.

3.2.3 Repairing/Replacement activities

Given the crosscutting perspective of this category, relevant CPV-codes for the activity Repairing/Replacement of public spaces are distributed between several divisions in accordance with its main features and typologies. Among these typologies, we found the following: Urban furniture replacement, Signage and wayfinding elements and Gardening and parks replacement.

The Urban furniture replacement and repairing typology is listed under the CPV category *349284, Urban furniture.* Within this category are included the following sub-categories:

- 34928410, Marker Posts
- 34928420, Road-Danger Lamps
- 34928430, Beacons
- 34928440, Bus-stop Posts
- 34928450, Bollards
- 34928460, Road cones
- 34928480, Waste and rubbish containers and bins

Regarding the Signage and wayfinding elements typology, the CPV system included under the categories 349920*, Signs and illuminated signs* and *349920, Signs and illuminated signs;* the following sub-categories:

- 34928470, Signage
- 34928471, Sign materials
- 34928472, Signposts
- 34992200, Road Signs
- 34992300, Street Signs

Under the CPV category *163110, Lawnmowers* and its sub-category *16311100, Lawn, park or sport-ground mowers* is collected all of the activities included in the gardening and parks replacement category.

Within NACE, repairing and replacement activities fall under one of the following categories: group 33.1 "Repair of fabricated metal products, machinery and equipment" and division 43 "Specialised construction activities". PRODCOM is not relevant for this category, because it only covers the classification of products and not of services.

3.2.4 Painting/Repainting activities

The common procurement vocabulary (CPV) classification does not distinguish between outdoor painting and repainting activities and those activities set up indoor public spaces or buildings in general. Therefore, many of the painting work developed under the category *454421, Painting work* concern the painting works of building and infrastructures not necessarily included under the scope of the study. However, the following represent some crucial categories that can mainly be associated with Maintenance services of outdoor spaces:

- 45442120-4, Painting and protective-coating work of structures
- 45442200-9, Application work of anti-corrosion coatings
- 45442300-0, Surface-protection work
- 50232200-2, Traffic-signal maintenance services

NACE painting services fall under division *43 Specialised construction activities,* this division includes the provision of services for exterior painting of buildings and painting of civil engineering structures. PRODCOM is not relevant for this category, because it only covers the classification of products and not of services.

3.2.5 Equipment items: vehicles

Regarding the vehicles employed for the maintenance of public spaces, we identify the following CPV-groups included under the division *16, Agricultural machinery*:

- 16311000, Lawnmowers
- 16311100, Lawn, park or sport-ground mowers
- 16500000, Self-loading or unloading trailers and semi-trailers for agriculture
- 16510000, Self-loading trailers for agriculture
- 16520000, Unloading trailers for agriculture
- 16530000, Self-loading semi-trailers for agriculture
- 16540000, Unloading semi-trailers for agriculture
- 16700000, Tractors

Except for the first two categories, the rest include many statistical items that could not be considered within the public space maintenance sector. Thus, many of the statistical items considered under this statistical frame could be committed to agricultural or livestock purposes. On the other hand, when considering the study of the vehicles involved in the maintenance of public spaces sector, the EU Green Public Procurement Criteria for Transport developed in 2016, should be taken into account. Many of the statistical categories collected under these criteria are devoted to the maintenance of public spaces.

In this regard, as stated in the EU Green Public Procurement Criteria for Transport, the relevant CPV codes for cars and Light Commercial Vehicles (LCVs) are listed under the division *34, Transport equipment and auxiliary products to transportation.* Motor vehicles for the transport of machinery, goods and services used on the maintenance of public spaces fall within category *3413, Motor vehicles for the transport of goods.* Thus, we identify the following groups:

- 34131000, Pick-ups
- 34134200, Tipper trucks

- 34136000, Light vans
- 34136200, Panel vans

On the other hand, specific vehicles employed on the maintenance of public spaces as parks, streets or gardens; could be identified under the group *341440, Special-purpose motor vehicles:*

- 34144410, Gully emptiers
- 34144420, Salt spreaders
- 34144430, Road-sweeping vehicles
- 34144431, Suction-sweeper vehicles
- 34144440, Gritter vehicles
- 34144450, Sprinkler vehicles
- 34144510, Vehicles for refuse
- 34144900, Electric vehicles

Within NACE there is no specific partition between vehicles used for the maintenance of public spaces and other categories such as agriculture and forestry. In addition, as NACE only describes economic activities and not products, there are no relevant definitions for cars and LCVs in NACE. The manufacturing of vehicles falls under C *Manufacturing*, which includes different definitions for motor vehicles, bodies for motor vehicles and part and accessories. However, within public procurement procedures transport related criteria are only likely to define the end characteristics of vehicles and will not cover manufacturing processes.

The PRODCOM list uses various technical characteristics to define vehicles, such as the type of combustion and cylinder capacity. The relevant categories are included under code *29.10*. Note that the codes for good vehicles only differentiate between the type of combustion and do not include any reference to the purpose of the vehicle. Therefore, differentiating among those used on the maintenance of public spaces and the rest of vehicles it will be unfeasible.

3.2.6 Equipment items: machinery

The relevant CPV-codes for machinery used for the maintenance of public spaces are listed under one main division 16, Agricultural machinery. 39, Furniture (incl. office furniture), furnishings, domestic appliances (excl. lighting) and cleaning products and 42, Industrial machinery. The division 16, Agricultural machinery includes the following groups 1610, Agricultural and forestry machinery for soil preparation or cultivation; 1640, Spraying machinery for agriculture or horticulture and finally the group 1680, Parts of agricultural and forestry machinery. Additionally, each category contains the following groups:

- 16120000, Harrows, scarifiers, cultivators, weeders or hoes
- 16130000, Seeders, planters or transplanters
- 16150000, Lawn or sports-ground rollers
- 16160000, Miscellaneous gardening equipment
- 16820000, Parts of forestry machinery

The pertinent groups for the study of the cleaning products and machinery used on the maintenance of the furniture within the public spaces are under division *39, Furniture (incl. office furniture), furnishings, domestic appliances (excl. lighting) and cleaning products*:

- 39830000, Cleaning products
- 39713400, Floor-maintenance machines

- 39713430, Vacuum cleaners
- 39224000, Brooms and brushes and other articles of various types

Finally, the division *42, Industrial machinery* contains the last categories under study:

- 42924730, Pressurised Water Cleaning Apparatus;
- 42924740, High-Pressure Cleaning Apparatus;

As happens with the vehicle equipment items, it is necessary to take into account that each of these categories includes many statistical items that should not be considered within the public space maintenance sector, since items included under this scope could be used as well for the maintenance of indoor public spaces, or agricultural and livestock purposes. Nevertheless, all the agricultural and forestry machinery, and the cleaning machinery procured by the public authorities could not be distinguished from the machinery used in the maintenance of public spaces when the study is based on the CPV-system classification. Similar to the vehicles category, within NACE and PRODCOM, there is no specific separation between machinery used for the maintenance of public spaces and other categories such as agriculture and forestry, cleaning products or reparation services.

4 First Stakeholders Questionnaire: Product definition, scope and criteria

As a result of previous described activities, the first document elaborated has been the First Stakeholders Questionnaire.

The complete questionnaire is available at the following link
http://susproc.jrc.ec.europa.eu/Public_space_maintenance/documents.html

The First questionnaire consists in the following sections:

- **Section A - Your Company or Organisation details**

General questions aiming to collect personal and professional information from the participants, in order to understand if the participant is to be considered a stakeholder from supply side, demand side or a third side.

- **Section B - Background information**

Four questions asking about previous knowledge of GPP Criteria, concerning in detail: previous use of environmental criteria in procurements, knowledge of the existence of guidelines or GPP for the maintenance of public space, previous experiences with GPP in general and knowledge of key data about the product group.

- **Section C - Scope and Definitions**

A check list organized in three parts around three main categories, described as followed:

- **Places.** To mention a few: Gardens and parks (manmade), Streets, roads, avenues and boulevards, Street vegetation, Sidewalks, Bike lanes, Parking lots, Pedestrian areas, pathways and plazas, etc.
- **Activities.** Organized around main services, such as:

    8. Cleaning (including Mechanical & manual sweeping, Litter removal, Bins' litter collection and sorting, etc.),
    9. Gardening & landscaping (including Fertilization, Pruning, Planting, Plant and trees replacement, etc.),
    10. Repairing/Replacement (of element such as: Sidewalk/bike lane/road pavement, Playground elements, Signage and wayfinding element, etc.)
    11. Painting/Repainting (Façade/surface painting, Urban Furniture painting)
    12. Assembly and removal of temporary elements (Seasonal shading system, Temporary fairs and pavilions)

- **Equipment Items**, such as Human-controlled vehicles, Remote controlled, autonomous or robotic vehicles, Sweepers and street cleaning vehicles (e.g., mechanical brooms), Sweepers and street cleaning vehicles (e.g., mechanical brooms), etc.

For each item participants are asked to specify if they believe it should be included, modified or discarded in the scope of GPP Criteria.

- **Section D - Close**

Contacts and deadlines for submission (17th March)

For a more detailed description of the items included in the questionnaire, please refer to the complete text, available at
http://susproc.jrc.ec.europa.eu/Public_space_maintenance/documents.html

4.1 Results

Stakeholders involved in this first scoping phase of the definition of EU GPP Criteria for Public Space Maintenance represent the main geographical areas of EU. The total number is 14 that were in detail from: Spain (4), Romania, Ireland, Sweden, Belgium, Portugal, Italy, Netherlands, Finland and Albania. Although the stakeholder list included in almost equal percentage possible stakeholders from supply side, demand side and third side (academia, NGOs, researchers, professionals involved in European projects, etc.), it is remarkable that most of respondents represent the demand side, being public procurers or policy makers. Indeed, almost half of participants to the survey reported previous experience with GPP (section B of the questionnaire), detailing their knowledge and even in some cases engagement with EU GPP policies, in particular at the national level.

From the analysis of received responses to the section C of the questionnaire the following assumptions are remarked:

Places:

- From different stakeholders, it is suggested to exclude Playgrounds and Public Sport Facilities from the scope of this EU GPP due to the complexity of these topics. It is suggested to consider them as separate product groups.
- Canopies and shadow elements as well as Advertising Columns are also suggested to be excluded from the scope
- Doubts about public furniture in general also have been expressed. In particular, it has been suggested to stick to services related with public space maintenance, and not to include products or public furniture elements, that should be considered as a separate category (e.g. outdoor furniture)

Activities:

- Several stakeholders propose to discard Disaster assistance: debris removal and After event cleaning. It should be clarified that "After event cleaning" refers to events of a social nature like concerts, festivals, fairs, etc. Natural weather events (like storms or heavy rain/snow fall) also require cleaning in their aftermath and these activities will be under the scope.
- Assembly and removal of temporary elements, such as Seasonal shading system and Temporary fairs and pavilions, also has been marked as excludable by different participants
- Some respondents have suggested that certain elements of Repairing/Replacement services should be excluded from the scope. In particular, the repairing and replacement of the following items: Irrigation and Pumping systems and Sidewalk/bike lane/road pavement.

Equipment items:

- Almost all stakeholders agree about the items proposed in the questionnaire

It is important to mention that a number of respondents showed a deep awareness and knowledge of GPP policies and therefore were able to provide very significant and helpful feedback.

5 Proposals of the scope and definition of Public Space Maintenance Categories

The proposals of the scope and definitions of the categories that might be covered in the EU GPP criteria for Public Space Maintenance are based on the findings and the survey carried out to develop the Task 1 of the project.

In accordance with the maintenance definitions reported at the beginning of this Report, it is established that this EU GPP Criteria will take into account mainly preventive (known also as ordinary) maintenance services, while corrective maintenance activities will be generally excluded.

Public Space Maintenance will cover routine maintenance activities and equipment, either of preventive or corrective character, done in either green of built public spaces. In order to limit the scope of this EU GPP, an ad-hoc definition of routine maintenance in the context of public space maintenance is provided below.

Routine maintenance: work undertaken on a regular basis or as an exceptional activity to preserve or restore serviceability and to extend the service life of an existing Public Space. Routine maintenance is typically applied to green areas, surfaces such as paved areas or public space elements in good condition having significant remaining service life, without significantly altering their structural capacity, appearance, functioning.

As previously mentioned, public space could refer to a multitude of urban and rural areas. In order to limit the scope of this EU GPP, only certain public spaces will be considered.
Specifically, the public spaces that are covered under the scope are:

- Streets, roads, avenues and boulevards
- Bike lanes
- Pedestrian areas including Sidewalks, Underways, Stairways, Plazas, etc.
- Man-made gardens and parks
- Beaches
- Fountains, lakes and ponds

The spaces that are excluded from the scope are:

- Natural parks and forests,
- Ports, canals, coastal lines, etc…

5.1 Proposed scope

An overview of the specific activities and equipment considered as part of the scope is considered necessary before dividing them in more detailed categories.

The specific **activities covered** under the scope are:

- *Cleaning, including manual or mechanical sweeping and water jet cleaning, graffiti removal, façade cleaning, litter removal, etc…*
- *Snow removal*
- *Pruning, Trimming, Planting, Lawn replacement, irrigation*
- *Fertilization, Weed control and pesticides use*
- *Repairing of pavement*

The **activities** that are **excluded** from the scope are:

- *Replacement of pavement and urban furniture*
- *Repairing or replacement of irrigation systems, fountains, street signs, urban furniture and mechanical equipment (e.g., gates)*
- *Maintenance of sewage*
- *Painting and repainting activities*

The specific **equipment covered** under the scope are:

- *Vehicles (human controlled or autonomous) for the transport of workers and equipment*
- *Sweepers and street cleaning vehicles*
- *Machinery used for gardening (Lawn-mowers, Chainsaws, trimmers; Leaf collectors and leaf blowers, etc.)*

The following **equipment** are explicitly **excluded** from the scope:

- *Waste collection vehicles*

As the first step in the definition of the scope of the EU GPP for Public Space Maintenance the following four categories are proposed:

1. Cleaning Services and Cleaning Products

As preface to the Cleaning services included in this category, it results essential to define which type of public space should be taken into consideration and defined as part of the scope of EU GPP for Public Space Maintenance. From the first stakeholder questionnaire, it emerged that the places requiring cleaning services that should be considered as part of the scope are the following built urban areas:

- *Streets, roads, avenues and boulevards*
- *Sidewalks*
- *Bike lanes*
- *Parking lots*
- *Pedestrian areas, pathways and plazas*
- *Underways*
- *Stairways*

Public furniture and façade/surface also have to be considered a target of cleaning services.

Following the suggestion of different stakeholders, it seems appropriate to exclude Playgrounds and Public sports facilities from the scope of this EU GPP.

Cleaning services include:

- Mechanical & manual sweeping of sidewalk, bike lane, road (asphalt, roadbed) and roadside (shoulders, curbs, green areas): corresponding to CPV code 90610000, Street-cleaning and sweeping services
- Litter removal from the ground.
- Bins' litter collection and sorting: corresponding to CPV code 90918000, Bin-cleaning services
- Mechanical & manual water jet cleaning: corresponding to CPV code 42924730, Pressurised Water Cleaning Apparatus and 42924740-8, High-Pressure Cleaning Apparatus

- Façade/surface cleaning
- Graffiti removal: corresponding to CPV code 90690000, Graffiti removal services
- Snow and ice removal from sidewalks, bike lanes and roads, corresponding to CPV code 90620000, Snow-clearing services and 90630000, Ice-clearing services
- Beach cleaning: corresponding to CPV code 90680000, Beach cleaning services
- Cleaning of fountains, lakes and ponds

Some Cleaning services remain outside of the scope of EU GPP for Public Space Maintenance, due to their occasional nature. In fact, following the suggestions of certain stakeholders it has been established that services as "Disaster assistance: debris removal" and "after event cleaning" are out of the scope since these can't be defined as routine maintenance services. It should be clarified that "After event cleaning" refers to events of a social nature like concerts, festivals, fairs, etc. Natural weather events (like storms or heavy rain/snow fall) also require cleaning in their aftermath and these activities will be under the scope.

Cleaning products:
- All-purpose cleaners
- Substances for snow and ice removal: (Salt and sand-and-salt-mixture – called grit - used for removing and calcium chloride ($CaCl_2$) as a dust binder for spring cleaning)

Other supplies/accessories/ machinery parts:
- Brushes, rolls,

2. Gardening and Landscaping Services and Products

As preface to the Gardening services included in this category, it results essential to define which type of green areas should be taken into consideration and defined as part of the scope of EU GPP for Public Space Maintenance. From the first stakeholder questionnaire, it emerged that the places requiring gardening and landscaping services that should be considered as part of the scope are the following green areas:
- Man-made Gardens and Parks
- Street vegetation

More in detail it is possible to define different configurations of green areas by considering different vegetation typologies. The following classification derives from the Dutch Criteria for Sustainable Procurements of Green Spaces[58], and it is considered well appropriated also for the EU GPP of Public Space Maintenance purpose.
- Trees: Trees that stand on their own, in rows or in small groups, not as part of a forest or small cluster of trees and bushes.
- Cluster of trees and bushes: Contiguous area covered by planted bushes possibly with scattered trees.
- Hedges and shrubs: Bushes, on their own, in small groups or in rows, usually closely maintained by trimming or closing off.
- Plant patches: Patches of permanent and annual herbaceous plants (usually decorative) and bulbous plants.
- Lawns: Short grass that is frequently mowed.
- Rough grass and herbage: Grass and rough herbage that is mowed at most twice per year.

[58] Criteria for the sustainable procurement of Green Spaces Version: 1.5 Date: October 2011. Available at: http://english.rvo.nl/sites/default/files/2013/12/Criteriadocument%20Green%20Spaces.pdf

- Banks and water: Open water and the areas that border dry land.

N.B. Two items originally included in the Dutch Criteria have been removed from the scope of EU GPP of Public Space Maintenance. These are: Forest, defined as "Contiguous area covered by trees that may or may not have bushes (larger than 2 500 m^2)", excluded for not being man made green area; and Sports and playing fields (grass) defined as "Grass fields primarily intended for sports and play activities", excluded for being associated with public sports facilities, previously excluded from the scope.

For general landscaping services the statistical categories used as reference correspond to 77313000, Parks maintenance services, 45112710, Landscaping works for green areas, 45112711, Landscaping work for parks, 45112712, Landscaping work for gardens; 45112713, Landscaping work for roof gardens; 77311000, Ornamental and pleasure gardens maintenance services

Gardening and Landscape Services include:

- Pruning: corresponding to CPV code 77341000, Tree pruning
- Trimming: corresponding to CPV code 77342000, Hedge trimming
- Planting and Plant and trees replacement: corresponding to CPV code 77330000, Floral display services; 03121100. Live plants, bulbs, roots, cuttings and slips; 03440000, Forestry products; 03441000. Ornamental plants, grasses, mosses or lichens; 03451000, Plants; 03451100, Bedding Plants; 03451200, Flower bulbs; 03451300, Shrubs; 03452000, Trees; 77314100, Grassing services; 77315000, Seeding services
- Fertilization
- Weed control and pesticides use: partially corresponding to CPV code 77312000, Weed-clearance services
- Lawn replacement
- Manual & automated irrigation

Gardening Products include:
- Soil improvers
- Ornamental plants
- Irrigation systems
- Lubricant oils
- Herbicides and pesticides

3. Vehicles used for Public Space Maintenance

- Human-controlled vehicles
- Sweepers and street cleaning vehicles (e.g., mechanical brooms)
- High Pressure cleaner vehicle (water/sand)
- Snow removal vehicles (with plough blades and salt spreader)
- Maintenance utility vehicles for public green spaces
- Maintenance utility vehicles for watering green spaces
- Maintenance utility vehicles for transporting goods and branches
- Remote controlled, autonomous or robotic vehicles

4. Machinery used for Public Space Maintenance

- Lawn-mowers (including lawn tractors) and scarifiers
- Chainsaws
- Brush saws
- Strimmers
- Hedge trimmers
- Pruners and similar hand-operated machines
- Leaf collectors and leaf blowers
- Auto-scythes
- Auto-hoes
- Rotary cultivators
- Compost shredders

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PART II: MARKET AND COST DATA

Introduction

Europe's public authorities are major consumers. The European public service spends approximately 16% of European Union's Gross Domestic Product on purchasing a large variety of products. By taking into account environmental criteria in its procurement procedures, contracting authorities promote modes of production that are more environmentally friendly and stimulate the supply of 'green' goods and services. Thus, they can make an important contribution to the development of environmentally green technologies - which is called Green Public Procurement (GPP) or green purchasing.
Although GPP is a voluntary instrument, it has a key role to play in the EU's efforts to become a more resource-efficient economy. It can help stimulate a critical mass of demand for more environmentally friendly goods and services which otherwise would be difficult to get onto the market. To achieve the objectives, environmental criteria should be developed for a large range of products and services involved in the maintenance of public spaces.
This document presents the results of a market research regarding the situation of the public spaces maintenance sector in the European context with the aim of providing a description of this segment and the related services and hardware from a technical point of view. In order to be able to give an accurate and comprehensive overview of the sector, it is essential to collect key information which enables a quantitative assessment of the economic and environmental relevance of the products and services included within the sector. This includes a description of public space maintenance services and the related products from a managerial, organisational and functional point of view. In addition, the market will be characterised according to market segmentation (geographical, technological, target group related), with an overview of the respective products and services, as well as identifying the key manufacturers/service providers and consumer groups/procurement entities.
Therefore, following the methodology of a market analysis the public space maintenance sector has been characterised according to the volume of the public procurement purchases in EU 28 (product/service supply and demand) and its market structure. Providing specific cases on future trends in the maintenance of public spaces is a key aspect in identifying service/manufacturers suppliers and consumer groups/procurement entities. In addition, the public spaces maintenance market has been segmented taking into account the data collected on the previous analysis and the scope established on the Task 1 Report (stakeholder survey, statistical, legal and criteria review, scope and definition proposal). Finally, an analysis on future trends within the public spaces maintenance sector is provided, among other things, by distinguishing between the advantages and disadvantages between outsourced maintenance services and in-house provisions of public spaces maintenance.
In the European context the maintenance of public spaces sector has a significant turnover. However, there is little information on the market performance. In this sense, the lack of updated information has constituted a serious limitation for the achievement of the research goals. Therefore, the data on the maintenance expenses and costs provided should be interpreted with caution, as the different European typologies require that each study be analysed according to its particular context.

6 Market analysis of the public space maintenance sector of report

In 2003, the European Commission on its Communication on Integrated Product Policy encouraged Member States to draw up National Action Plans for GPP to steer the market towards more environmentally friendly products. The National GPP Action Plans are not legally-binding but provide political impetus to the process of implementing and raising awareness of GPP. They allow Member States to choose the options that best suit their political framework and the level they have reached.
Table 1 shows the current situation of the National GPP Actions Plans in EU countries as of November 2014. A comprehensive overview of the situation in each EU Member States can be found in the document National GPP Action Plans (policies and guidelines).

Table 3 : Status of the National GPP Actions Plans.

Status	**Countries**
National Action Plan or equivalent document adopted	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, UK
No existing National Action Plan	Estonia, Greece, Hungary, Luxembourg, Romania

Source: National GPP Action Plans: http://ec.europa.eu/environment/gpp/action_plan_en.htm.

Table 4 summarizes the current situation regarding GPP in some EU countries, including the percentage of public bids with environmental criteria and priority aspects, such as GPP targets or products.

Table 4: Status of GPP in some EU countries.

Country	**% GDP for public procurement**	**Bidding with environmental criteria**	**Priority aspects: targets & products**
Austria	16%	60%	Under definition.
Denmark	19%	50%	Computer equipment, cleaning products, recycled paper.
Finland	16%	50%	n/a
France	16%	30%	Vehicles, construction, wooden products.
Germany	17%	70%	n/a
Italy	12%	30%	Energy efficiency and recycled material content in products.
Netherlands	21%	50%	In 2010, 100% GPP in Central Government and 50% in other public authorities.
Spain	13%	30%	n/a
Sweden	20%	80%	n/a
UK	17%	70%	Construction, catering, textiles, waste, paper and printing, energy, energy consumables and equipment, furniture, transport.

Source: National GPP Action Plans: http://ec.europa.eu/environment/gpp/action_plan_en.htm.

This study focuses primarily on understanding how the public spaces maintenance market works. Before any consideration or recommendation about the GPP criteria on maintenance of public spaces, it is essential to deepen the study of the market volume and market structure in the European context. The next section provides information on the function of the market of the product/service group from both the service provider and procurer perspective in order to interpret and identify relevant trends, drivers and innovations.

6.1 EU market overview

On the technical state of play analysis, the elaboration of a comprehensive database has been carried out. This database collected multiple groups of goods and services related to the maintenance of public spaces according to the scope identified on the Task 1 Report: stakeholder survey, statistical, legal and criteria review, scope and definition proposal.
In order to retrieve the most relevant information for our research purposes, this data was identified according to their Common Procurement Vocabulary (CPV). Within the CPV classification, many categories of supplies, works and services have been identified under its suitability to the Public Space Maintenance sector. This research methodology tries to gather within a unique database key information (relevant to the scope of the study) which will enable quantitative assessment of the economic relevance of the sector. Data for the following was collected:

- volume of the sector in EU 28
  - product/service supply and demand in approx. contract volumes
  - in EU total
  - at Member State level
  - Annual growth rates and public procurement volumes of purchases.

Although the CPV system is the most reliable, its level of accuracy is not absolute. According to the report Review of the Functioning of the CPV Codes/System across Europe[59], submitted in 2012, the benefit of the CPV system for contracting authorities was assessed as high. The report estimated that 90% of all tenders issued were correctly coded with roughly 10% of all publishing authorities applying a code which does not correctly describe the nature of a tender.

There are several reasons why codes might be applied incorrectly; e.g., some contracting authorities have very little experience with the CPV. Therefore these contracting authorities make mistakes by not providing the adequate code.
In addition, another problem identified for the use of CPV Codes/System was to take the supplier's perspective more into account. According to many suppliers, the CPV structure does not represent business sectors – which causes inconsistencies for users. Language barriers still seem to be a difficulty for users at the European context. The original text that describes the tender is shown only in the language of the contracting authority; only the code text is shown in other languages. As some contracting authorities tend not to use the codes which are an exact fit, the code text does not always suit the object of a tender.
These problems have limited the depth of the market study, creating difficulties in obtaining a comprehensive database that enables an in-depth knowledge and understanding of the maintenance of public space sector in every European country. Therefore, and due to the language constraints which limit the accessibility to the primary sources (mainly national public procurement institutions), the European Tender

[59] European Commission DG Internal Market and Services, December 2012. Available at: https://www.pianoo.nl/sites/default/files/documents/documents/121219report-review-cpv-codes-functioningen.pdf.

Electronic Daily (TED), the online version of the Supplement to the Official Journal of the EU (OJS), dedicated to European public procurement were consulted. According to European Directive on public procurement, notices for procurement procedures of public authorities must be published in the Official Journals.
The awarding authorities for tenders included within TED, are central governments, local or regional authorities, bodies governed by public law, or associations consisting of one or more of these authorities or bodies governed by public law. Each year supply and public works contracts worth about 420 billion euros are published by public authorities in the EU. Every day the Supplement to the Official Journal publishes over 1,800 tenders containing invitations to tender among the following sectors:

- Public contracts for works, supply and services from all EU Member States.
- Utilities contracts (water, energy, transport and telecommunications sectors).
- Public contracts from EU institutions.
- Phare, Tacis and other contracts from Central and Eastern Europe.
- European Investment Bank (EIB), European Central Bank (ECB) and European Bank for Reconstruction and Development (EBRD) financed projects.

Thus, according to the scope of the study, the following categories have been studied by TED:

- **Activities** related with Public Space Maintenance, organized around two main categories:
  - Cleaning
  - Gardening & landscaping
- **Equipment Items**, needed to accomplish maintenance activities, mainly:
  - Vehicles
  - Machinery

Hereafter, data management and its specific characteristics will be explained to help the data interpretation.

6.1.1 Data characteristics

The data shown in this report comes from public procurement standard forms, which are filled in by contracting bodies and sent as notices for publication in TED. Within TED, information on public procurement contracts, according to the EU rules can be found for the EU Member States. Generally, this data is provided "as is", because sometimes the source of the data is unverified output from contracting authorities or entities across Europe. As said before, it is not uncommon for data to be input incorrectly or to be missing, and thus great care has been taken with data management and its interpretation.
On the other hand, much of the data provided consists of notices above the procurement thresholds. However, publishing below threshold notes in TED is considered good practice, and thus a non-negligible number of below threshold notices is present as well.
Since September 2008, the common procurement vocabulary has changed. For this reason, the analysis was based only on data from 2009 onwards. In addition, according to the multiple levels provided by the European Union Open Data Portal (Contract Award Notices, Contract Awards and Contract Notices); for the purpose of our study, it is enough to work with the Contract Award Notices (CAN) files (which contain the CAN and Contract Awards levels of the data). Since, generally, the CAN informs on the final result of the procurement.
In a file with CANs, each row begins with the information from a CAN, including a Contract Awards (CA). When a CAN has multiple CA, then the information from the non-CA parts of the notice will be repeated.

6.1.2 Data management methodology

A subset of data was downloaded from Tenders Electronic Daily (TED) online platform covering public procurement for the European Economic Area and Switzerland from 2009-01-01 to 2015-12-31 in comma separated value format. This data included the most important fields from the contract notice and contract award notice standard forms.
Subsequently, for the period selected, a subset of data was filtered according to the relevant CPV-codes identified for every category included within the scope of the studio. Specifically, the information under the following CPV-codes was collected. As stated below, in a file with Contract Award Notices (CANs), when a CAN has multiple Contract Awards (CAs), the information from the non-CA parts of the notice will be repeated. Therefore, in our analysis we remove the information duplicated based on the ID_NOTICE_CAN, resulting for the year 2009 in a dataset of 761 rows (Filter single values or remove duplicate values).
In order to adapt the datasets to the European format, the points founded in the contract amounts were replaced by commas. The following activities related to Public Space Maintenance, and organized around five main services, were studied.

6.1.2.1 Cleaning activities market overview

The relevant CPV-codes for cleaning activities are mostly listed in: Division 90 Sewage, refuse, cleaning and environmental services. Specifically, under the group 9060 Cleaning and sanitation services in urban or rural areas, and related services, within which are included the following categories:

- 90610000, Street-cleaning and sweeping services
- 90620000, Snow-clearing services
- 90630000, Ice-clearing services
- 90640000, Gully cleaning and emptying services
- 90650000, Asbestos removal services
- 90660000, Deleading services
- 90670000, Disinfecting and exterminating services in urban or rural areas.
- 90680000, Beach cleaning services

In addition, three classes of the group 9091 Cleaning services have been included within the cleaning activities for the maintenance of public spaces:

- 90914000, Car park cleaning services
- 90918000, Bin-cleaning services

In 2015, the cleaning activities regarding the maintenance of public spaces involved more than 800 million euros of (CANs),. As reflected in Figure 1, between 2009 and 2015, the total value of the services included under this category maintained an irregular pattern, exposed to the ups and downs based on budget constraints. While in 2010 the volume of contracts experienced an increase of 70%, 2014 saw a decrease of 28% in the volume of CAN. During this entire period the total purchase of cleaning activities was never below 600 million euros. The total average number of CAN for these 7 years was 831 million euros, reflecting the large volume of this market in the European context. On the other hand, the average number of CAN published on TED about this topic was 935 contracts. Since the geographical coverage included in the dataset (Former Yugoslav Republic of Macedonia, Iceland, Norway, Switzerland, Liechtenstein and EU28) the value distribution of cleaning activities contracted, registered remarkable differences between each country.

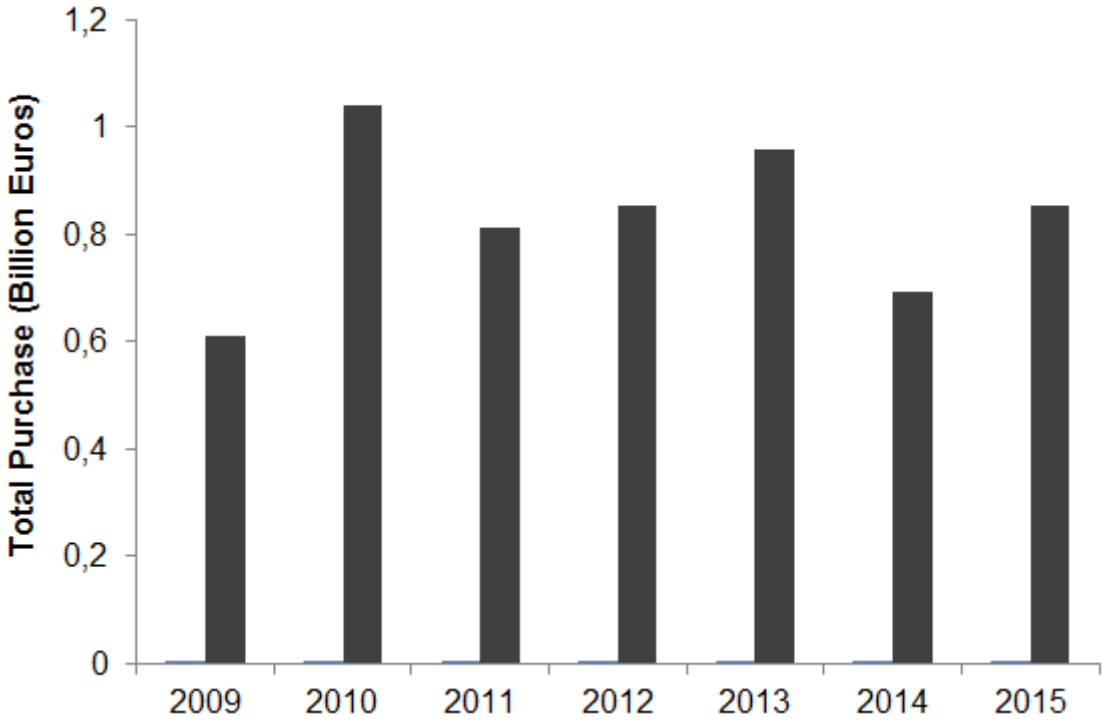

Figure 2: Total purchase of cleaning activities

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

As shown in Figure 3, the highest value spent on cleaning activities by the public authorities contracting in the year 2015 belongs to Poland, followed by the public contracting authorities of Latvia, registering more than 200 million euros and 100 million euros, respectively. Romania, France, Italy, United Kingdom and Germany exceed 50 million euros in volume of contracts, while countries like Spain, Finland and Denmark are above 15 million in volume of contracts for the year 2015. The weight of each country within the total percentage fluctuates remarkably for each year analyzed; however countries such as Poland, France, Italy, the United Kingdom, Germany or Spain maintain a predominant weight throughout the period 2009-2015.

Despite the fact that these services should be contracted periodically, the volume and number of cleaning activities and services contracted by the public authorities in each country vary widely between different years. Two specific cases draw a lot of attention. In 2009, Latvia registered a contracting volume of cleaning services and activities of 117 million euros. During the next five years, total public procurement in Latvia for cleaning services was approximately 8 million euros. On the contrary, the year 2015 Latvia recorded a contracting volume of 135 million euros. This irregular trend in public contracts can be explained considering the validity of public contracts, being the responsibility of each country to set up their own public contract terms.

The case of Spain is representative because it reflects the role of public entities as instruments of national economic policy. The volume of services and cleaning activities contracted by public bodies in Spain in 2010 was 415 million euros, a figure well above the average recorded for the period 2009-2015 (31 million euros). This disproportionate increase reflects the weight of public expenditure as an instrument to counteract the effects of economic crisis on unemployment due to the Spanish real estate crisis that took place during these years.

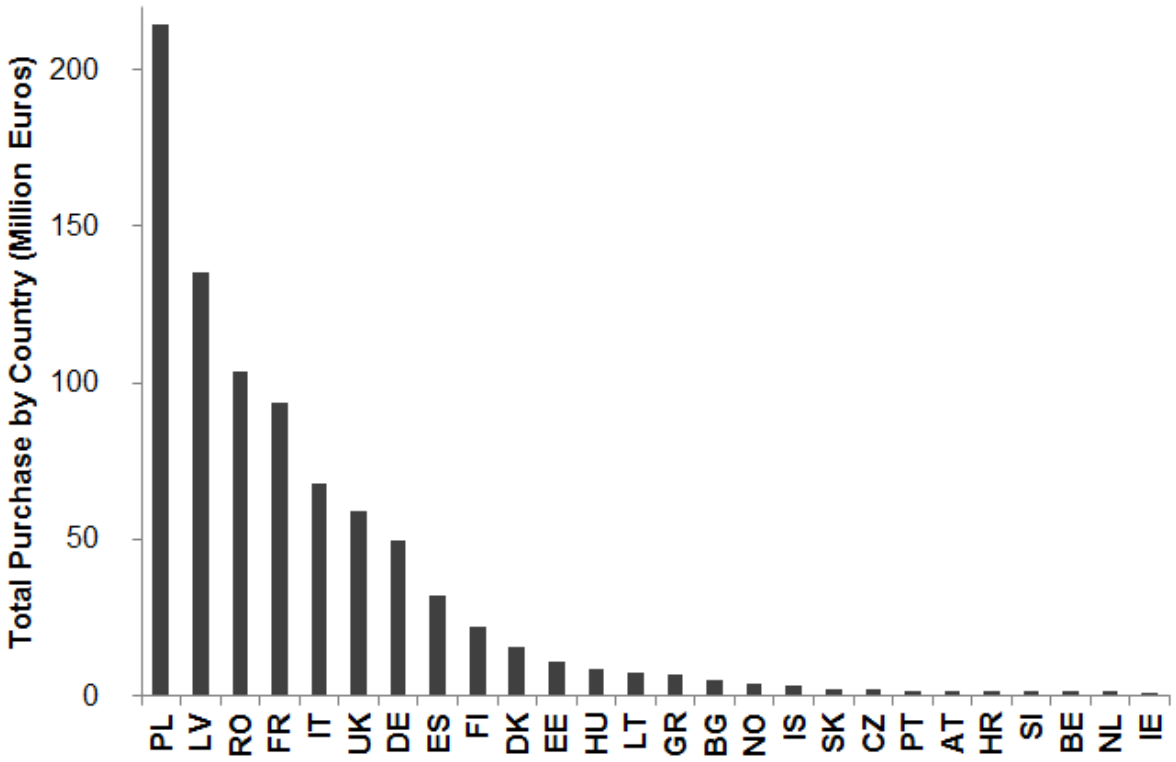

Figure 3: Total purchase of cleaning activities by country (2015)

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

As shown in Figure 4, the weight of cleaning activities within the maintenance of public space sector is very high in the European context. These activities maintain an average relative weight in relation to the rest of activities of approximately 59% of the total, surpassing in the years 2010, 2012 and 2015 the 60% of contract award notices registered at the European level. The average of the CAN total volume for the study period is 1,410 million euros. By contrast, the cleaning activities under the scope of the study registered a total average 831 million euros.
It should be noted, on the other hand, the steady evolution of the volume of cleaning activities collected under the scope of the study. By maintaining a constant weight within the maintenance of public spaces sector, the importance of this sector for the periodic maintenance should be remarkable. After the research of the market conditions for the cleaning activities under the scope of this study could be concluded that these activities are essential for the maintenance of public spaces in the European context.

In the following sections we will study the market share of the rest of the activities identified: gardening and landscaping activities, repair and replacement and equipment items.

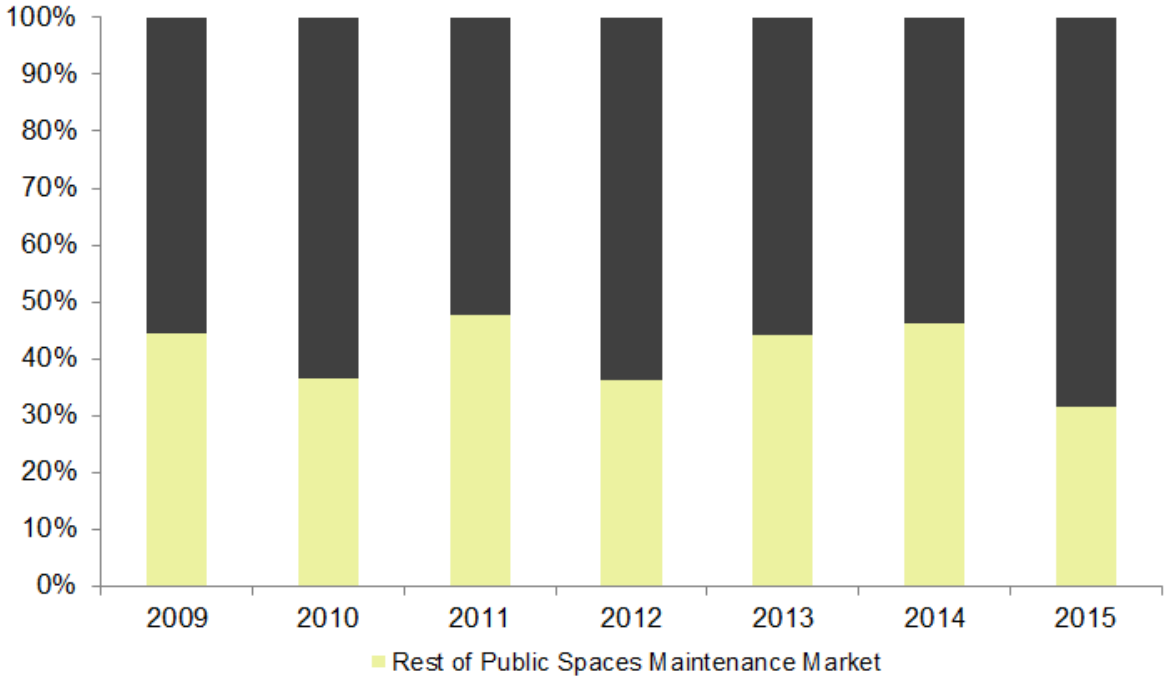

Figure 4: Cleaning activities market share

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

6.1.2.2 Gardening and landscaping activities market overview

Regarding the gardening and landscaping activities, the relevant CPV-codes included for the market analysis are listed under three main divisions: Division 77 Agricultural, forestry, horticultural, aquacultural and apicultural services, Division 03 Agricultural, farming, fishing, forestry and related products and Division 45, Construction work. Specifically, under the groups 7731 Planting and maintenance services of green areas, 7734 Tree pruning and hedge trimming, 0345 Tree-nursery products and 4511 Building demolition and wrecking work and earthmoving work. Within these divisions are included the following categories:

- 77341000, Tree pruning
- 77342000, Hedge trimming
- 77313000, Parks maintenance services
- 77314000, Grounds maintenance services
- 45236230, Flatwork for gardens
- 45236250, Flatwork for parks
- 77311000, Ornamental and pleasure gardens maintenance services
- 77330000, Floral display services
- 77312000, Weed-clearance services
- 03121100. Live plants, bulbs, roots, cuttings and slips
- 03440000, Forestry products
- 03441000. Ornamental plants, grasses, mosses or lichens
- 03451000, Plants
- 03451100, Bedding Plants
- 03451200, Flower bulbs
- 03451300, Shrubs
- 03452000, Trees

- 77314100, Grassing services
- 77315000, Seeding services
- 45112710, Landscaping works for green areas
- 45112711, Landscaping work for parks
- 45112712, Landscaping work for gardens
- 45112713, Landscaping work for roof gardens
- 45112714, Landscaping work for cemeteries

In 2015, the gardening and landscaping activities regarding the maintenance of public spaces involved 279 million euros of Contract Award Notices. Similar to cleaning activities between 2009 and 2015, the total values of the services included under this category maintained an irregular pattern, exposed to the ups and downs based on budget constraints (Figure 6). Although the volume of contracts experienced an increase of 89% in 2013, it suffered a decrease of 41% in the volume of CAN in 2012. During this entire period the average total purchase of cleaning activities was 371 million euros. On the other hand, the average number of CAN published on TED about this topic was 494 contracts. Since the geographical coverage included in the dataset (Former Yugoslav Republic of Macedonia, Iceland, Norway, Switzerland, Liechtenstein and EU28) the value distribution of gardening and landscaping activities contracted, registered remarkable differences between each country.

The following figures present the market share of the gardening and landscaping activities in relation to other activities under the scope of the research. Additionally, the contribution of each European country in relation to these activities is illustrated.

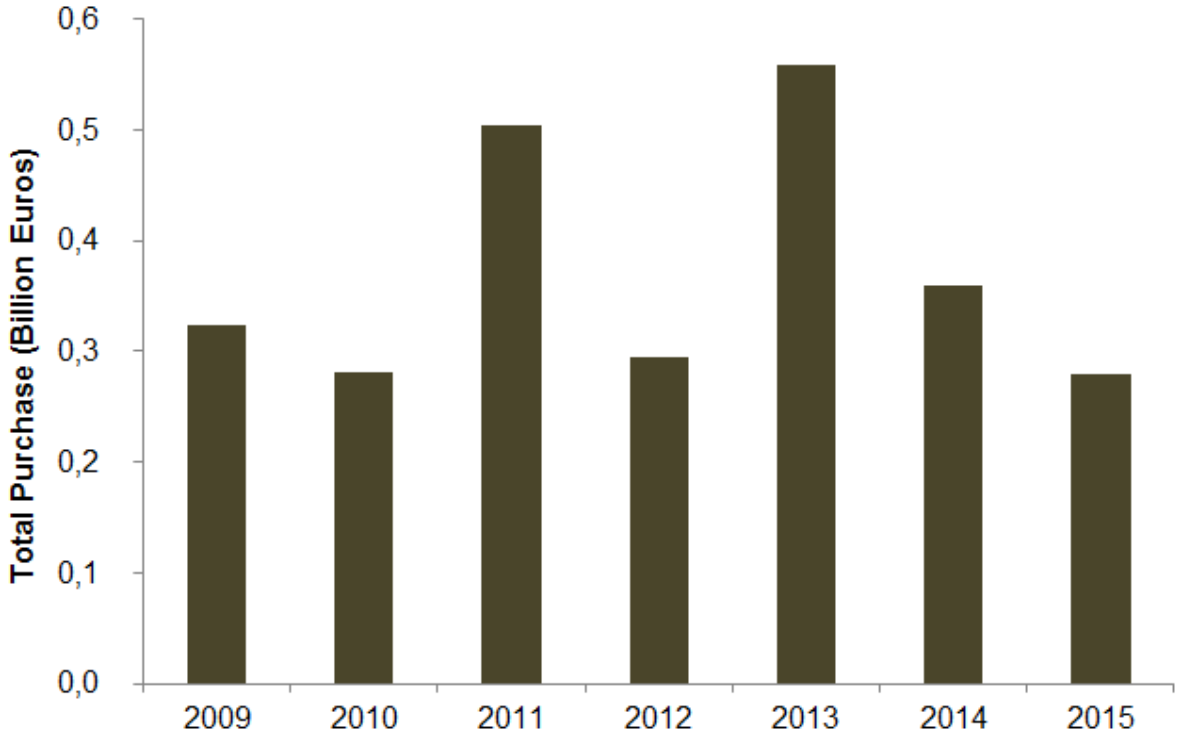

Figure 5: Total purchase of gardening and landscaping activities

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

As seen in Figure 6, the highest value spent on cleaning activities by the public authorities contracting in the year 2015 belongs to the United Kingdom, registering more than 100 million euros. Following the United Kingdom, are the public contracting authorities of Austria, Spain and Poland, each registering 51, 31 and 17 million euros respectively. Above 10 million euros in volume of contracts are Italy, France and Estonia, while countries like Germany, Romania and Portugal are above 5 million euros in volume of contracts for the year 2015. The weight of each country within the total percentage fluctuates remarkably for each year analyzed; however countries such as United Kingdom, Poland, Spain, Italy, France and Germany maintain a predominant weight throughout the period 2009-2015.

In addition, and similar to the case of cleaning activities, despite the fact that these services are contracted periodically, the volume and number of cleaning activities and services contracted by the public authorities in each country vary widely between different years.

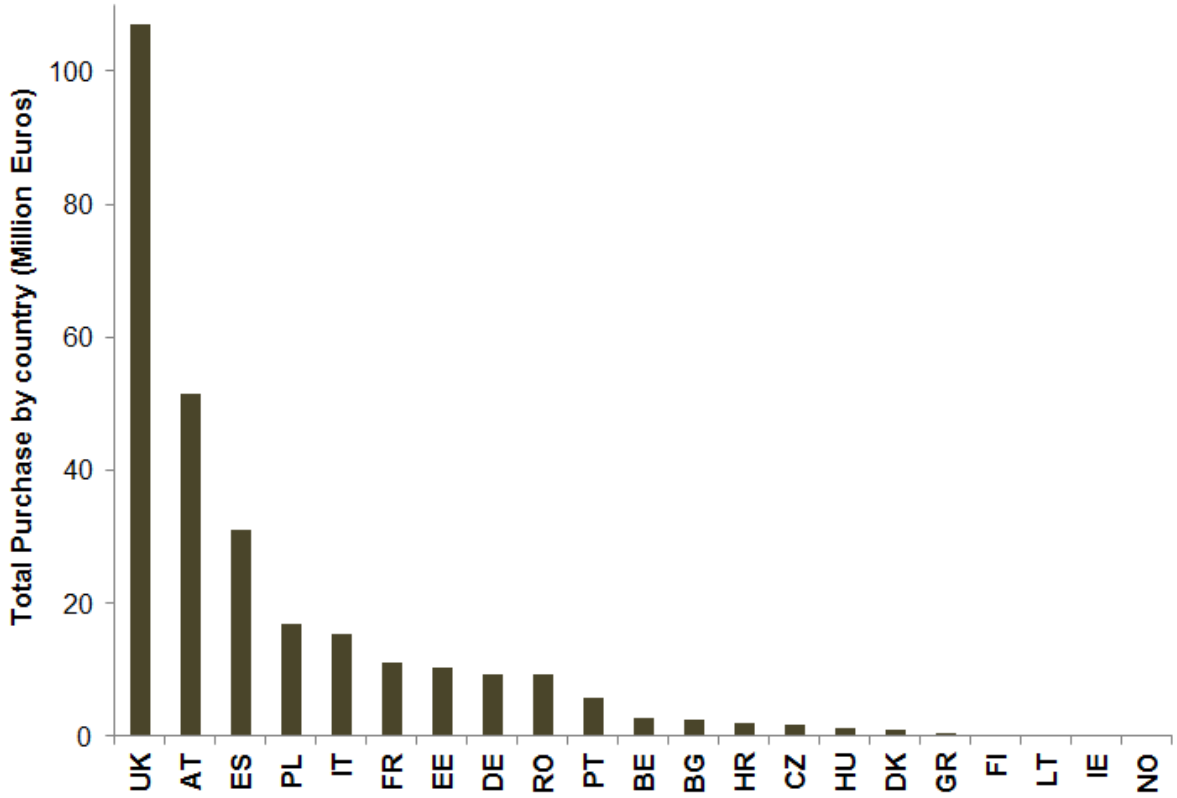

Figure 6: Total purchase of gardening and landscaping activities by country (2015)

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

As noticed in Figure 7, the weight of gardening and landscaping activities within the maintenance of public spaces sector is quite high in the European context, placed just behind the cleaning activities, which as mentioned before represent a greater volume of activities included within the public space maintenance. These activities maintain an average relative weight in relation to the rest of activities of approximately 26% of the total, surpassing in the years 2011 and 2013 the 30% of contract award notices registered at European level. The average volume of gardening and landscaping activities for the study period is 371 million euros. By contrast, the repairing and replacement activities under the scope of the studio register a total average of 189 million euros.

Unlike the steady evolution of cleaning activities, the evolution of the volume in gardening and landscaping activities collected under the scope of the study shows fluctuations. While in 2011 the activities of gardening and landscaping accounted for almost 35% of the total of CANs, in 2010 these activities only constituted for 17% of the total. Thus, in 2012 a greater share of CANs belonged to Italy with 70 million euros. By contrast, in 2014 the Spanish public authorities made an expenditure of 110 million euros making it the highest market share of that year.

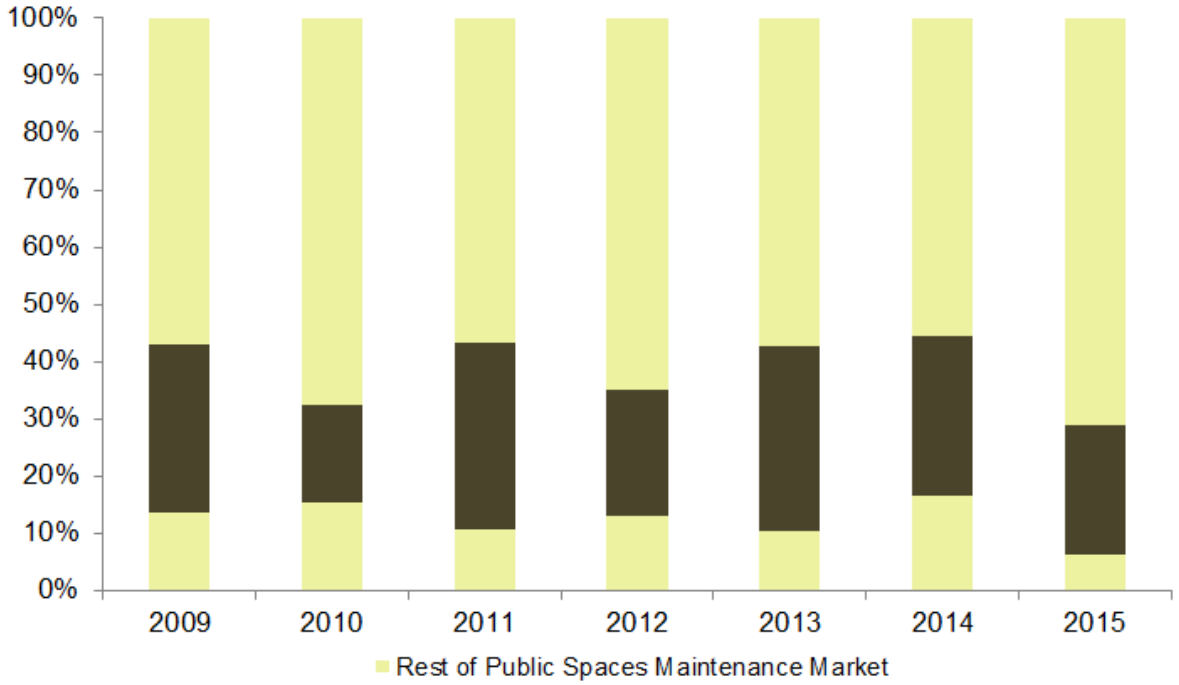

Figure 7: Gardening and landscaping activities market share

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

6.1.2.3 Equipment items: Vehicles market overview

Regarding the vehicles employed for the maintenance of public spaces, we identified the following CPV-groups included under the division 16, Agricultural machinery:

- 16500000, Self-loading or unloading trailers and semi-trailers for agriculture
- 16510000, Self-loading trailers for agriculture
- 16520000, Unloading trailers for agriculture
- 16530000, Self-loading semi-trailers for agriculture
- 16540000, Unloading semi-trailers for agriculture
- 16700000, Tractors

Each of these categories include many statistical items that should not be considered within the public space maintenance sector. Thus, many of the statistical items studied under this statistical frame could be committed to agricultural or livestock purposes. The introduction of such data within the vehicles category would cause great distortion. Therefore, those CPV-groups have been put aside for the current study.

By contrast, the procurements collected under the CPV category 163110, Lawnmowers and its subcategory 16311100, Lawn, park or sport-ground mowers; also considered as vehicles, sustain a great proportion of the services assigned to the maintenance of the parks and public gardens. On the other hand, when considering the study of the vehicles involved in the maintenance of public spaces sector, the EU Green Public Procurement Criteria for Transport developed in 2016, should be taken into account. Many of the statistical categories collected under these criteria are devoted to the maintenance of public spaces.

In this regard, and as stated in the EU Green Public Procurement Criteria for Transport, the relevant CPV codes for cars and Light Commercial Vehicles (LCVs) are listed under

the division 34, Transport equipment and auxiliary products to transportation. Motor vehicles for the transport of machinery, goods and services used on the maintenance of public spaces fall within category 3413, Motor vehicles for the transport of goods. Thus, we identify the following subgroups:

- 34131000, Pick-ups
- 34134200, Tipper trucks
- 34136000, Light vans
- 34136200, Panel vans

In addition, specific vehicles employed on the maintenance of public spaces as parks, streets or gardens; could be identified under the group 341440, Special-purpose motor vehicles:

- 34144410, Gully emptiers
- 34144420, Salt spreaders
- 34144430, Road-sweeping vehicles
- 34144431, Suction-sweeper vehicles
- 34144440, Gritter vehicles
- 34144450, Sprinkler vehicles
- 34144900, Electric vehicles

In year 2015, the equipment vehicles regarding the maintenance of public spaces involved almost 79 million euros of CANs. As happened with the activities included under the scope of the market overview, equipment vehicles maintained an irregular evolution between 2009 and 2015. Thus, the total values of the services included under this category maintained an irregular pattern, averaging 172 million euros with major fluctuations (Figure 9). As a sample of this irregular evolution, 2015 registered a sharp fall with a reduction of 63% compared to the previous year.

During this entire period the total purchase of products under this category was 1.21 billion euros. This volume of contract contrasts sharply with that recorded for the same period on cleaning or gardening and landscaping. The average number of CANs published on TED on this topic was 290 contracts.

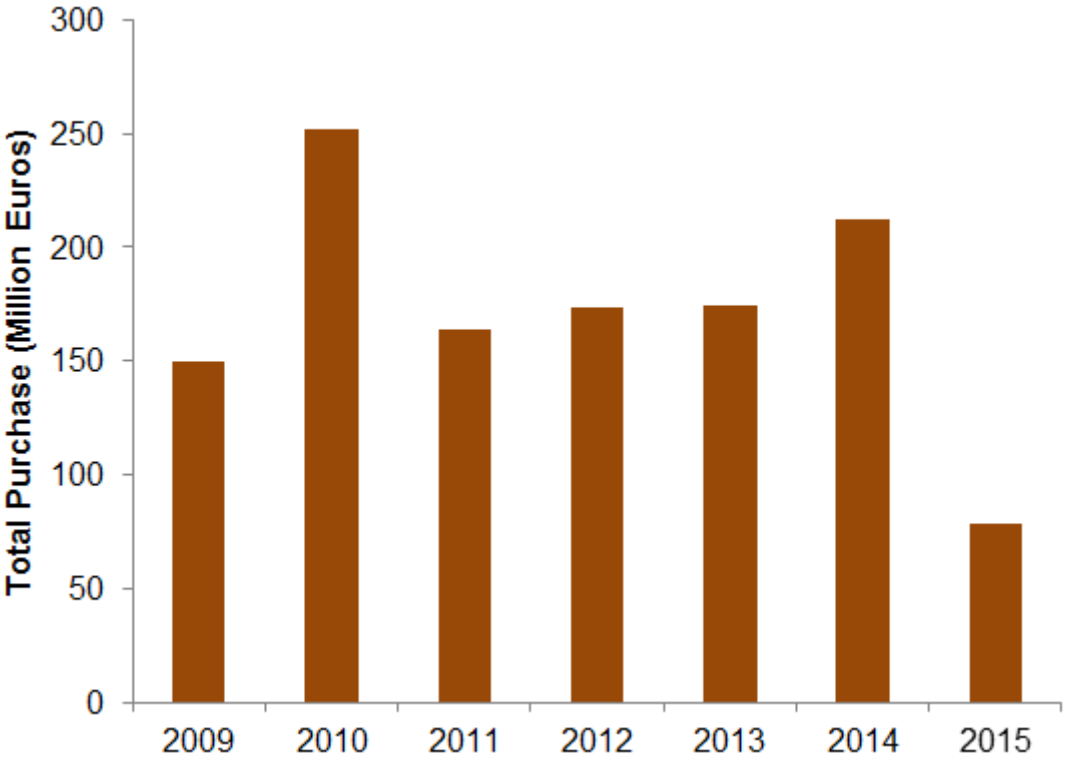

Figure 8: Total purchase of Vehicles

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

Figure 10 shows the expenditure of every European country on equipment vehicles contracted in the year 2015. The highest expenditure belongs to Hungary, registering more than 13 million euros. Following Hungary, the public contracting authorities of Italy, Slovakia, Czech Republic and Poland; register 13, 10, 8 and 7 million euros respectively. Above 2 million euros in volume of contracts are also Romania, Finland, Germany, France and United Kingdom; while countries like Spain, Denmark, Estonia or Belgium are above 1 million euros in volume of contracts for the year 2015. The weight of each country within the total percentage does not fluctuate considerably between different years. Accordingly, countries such as the United Kingdom, Poland, Spain, Italy, France and Germany maintain a predominant weight throughout the period 2009-2015.

Unlike the services and activities included within the scope of the study, the purchase of vehicles by the European public authorities seems to show a periodicity. Hence, the volume and number of vehicles contracted in each country does not vary widely between different years.

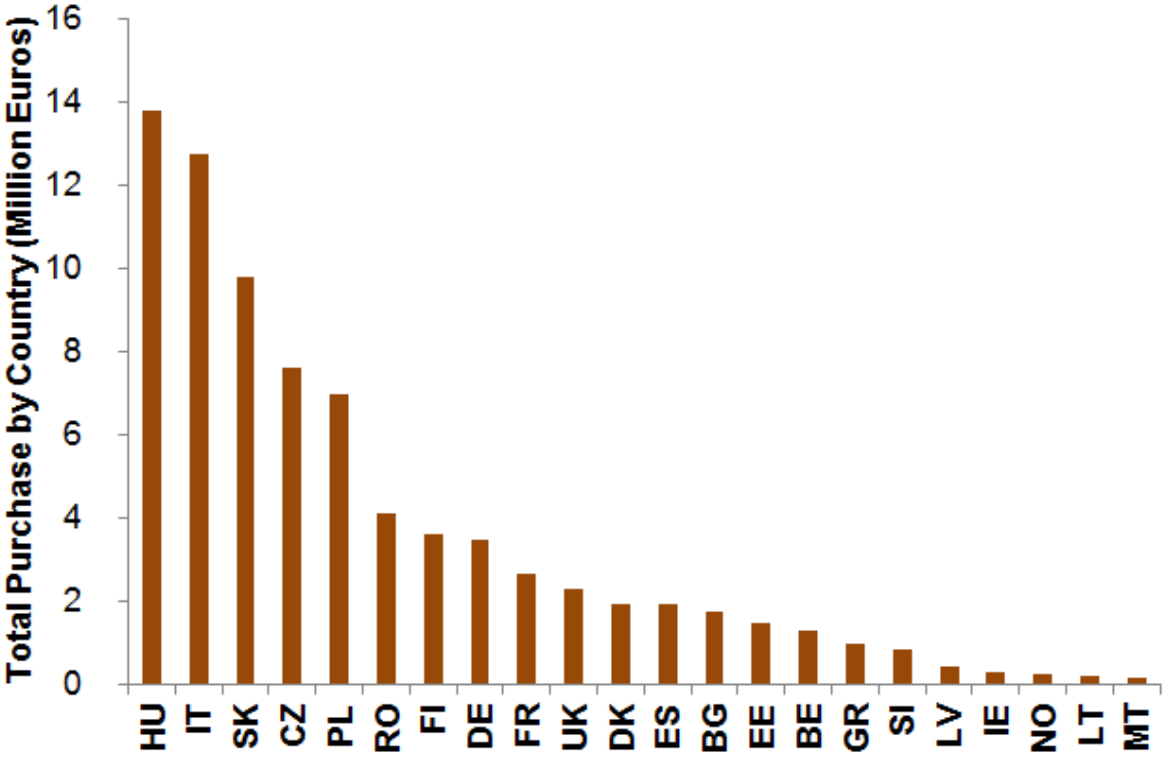

Figure 9: Total purchase of Vehicles by country 2015

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

The weight of vehicles purchased within the maintenance of public spaces sector maintained an average market share of 12% for the entire study period. Hence, the evolution of vehicles within the maintenance of public spaces sector showed a regular behavior for the period 2009-2014. By contrast, 2015 registered a sharp fall on the vehicles purchase market share, showing a relative weight of 6%. As previously stated, these activities maintained an average relative weight in relation to the rest of activities of approximately 12% of the total, reaching in the years 2010 and 2014, 15% and 16% respectively, of contract award notices registered in the European context. 2015 recorded the lowest market share of the vehicles on the total purchase of items dedicated to the maintenance of public spaces. The average volume of equipment vehicles for the study period is 172 million euros. Below the data on equipment vehicles market share is presented graphically.

The main conclusion that can be drawn from these data is that the steady behavior in the procurement of products by the European public authorities on the maintenance of public spaces. It should be noted, however, that the highest share of contract number and market volume belong to the vehicles identified under the group 341440, maintaining an average market share of almost 70%. Thus, the Special-purpose motor vehicles employed on the maintenance of public spaces as parks, streets or gardens, register the most important turnover within this category. By contrast, within the category of equipment vehicles employed on the maintenance of public spaces, those which fall under the category 3413, Motor vehicles for the transport of goods; represented a smaller percentage of the total.

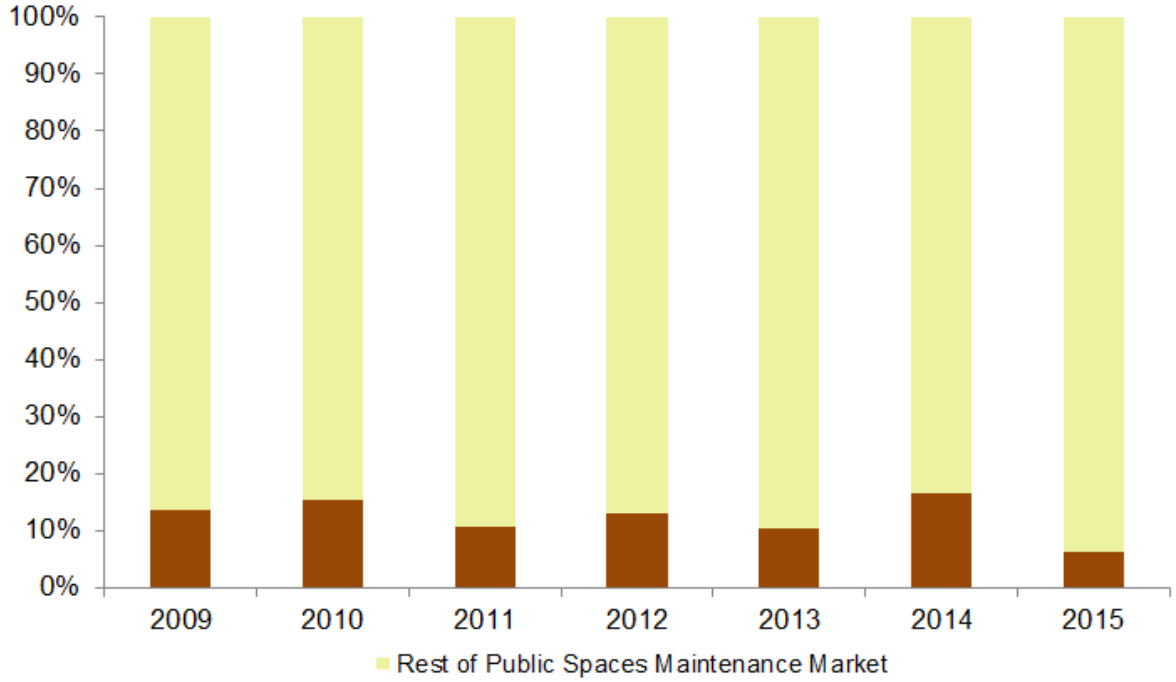

Figure 10: Vehicles market share

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

6.1.2.4 Equipment items: Machinery market overview

The relevant CPV-codes for machinery used for the maintenance of public spaces are listed under three main divisions 16, Agricultural machinery; 39, Furniture (incl. office furniture), furnishings, domestic appliances (excl. lighting) and cleaning products and 42, Industrial machinery. The division 16, Agricultural machinery includes the following groups 1610, Agricultural and forestry machinery for soil preparation or cultivation; 1640, Spraying machinery for agriculture or horticulture and finally the group 1680, Parts of agricultural and forestry machinery. Each category contains the following groups:

- 16120000, Harrows, scarifiers, cultivators, weeders or hoes
- 16130000, Seeders, planters or transplanters
- 16150000, Lawn or sports-ground rollers
- 16160000, Miscellaneous gardening equipment
- 16400000, Spraying machinery for agriculture or horticulture
- 16820000, Parts of forestry machinery

The pertinent groups for the study of the cleaning products and machinery used on the maintenance of the furniture within the public spaces are under division 39, Furniture (incl. office furniture), furnishings, domestic appliances (excl. lighting) and cleaning products:

- 39830000, Cleaning products

- 39713400, Floor-maintenance machines
- 39713430, Vacuum cleaners
- 39224000, Brooms and brushes and other articles of various types

Finally, the division 42, Industrial machinery contains the last categories under study:

- 42924730, Pressurised Water Cleaning Apparatus
- 42924740, High-Pressure Cleaning Apparatus

Just as it happens with vehicles equipment items, it is necessary to take into account that each of these categories include many statistical items that should not be considered within the public space maintenance sector, since items included under this scope could be used as well for the maintenance of indoor public spaces, or agricultural and livestock purposes. Nevertheless, all the agricultural and forestry machinery, and the cleaning machinery procured by the public authorities could not be distinguished from the machinery used in the maintenance of public spaces when the study is based on the CPV-system classification.

On the other hand, most cleaning products (detergents, anti-dust products, etc.) have been dispensed due to its high volume of CANs. In spite of having a residual weight in the maintenance of public spaces their relative volume distorts the rest of the data. Therefore only cleaning products under division 39 related to the following activities have been included on the study:

- Housing and community amenities
- General public\services
- General public\services, Other
- Environment, General public\ services, Other
- General public\services, Housing and community amenities
- Public order and safety
- General public\services, Public Order and Safety
- General public\services, Recreation, culture and religion

The equipment machinery regarding the maintenance of public spaces involved almost 34 million euros of Contract Award Notices in year 2015 (Figure 16). Unlike the equipment vehicles included under the scope of the market overview, the machinery maintained an irregular pattern between 2009 and 2015, exposed to the ups and downs based on budget constraints. While in 2010 the volumes of contracts show an outstanding increase of 286%, 2012 suffered a decrease of 78% in the volume of CANs. During this entire period the average total purchase of cleaning activities was 35 million euros. The average number of CANs published on TED on this topic was 110 contracts. Since the geographical coverage included in the dataset (Former Yugoslav Republic of Macedonia, Iceland, Norway, Switzerland, Liechtenstein and EU28) the value distribution of the equipment machinery contracted, registered remarkable differences between each country.

During this entire period the total purchase of products under this category was 274 million euros. This volume of contract contrasts sharply with that recorded for the same period on equipment vehicles.

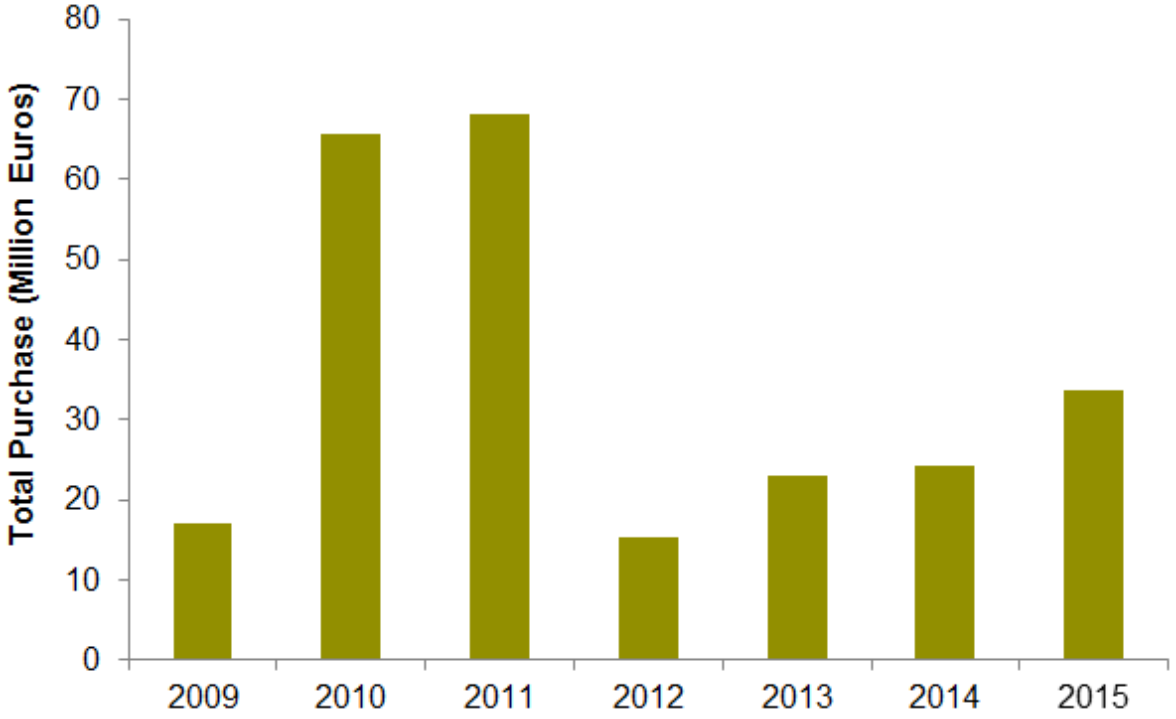

Figure 11: Total purchase of Machinery

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

Figure 13 shows the amount contracted by every European country on equipment vehicles for the period 2009-2015. The highest expenditure belongs to the United Kingdom, registering more than 102 million euros. Following the United Kingdom, the public contracting authorities of France, Denmark and Germany; register 35, 33 and 30 million euros respectively. Above 4 million euros in volume of contracts are also Finland, Portugal, Spain and Italy. As happens with the rest of categories, countries such as the United Kingdom, France, Germany, Italy and Spain maintain a predominant weight throughout the period 2009-2015. In any case, it must be emphasized the big difference existing between the volume of contract award notices between the United Kingdom and the rest of the European countries, in such a way that its amount is above the sum of the CANs for France, Denmark and Germany.

Unlike the vehicles included within the scope of the study, the purchase of machinery for the maintenance of public spaces by the European public authorities does not seem to show any trend. Hence, the volume and number of machinery contracted in each country vary widely between different years.

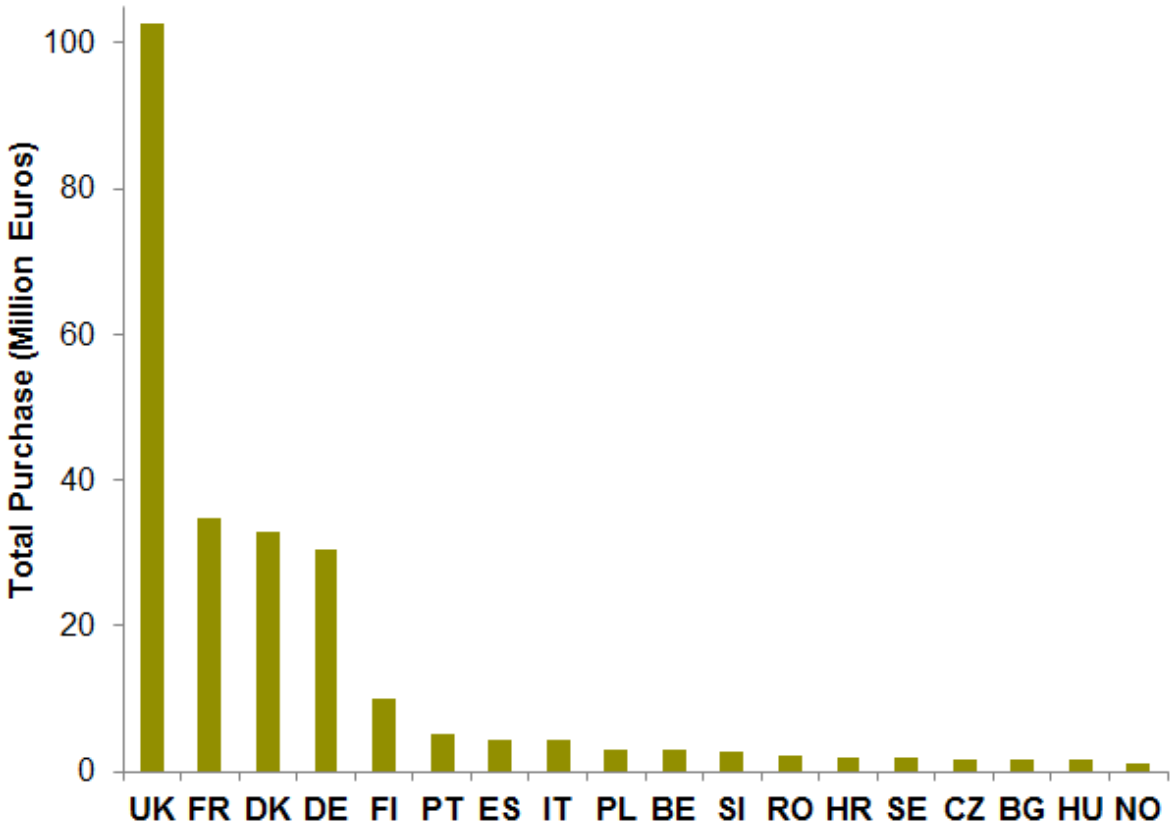

Figure 12: Total purchase of Machinery by country 2009-2015

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

The weight of machinery purchase within the maintenance of public spaces sector maintained a market share of 2% for the entire study period. As happens with other categories involved on the public spaces maintenance like the assembly and removal of temporary elements its market share is almost negligible related to the rest and products and activities covered under the scope of the research. Despite the remarkable ups and downs for the period 2009-2015, these changes have not affected the evolution of the total volume of contracts purchased by the public authorities at the European context. The average volume of machinery during the study period is 35 million euros. By contrast, the vehicles under the scope of the studio register a total average of 172 million euros.

Thus, the evolution of machinery within the maintenance of public spaces sector showed an irregular behavior for the period 2009-2015. As previously stated, these activities

maintained an average relative weight in relation to the rest of activities of approximately 2% of the total, reaching in the years 2010 and 2011 a 4% of the total volume of contract award notices registered in the European context. On the contrary, 2009, 2012, 2013 and 2014 recorded less than 2% of market share on the total purchase of items dedicated to the maintenance of public spaces. The total volume of machinery for the study period is 247 million euros. Below the data on equipment vehicles market share is presented.

It should be noted that the highest share of contract number and market volume obey to the machinery identified under the group 3983, Cleaning products; employed on the maintenance of public spaces as parks, streets or gardens. By contrast, within the category of equipment machinery employed on the maintenance of public spaces, those which fall under the division 42, Industrial machinery; represented a smaller percentage of the total.

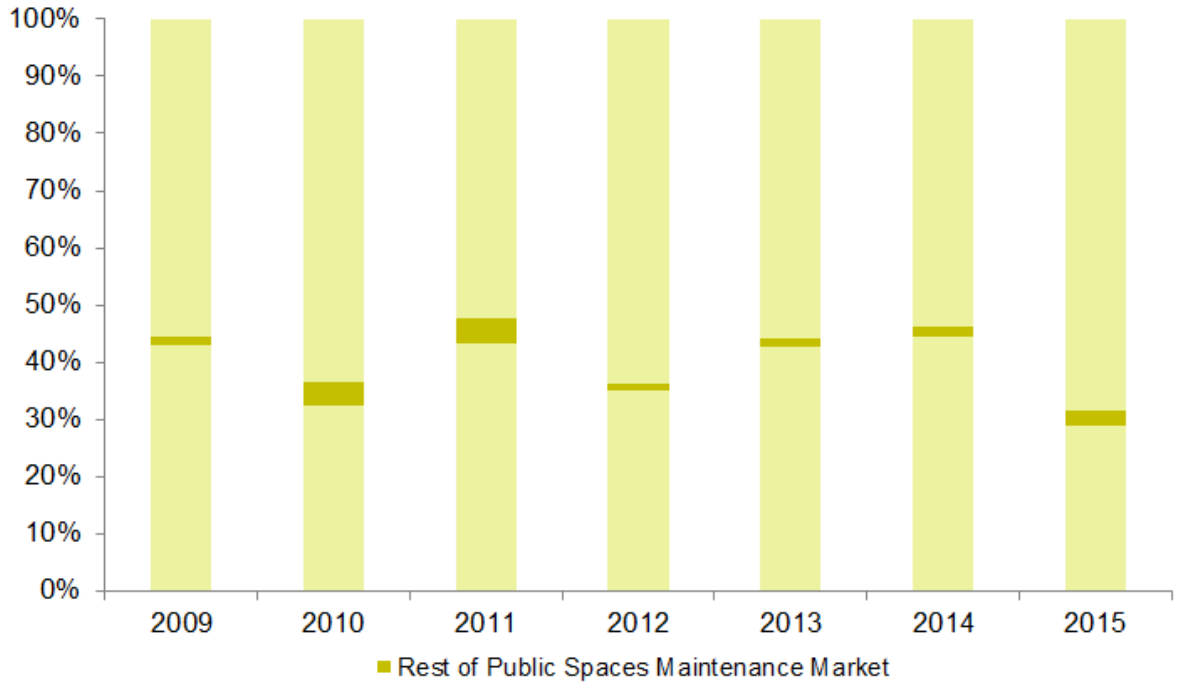

Figure 13: Machinery market share

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

6.1.3 Global overview of the European Market

For the period 2009-2015, the total purchase of services and products regarding the maintenance of public spaces involved more than 12 billion euros of CANs. As reflected in Figure 15, between 2009 and 2015, the total values of the services and products included under the scope maintained an irregular pattern, exposed to the ups and downs based on budget constraints. While in 2013 the volume of contracts experienced a remarkable increase of 34%, 2014 saw a decrease of 20% in the volume of CANs. During this entire period the total purchase of public space maintenance activities was never below 1,5 billion euros. The total average number of CANs for these 7 years was 1,7 billion euros, reflecting the large volume of this market in the European context. As has happened for every service and product group the value distribution of cleaning activities contracted registered remarkable differences between each country.

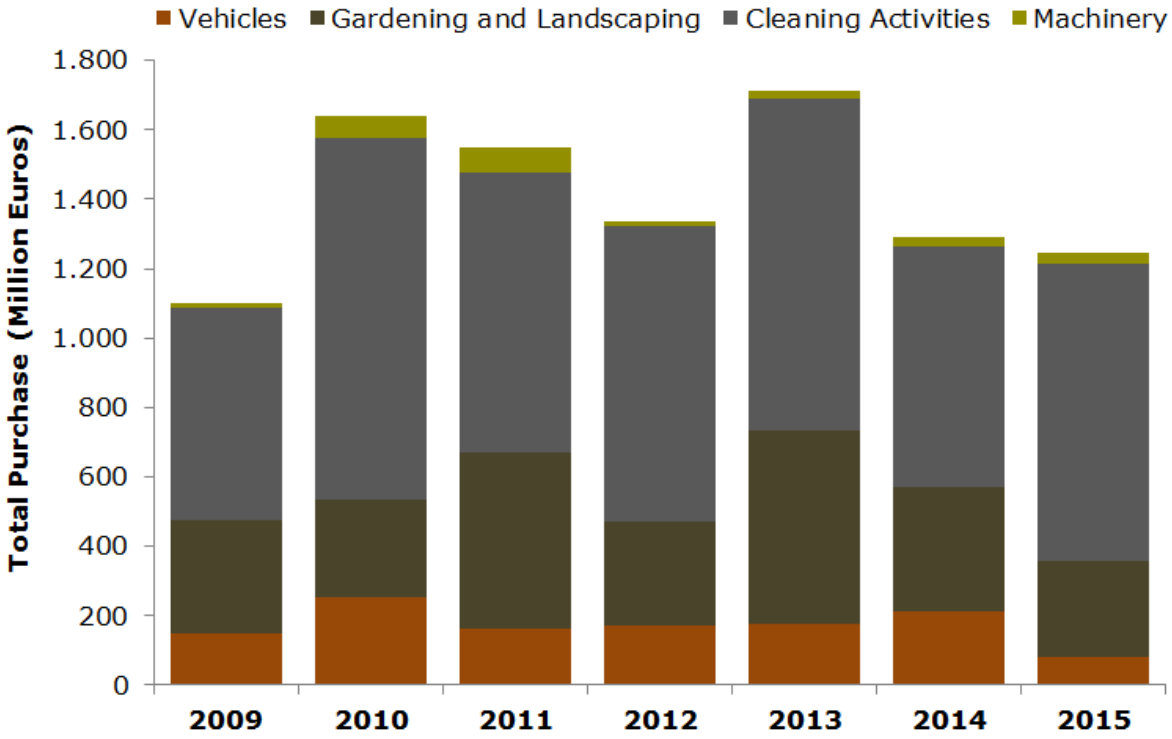

Figure 14: Total purchase of Maintenance of Public Spaces (2009-2015)

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

As shown in Figure 16, the highest value spent on maintenance of public spaces by public contracting authorities for the period 2009-2015 belongs to the United Kingdom with 2,6 billion euros. Following the United Kingdom, the Polish public contracting authorities, register more than 2,3 billion euros. Spain and Italy exceed one billion euros (1,3 and 1,1 billion respectively) on the purchase of products and services for the maintenance of public spaces. While France, Romania and Germany are above 500 million euros in volume of contracts for 2009-2015. The weight of each country within the total percentage fluctuates remarkably for each year analyzed; however countries such as Poland, France, Italy, United Kingdom, Germany or Spain maintain a predominant weight throughout the entire period 2009-2015. Furthermore, it is important to highlight the market share of countries like Hungary, Romania or Denmark within the maintenance of public spaces sector, which public purchase volume contrasts with the country size.

By contrast, and as it happens with every single activity analyzed, the volume and number of activities and services for the maintenance of public spaces contracted by the public authorities in each country vary widely between different years. In 2015, Austria registered a contracting volume of gardening and landscaping services and activities of 51 million euros. During the previous six years, total public procurement in Austria for these services was approximately 5 million euros, eleven times the procurement volume than the volume registered for the period 2009-2014. On the other hand, in 2010 the Spanish public authorities recorded a contracting volume of 400 million euros of cleaning activities related to the maintenance of public spaces. This contracting volume represents 65% of the total activities contracted for the period 2009-2015. This irregular evolution could be explained by the role of public expenditure as an instrument to counteract the effects of the economic situation.

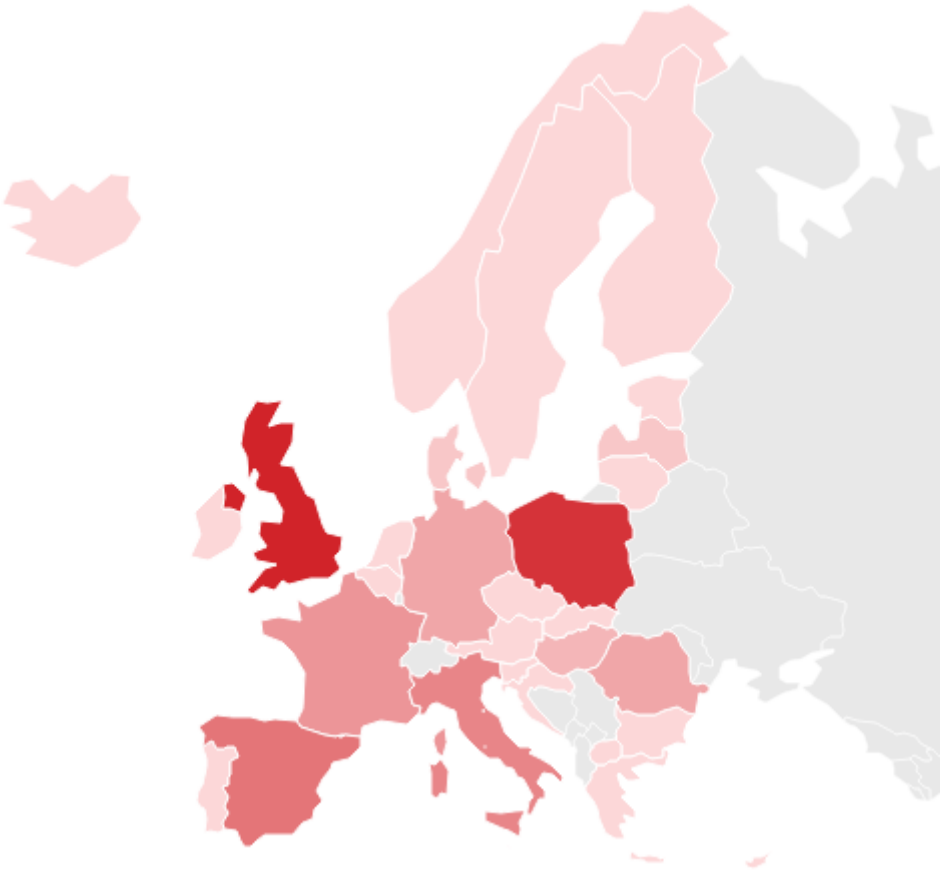

Figure 15: Total purchase of Maintenance of Public Spaces by Country ([1]) 2009- 2015

Note: ([1]) Red darkness is determined by Contract Awards Notices values for every country (2009-2015).
Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

6.2 Market structure

Urban public spaces are mostly provided by the public sector. This is because such spaces are among the public goods and services, which are not normally produced by the private sector as they do not provide any tangible rewards to a private investor. When the private agencies invest in the public spaces of their urban development schemes, their tendency is to limit access so that these spaces can be controlled, so that use and maintenance costs can be limited. By contrast, the provision and maintenance of public spaces is part of the delivery of public services, which in turn is one of the central ways with which social challenges can be addressed. Furthermore, it is part of the quality of the urban environment, which is a social asset for all. In particular, the quality of urban environment in deprived neighborhoods has been one of the priorities set by the Leipzig Charter on Sustainable European Cities agreed by the Member States Ministers responsible for urban development. Thus, other European strategies and policy documents consider the quality and maintenance of public spaces as a necessary ingredient of sustainable development and social cohesion.

To understand the structure of the maintenance of public spaces market, it is necessary to interpret first the different forms of public space management that have emerged recently across Europe, notably at the local authority level, and their significance for such spaces and their governance. The episodes of successful innovation that have been found in the academic research point towards an emerging public space agenda with top-down but also bottom-up influences, which seem to suggest a potential way forward in bringing public space management forward as a more coherent and effective area of government activity.

Based on the research carried out by Claudio de Magalhaes and Matthew Carmona[60] on public space management in 290 local authorities in England, public space management occurs in different structures in different local authorities demonstrating the confusion that the concept of public space creates in local authorities, and the fragmented management structure that result. This diagnosis made by the two academics from the Bartlett School of Planning on the structural management of public spaces in England could be transferred, taking into account the specific characteristics of each country, to the European context. Very few local authorities possess departments dedicated to public space management in a holistic way. Most typically, public spaces are either managed within a much larger unit taking in many non-public space functions as well, or in much smaller units that break public space and its management down into separate public space types and management functions.

Historically, green public spaces have tended to be treated as a single entity, but streets and other hard urban public spaces have lacked an integrated approach. Therefore, most local authorities continue to have separate lines of responsibility for the management of open spaces and the street scene. Having a single supra-department responsible for public space would help to the co-ordination, but could also act like three or four separate departments if divisions within the larger unit do not coordinate their activities.

In addition, regarding the local authorities involved in the maintenance of public sector, De Magalhaes and Carmona found in their research for 290 local authorities in England, that the community and the private sector were taking a more active role in the case study areas, as local authorities attempted to harness the expertise and knowledge of key stakeholder groups. This trend is also transferable to the European context. They also found that authorities identified a number of major process problems relating to the maintenance of public spaces. Perhaps the most fundamental was the insufficient level of investment in maintenance: because this activity has historically not been recognized as important by council members. This is one of the most pressing problems faced by public authorities in the management of public spaces. Besides, an associated squeeze on local authority finances, as consequence of the recent crisis, have driven costs, and therefore service levels, right down.

Within the maintenance of public spaces market another pressing problem lies in procurement practices and the relationship between client and contractor functions within local authorities, and between the authority and external contractors. The practice of tendering out services led sometimes to a lack of ownership of maintenance process, as there might be several layers of management, and reduced responsiveness due to long lines of communication between council management and those actually doing the work. Local authority officers also highlighted barriers to the coordination of maintenance routines and standards in areas where two-tier local government regimes are in place, and between local government and other organizations. To avoid this, some local authorities try to coordinate maintenance between itself and its district authorities by promoting the use of shared contracts.

A final set of problems relate to conflicts between the maintenance of public spaces and its management objectives, for example street cleaning versus tree planting, and short-

[60] Carmona, M. & De Magalhaes, C. 2006.

term development costs versus long-term maintenance concerns. These challenges are regarded as structural, and are not amenable to easy solutions.

Structural barriers impacting on maintenance of public spaces market:

- An insufficient level of investment in maintenance.
- Problematic relationships between client and contractor functions, reinforced by Compulsory Competitive Tendering (CCT) practices.
- A lack of coordination of maintenance routines and standards between agencies (internal and external to the local authority).
- A mismatch between community expectations in terms of standards and what can be accommodated within the local authority's budget.
- Design conflicts and lack of concern with maintenance during design.
- Intensive use of certain spaces leading to conflict between maintenance routines and some users/uses.

6.2.1 Public spaces maintenance market: supply side

The most reliable information source in relation to the maintenance of public spaces market is provided by corporate entities and professional institutions. These institutions (mostly private companies) give us the opportunity to explore the public space maintenance market from the supply side.
Furthermore, as the maintenance of public spaces sector is very broad, it is difficult to explain the operation of such a heterogeneous market. In order to simplify our approach to the maintenance of public spaces sector, we will focus on the supply side of the urban furniture elements employed in public spaces. This will include the following elements of macro and micro public spaces: public services, garden services, lighting, signage or wayfinding and cleaning machinery that contribute to the ordinary functioning of a city. To analyze the provision of these services within the public spaces maintenance market, we have focused on the main qualitative aspects of supply, as well as on the operation of the tender process by the main customer at European level, Public Administration.

There are many differences between each European public spaces maintenance market. However, there is a common typology that serves to explain every country market. Within each marketplace exists a large number of local small and medium-sized enterprises and a smaller number of large international companies with a large share of the European market[61]. Taking Italy as an example, the production share of the first four operators within the urban furniture market is 30.2%, while the top eight operators in the market account for 45% of the market. Many companies in this sector follow different market strategies such as diversifying or specializing in some of the subsectors of maintenance of public spaces or urban furniture. In this way, few companies are specialized in a unique segment and are in a position to propose a wide and coordinated offer, which generates a high level of competition.

Most small and medium-sized enterprises work primarily at the local and regional level, and competition is based on price, breadth of product and product innovation policies; all of these features are mandatory taking into account the current competitive environment. Lastly, the added advantage that companies can provide is the possibility of offering a pre and post-sale service, with a pre-sale and post-sale service. In order to adapt and customize the product or service according to the needs of the customer, usually the maintenance service providers work together with the public administration to adapt the needs to the offer.

The evolution of the maintenance sector does not depend to a great extent on the economic situation of every European country. On the contrary, it seems to be characterized by some independence because these are recurrent expenses. However,

[61] Amec-Urbis (http://www.amec.es/comunicacion/publicaciones/)

and due to the heterogeneity and extent of the sector, certain services such as the replacement of urban furniture, machinery or vehicles included within the maintenance of public spaces, could depend, such as investment products, on the economic situation of the country and the budget forecast of the public administration. Through the procurement process, the public administration imposes on the tender participants the specific requirements and technical characteristics of the materials to be used through the specifications. The latter acts as an internal barrier to foreign companies that avoids the free participation of companies at European level.

Besides, access to public tenders by foreign companies on the maintenance of public spaces market is not easy. Thus, it is essential in most European countries to have offices in the country where the subject of the public contract takes place. On the other hand, it is necessary to find out how the operation of the general administration works in every country with the aim of knowing the main responsible for the largest number of purchases of maintenance of public spaces services.

6.2.1.1 European cities public management on maintenance of public spaces

To explain the market structure of the maintenance of public spaces sector, it is required to focus on the organizational structure of public spaces, and its planning and management features. Most public space management departments in Europe have undergone large organizational changes in the past two or three decades in the framework of New Public Management (NPM). The main idea of NPM is that public organizations become more like companies and become more focused on outputs and customer service. A second NPM idea is that the role of public organizations should become smaller and that more tasks should be taken over by private companies. These changes have often resulted in separation of public space maintenance from public space management. A Nordic study by Randrup and Persson[62] showed that a public space management organization typically is responsible for the descriptions of the maintenance tasks, and controlling the results. The actual maintenance tasks have been usually outsourced to private contractors, or they are purchased from an in-house maintenance provider. Public space management organizations are often part of a larger technical or leisure department in the municipalities, up to two organizational levels removed from the political system.
According to the studio of Randrup and Persson, the maintenance of public spaces within the Nordic countries is clearly the most important task for the average municipal space management organization. They spend the majority (70-85%) of their resources (time and money) on maintenance tasks. However, many Nordic cities have experienced budget cuts in the past five years. Budgets for public space management are determined by municipal politicians, and the strong maintenance focus seems to have led to a relatively low interest from politicians in urban public spaces.

6.2.1.1.1 Urban Green Space Policies: Performance and Conditions in European Cities

Based on the information contained on another study carried out by the researchers Tüzin Baycan Levent and Peter Nijkamp[63] we can explore the annual public expenditure on green spaces related to the total budget of the city in 23 European cities. This study emerged with the aim of comparing and evaluating the current management practices in European Cities on the basis of the performance of urban green space policies. The data and information that they have used for comparison and evaluation are based on extensive survey questionnaires filled out by relevant departments or experts of municipalities in European cities that aim to share their experience in innovative green space policies and strategies.
According to the information collected on these surveys questionnaires, they developed a comprehensive framework where seven explanatory variables based on management and planning of urban green spaces were described to identify the green performance of cities from proper evaluation perspectives. Between these seven variables there are two

[62] Randrup, T.B. & Persson, B. 2009.
[63] Baycan-Levent, T & Nijkamp, P. 2009.

relevant for our market study, Annual budget for urban green spaces related to the total budget of the city (%) and changes in the budget for greenery in the last 2 years. This data was obtained directly from the representatives of municipalities by questionnaires. The changes are defined as an increase, a decrease or no change in the budget for greenery in the years 2002 and 2003.
According to Table 5, the proportion of the local budget allocated to the urban green spaces is very low, representing in most cases only 1% of the budget. Only the case of Alphen aan den Rijn stands out for devoting 34% of its total budget to the urban green spaces. However, there are many cities where the budget for greenery has increased from the previous year. This could mean an increasing trend on the budget allocated to the public space maintenance.

Table 5: Annual Budget for Urban Green Spaces in 23 European Cities.

Annual Budget for Urban Green Spaces in European Cities					
Cities	Country	Population	Availability of green spaces	Budget for green spaces	
			Proportion of green areas per 1000 inhabitant (m2)	Annual budget for urban green spaces related to the total budget of the city (%)	Changes in the budget for greenery in the last 2 years ([1])
Alphen aan den Rijn	NL	10.5579	57.153	34	1
Antwerp	BE	455.148	51.509	1,59	2
Berlin	DE	3.388.477	37.846	0,7	2
Bern	CH	127.519	30.510	-	2
Birmingham	UK	994.300	20.000	1,14	2
Budapest	HU	1.701.000	61.800	1	1
Cracovia	PL	757.430	65.455	-	1
Dublin	IE	1.144.800	40.000	3	1
Edinburgh	UK	453.700	144.592	-	2
Espoo	FI	227.472	140.000	1,3	1
Genoa	IT	601.338	49.394	1	3
Helsinki	FI	980.412	102.867	-	2
Leipzig	DE	497.531	93.652	1,27	2
Ljubljana	SI	267.563	25.971	-	1
Lodz	PL	774.004	65.600	0,5	1
Malaga	ES	547.731	7.790	1	1
Marseilles	FR	852.396	118.225	1	1
Montpellier	FR	257.092	33.000	4	1
Salzburg	AT	145.680	13.440	1,3	2
Turin	IT	867.857	19.444	1	3
Vienna	AT	1.598.626	125.441	1	3
Warsaw	PL	1.692.854	68.499	0,79	1
Zurich	CH	364.528	111.919	0,01-0,03	1

Note: ([1]) Changes in the budget for greenery in the last 2 years: (1) increase; (2) decrease; (3) no change.
Source: Baycan-Levent, T & Nijkamp, P. 2009.

6.2.1.1.2 Barcelona City Council

Furthermore, the data provided by the Barcelona City Council on maintenance and improving of public spaces is extremely relevant in understanding the structure of public expenditure in a European large city. According to the new transparency policy established, disaggregated data on the local budget must be published annually. In light of the data published on the open data portal of the Barcelona City Council, the volume of public expenditure dedicated to the maintenance and improving of public spaces

reached 15 million euros in the year 2016. As shown in Figure 17 the evolution of public expenditure on maintenance of public spaces vary widely between different years. While in 2015 the public space maintenance expenditure in the city of Barcelona was almost 50 million euros, for the year 2013 this expenditure was less than 10 million euros. The evolution of public expenditure in the city of Barcelona shows the absence of periodicity in the purchase of public spaces maintenance services. This absence of regularity suggests several key ideas on the structure and the specific characteristics of the maintenance of public spaces sector:

- Public procurement according to specific maintenance needs
- Absence of planning in the contracting of maintenance of public spaces services
- Improper use of the maintenance of public spaces sector with electoral purposes
- Counter cyclical economic role
- Public spaces maintenance services purchase based on the public financial situation

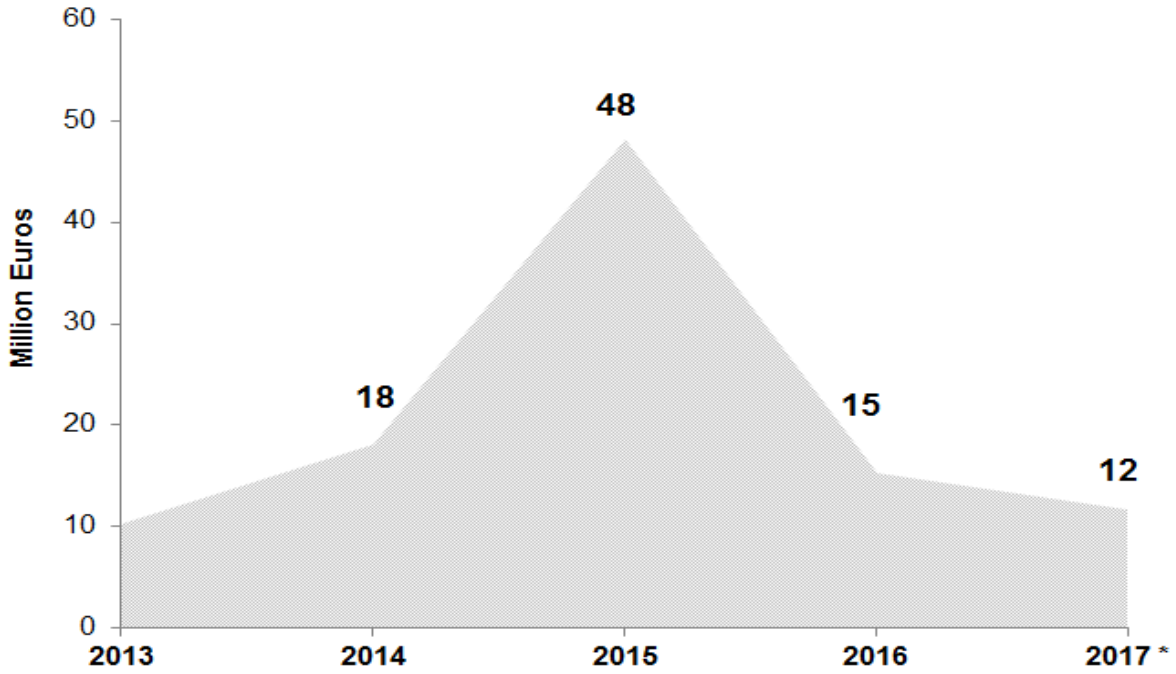

Figure 16: Expenditure on maintenance and improving of public spaces in Barcelona

Note: The 2007 data reflects the budgeted amount.
Source: Barcelona City Council, 2017;
http://ajuntament.barcelona.cat/estrategiaifinances/pressupostobert/en/programas/1534/public-space#view=functional.

According to the data published on the open data portal of the Barcelona City Council, the highest proportion of maintenance costs of public spaces is dedicated to other property investments, followed immediately by the current expenditure on goods and services. The category other property investments is comprised of three subcategories: New investment in infrastructures and assets for general use, Replacements investments for infrastructures and assets for general use and Replacement investments for operational running of public services. Moreover, the category current expenditure on goods and services include three subcategories: Materials, supplies and other; Maintenance, repairs and conservation and finally Compensation for services. The table shows the evolution of every category for the period 2013-2017.

Table 6: Maintenance of public spaces expenditure, Barcelona City Council.

	2013	2014	2015	2016	2017 *
Other property investments	**9.163.773**	**16.316.705**	**45.533.076**	**13.130.353**	**8.775.935**
New investment in infrastructures and assets for general use	6.546.119	-	30.991.733	5.301.054	-
Replacement investments for infrastructures and assets for general use	2.617.654	16.316.705	14.336.024	7.807.878	8.775.935
Replacement investments for operational running of public services	-	-	205.319	21.421	-
Current expenditure on goods and services	**787.986**	**1.581.078**	**2.281.509**	**2.030.132**	**2.727.109**
Materials, supplies and other	782.341	1.559.423	2.281.509	1.892.213	2.704.779
Maintenance, repairs and conservation	-	12.499	-	137.919	22.330
Compensation for services	5.645	9.157	-	-	-
Staff expenses	**145.978**	**135.459**	**156.446**	**96.159**	**37.785**
Government bodies and executive staff	61.763	61.934	63.858	18.210	-
Civil servants	29.791	22.981	30.796	22.979	-
Social-security contributions, benefits and expenses paid for by the employer	28.584	26.328	30.704	19.347	8.919
Workers	22.268	20.249	26.977	31.125	26.940
Performance incentives	3.571	3.967	4.110	4.499	1.925
Current transfers	**-**	**7.644**	**114.546**	**11.505**	**33.104**

Note: The 2007 data reflects the budgeted amount.
Source: Barcelona City Council, 2017; http://ajuntament.barcelona.cat/estrategiaifinances/pressupostobert/en/programas/1534/public-space#view=functional.

The average weight of the category current expenditure on goods and services within the maintenance of public spaces of Barcelona was 12% for the study period. The staff expenses and current transfers market share is almost negligible related to the category other property investments. By contrast, the average volume of other property investments during the study period is 18 million euro. As has happened on the European global market overview accomplished on the section 2.1.1, the remarkable ups and downs registered for the categories other property investments and current expenditure on goods and services between different years for the period 2013-2017 reinforce the perception that these expenditures obey to specific maintenance needs.

Thus, the evolution of public spaces maintenance activities for the city of Barcelona showed an irregular behavior for the period 2013-2017. The average volume of public space maintenance expenditure is 20 million euros.

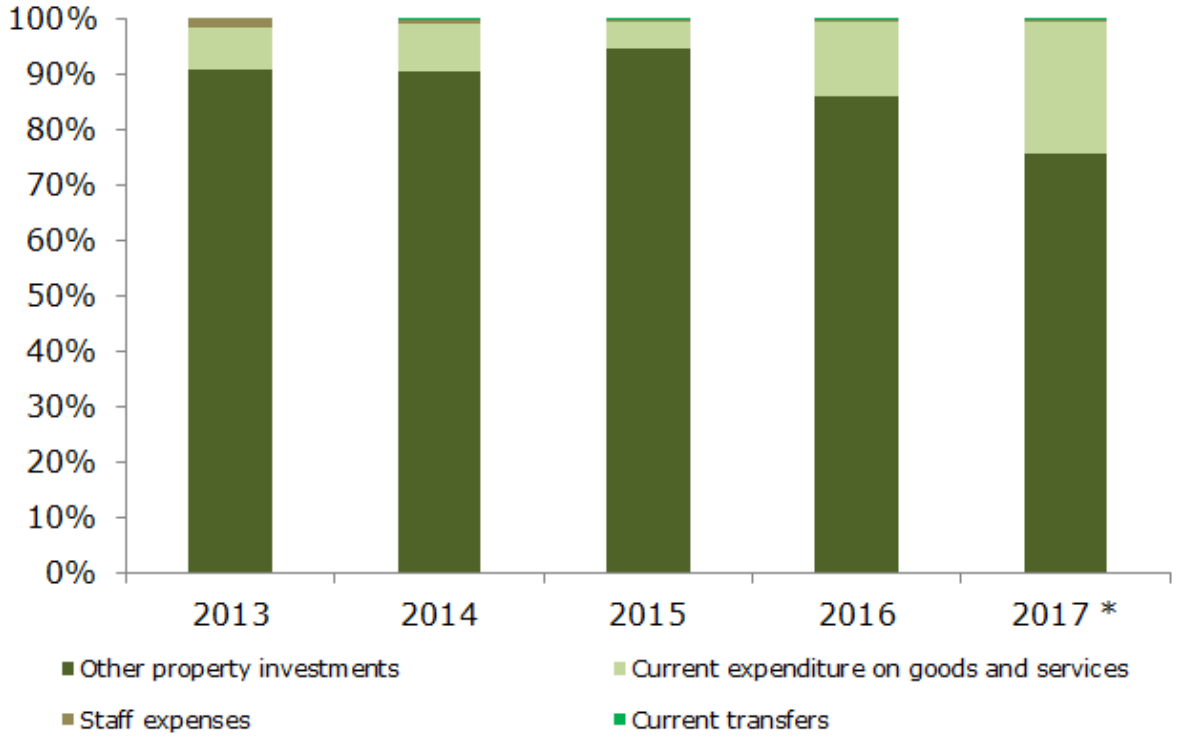

Figure 17: Evolution of the maintenance and improving of public spaces in Barcelona

Note: The 2007 data reflects the budgeted amount.

Source: Barcelona City Council, 2017; http://ajuntament.barcelona.cat/estrategiaifinances/pressupostobert/en/programas/1534/public-space#view=functional.

Figure 19 shows how expenditure on maintenance of public spaces evolved in a disaggregated way according to the data collected by the Barcelona City Council. The most important expenditure items in quantitative terms are new investment in infrastructures and assets for general use and the replacement investment for infrastructures and assets for general use.

Although market share of current expenditure on goods and services is smaller than the expenditure allocated on Other property investments, the latter years have increasingly been drawn to expenditure on goods and services because of the material and supplies acquisition. In 2017, 23% of the budgeted expenditure on maintenance of public services corresponds to the acquisition of materials, supplies and other. Only 1% of the market share is assigned to the staff expenses. The item new investment in infrastructures and assets for general use included within the category other property investments keeps a big share of the market. By contrast, the items replacement investments for operational running of public services and maintenance, repairs and conservation; do not reach a significant share of the total expenditure on the Barcelona public space maintenance.

During this entire period the total expenditure on new investment in infrastructures and assets for general use was 42 million euros. This volume of expenditure contrasts sharply with that recorded for the same period on the item maintenance, repairs and conservation (only 172.000 euros for the whole period). Probably due to the election year, 2015 shows a significant rebound in spending on all items, highlighting above the others the investment for infrastructure and assets for general use.

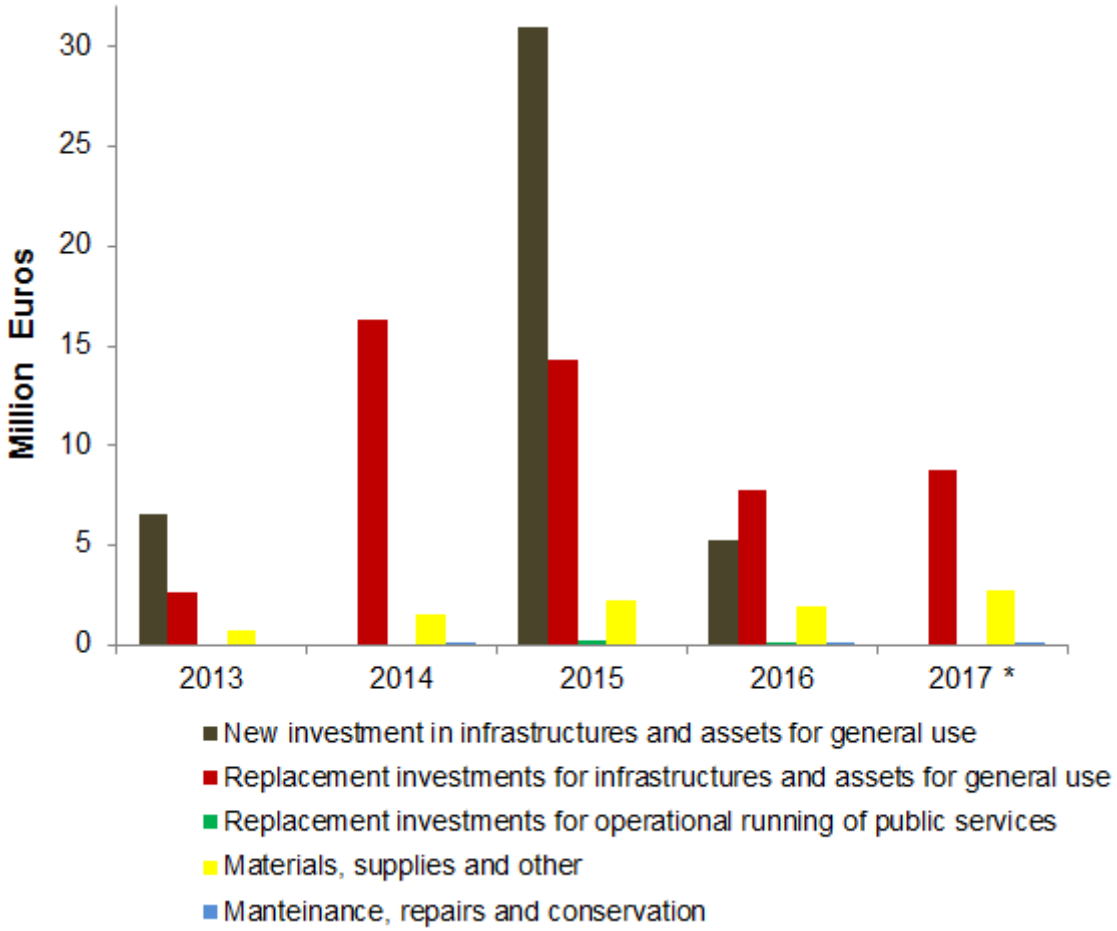

Figure 18: Disaggregated evolution of the maintenance of public spaces in Barcelona

Note: The 2007 data reflects the budgeted amount.
Source: Barcelona City Council, 2017; http://ajuntament.barcelona.cat/estrategiaifinances/pressupostobert/en/programas/1534/public-space#view=functional.

6.2.2 Market segmentation by type of maintenance of public spaces

The maintenance of public spaces sector is very diverse and rich in typology of companies, business segments and local roots degrees. The heterogeneity hinders integration. The common element for the majority of European countries is the final customer: the municipalities, which have as well as client / beneficiary of their services as the citizens.
Regarding the public spaces maintenance sector there are two types of companies:

- Companies 100% focused on cities (less common)
- Companies that sell products and services for the maintenance of public spaces within the cities, among a portfolio of different products and services.

Another characteristic of the sector is the coexistence and constant interaction between private and public actors. Most companies are small and medium-sized companies, which is a limiting factor for certain projects. The role of the stakeholders is essential (architects, consultants, public officials, etc) to define the equipment, products and services that will be included in the projects. Within this sector there is also a coexistence of public and private clients. This heterogeneity has a big influence on the level of exigency: terms, specifications, technical requirements and others. The public space maintenance sector is increasingly becoming an international sector.

As previously stated, one critical characteristic of the sector is the different role which plays the public administrations throughout the European context. Thus, the private market is totally linked to the evolution of construction and major projects: shopping centers, real estate developments with public spaces, public housing promotions, etc. Furthermore, the added value of the sector integrators is becoming less relevant due to the price pressures on the final customers in public tenders. The trend drivers lead to a demand focused service and production instead of being focused only on the product. The sector evolves from the four Ps (price, promotion, product and point of sale) to the two Ss (solution and service).
Taking into account the most relevant sector characteristics and according to the scope of the study, we have segmented the market according to the following items:

- **Activities**, related with Public Space Maintenance, organized around two main categories, which in turn include specific subservices, namely:
  - Cleaning services (Street-cleaning services, sweeping services, gully cleaning and emptying services, deleading services, etc.)
  - Gardening & landscaping (Tree pruning, hedge trimming, parks maintenance services, weed-clearance services, grassing services or landscaping works)

- **Equipment Items**, needed to accomplish maintenance activities, which in turn include specific subcategories, namely:
  - Vehicles (Gully emptiers, salt spreaders, road-sweeping vehicles, sprinkler vehicles)
  - Machinery (Harrows, scarifiers, cultivators, weeders, seeders, planters, lawn or sports-ground rollers, miscellaneous gardening equipment, cleaning machinery)

6.2.3 Maintenance of public spaces services supply chain

The activity of public spaces maintenance comprises a big business volume today. This business sector has a myriad of components across several European countries. Among them are, as main stakeholders, the government (national or regional authorities) and local authorities; a few main contractors (big companies specialized in gardening, urban furniture replacement, street cleaning and other maintenance activities), and a host of smaller contractors which are often linked to the larger contractors in supply chain relationships.

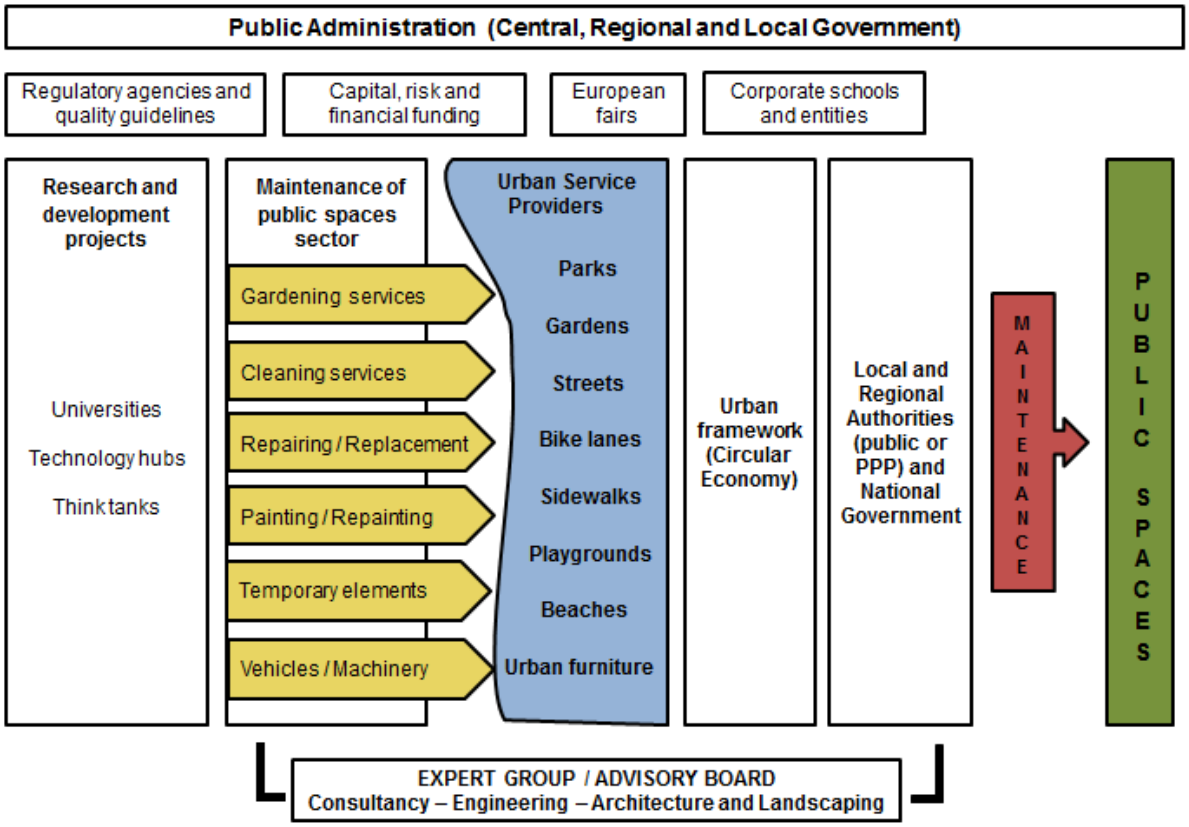

Figure 19: Maintenance of public spaces supply chain

Source: Own elaboration based on the cluster research carried out by AMEC-URBIS.

Along with the government, the local authorities, the main transnational contractors and a few hosts of smaller contractors, there are research and academic institutions developing a parallel task on designing the future trends and guidelines on the maintenance of public spaces. This role is performed by universities, think tanks and technology hubs. Furthermore, within the maintenance of public spaces sector the regulatory agencies and quality guidelines established by the public authorities at several levels play a key role on the definition of the technical and performing characteristics of the maintenance products and services. Another relevant feature to explain the context of the maintenance of public spaces sector is the availability of financial funding. This feature will determine the design and performance of the maintenance services as well as introduce constraints on the public spaces maintenance municipal management. Due to these financial constraints, usually across Europe the public authorities cannot set up a periodicity on the maintenance of public spaces procurement. This lack of regularity could show the degree of importance of this sector among the different public services.
One of the main agents operating in this market are specialized commercial fairs on public spaces maintenance. Across Europe several specialized fairs on this topic exist. Some examples of European fairs specialized on this topic are: Indumation (Kortrijk, Belgium), Intertraffic (Amsterdam, Netherlands), specialized in the sector of infrastructures and management of traffic, road safety and parking; and Astrad & AustroKommunal (Wels, Austria), specialized in the sector of the equipment for the municipal maintenance and road.

6.3 Future trends in maintenance of public spaces

At a time of shrinking budgets due to the latter financial crisis and with the threat of climate change, city authorities and other organizations are challenged with engaging the quality of public spaces and its environmentally friendly maintenance production.

Occasional investment decisions will require professional and integral maintenance and management using data increasingly more often. Local authorities are facing a complex task in the years ahead. Cut-backs, mergers and a new way of working with people and business are all making transparency become more and more important. The translation of management ambitions and budgets into the practical management of public spaces demands an integrated approach, across all sectors, with a focus on the entire life cycle and in collaboration with people and business.
On the other hand, the acquisition of new tools for the daily management of public spaces will be needed to improve the environmental efficiency of its daily maintenance. Therefore, implementing technological systems to transform every European city into a greener city will be necessary to compete in the global knowledge-based economy. With the aim of increasing the quality of public spaces and their inhabitants, the information and communication technologies should be applied while providing environmentally friendly public spaces maintenance. Through implementing information and communication technologies into maintenance of public spaces services, cities turn into being more intelligent in their management of resources. To achieve this, the transformation of urban spaces management should lay on three pillars: ubiquitous infrastructures, information and human capital.
In terms of ubiquitous infrastructures, every European city needs to be equipped with advanced infrastructures to evolve the Smart City concept from pure theory to reality, providing citizens and enterprises with a powerful platform to connect public spaces and let them interact effortlessly with each other and with their administration through electronic means. Stable sturdy infrastructures, from optical fiber networks covering the city act as a backbone to the installation of sensors, are the key for the development of intelligent solutions in the maintenance of public spaces.
In terms of information, it is the raw material to fuel innovation factories. Information coming from daily activity in the public spaces is an invaluable asset that needs to be collected and interpreted, creating an accurate public spaces information database that acts as the source to deliver smart-tailored maintenance services and better public space management. Several sources have been identified as those that follow the most important ones to construct the concept of smart public spaces. There are two main information sources: (1) information coming from the public space furniture or other city elements that involves sensors and Open Data (public sector information) and (2) information coming from the citizens as digital footprint, social media and crowdsourcing.
Regarding the first information source, some companies are developing digital furniture to integrate technology within street furniture and objects with the goal of creating smart and connected public spaces. For example, the Paris based French company, SmartUp Cities, is building smart recycling bins able to monitor the quantity of each waste fraction collected and then report it securely in a system through Blockchain technology. In addition, they build public smart benches equipped with solar powered Wi-Fi; smart planters able to monitor the flowers´ soil and start watering when needed and much more.
As a way to improve the maintenance of public spaces management they have introduced the following services:

- Smart Waste Containers & Recycling Bins

Smart Waste Containers equipped with Ultrasonic Fill-Level Sensors for Optimized Waste Management and Logistics. Their smart waste containers are equipped with internet connected ultrasonic sensors able to "feel" and report the level of waste in each bin. Knowing the exact level of waste from each container, the truck drivers can choose which containers must be picked and which not thus decreasing the use of fuel and service hours by up to 50% per day. Based on the data received from the waste containers sensors, the local authorities could create smart collecting routes, selecting the containers for the most efficient and optimized routes.

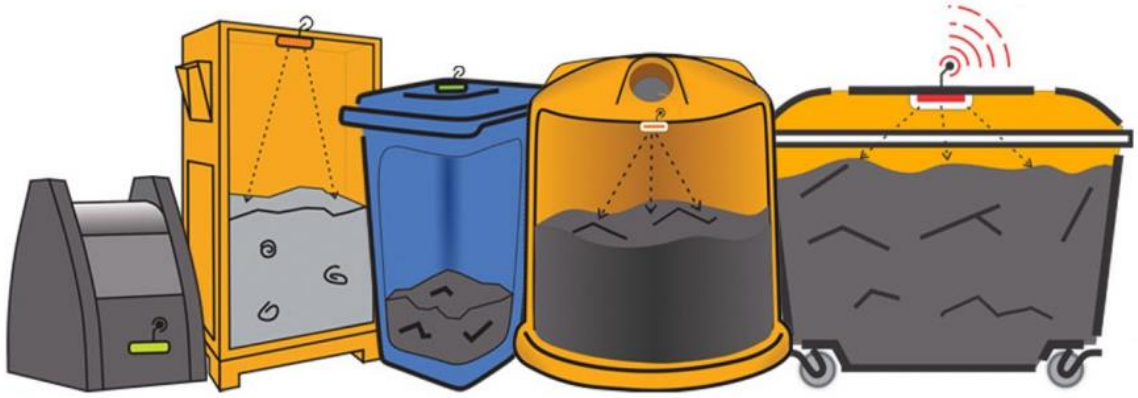

Figure 20: Smart Waste Containers & Recycling Bins

Source: SmartUp Cities webpage, http://www.smartupcities.com/smart-waste-containers/

• On-street Parking Sensors & Guidance Systems

Intelligent On-street & Off-street Smart Parking Sensors and Parking Guidance Systems providing real-time information on parking space occupancy, guiding drivers quickly and efficiently to the nearest available parking space in the area. Thus, every parking space is equipped with a smart sensor capable of detecting its occupancy status.

Figure 21: On-street Parking Sensors

Source: SmartUp Cities webpage http://www.smartupcities.com/smart-city-parking-sensors-guidance-systems/

The parking sensors can analyze the number of parking rotations thus able to create comprehensive reports and predictions about the parking needs of the area.

In addition, relating to the smart urban furniture within green public spaces, in February 2017 the City of London Corporation has launched an ideas competition to explore how smart technologies might enhance its green spaces.

On the other hand, it is urgent to employ the information coming from the citizens as the digital footprint, social media and crowdsourcing; as a tool to transform the public management of public spaces to a more efficient way. The public authorities should lead the digital transformation on cities, enabling the introduction of new technologies into the local public management. Finally, in terms of human capital, actors actively participating in the daily activity of the city are the ones that potentially could make a city smarter. The implementation of the Smart City is not only a concern of public administration but it

should also involve the population, innovation centers, companies and entrepreneurs. Faculties and society are knowledge producers, while companies and entrepreneurs generate new business opportunities.

6.3.1 In-house vs. outsourced services

Contracting out, where private companies, through law-regulated procedures for procurement, are delegated temporary responsibilities for providing various services in the public sector can be regarded as an innovation in the public sector on the same level as other recent reform elements such as performance management or user choice. Successful public sector innovations include phases of developing, testing, utilization and dissemination of new ideas within an organization or organizational field. Seen in the light of the increasing use of public procurement and contracting out in the Nordic municipalities since the beginning of the 1990s, it can be argued that public procurement and contracting out have been relatively successful innovations. However, ongoing political declarations, objectives and agreements regarding increased usage of contracting out on the municipal level continue to spur explorations of the innovative potential of contracting out.

Historically, contracting out has contributed to organizational change and development with respect to the opportunities offered by a 'standard' – or 'conventional' – approach characterized by standardization of services, a strategic focus on cost minimizing, arm-length managerial relations and the use of competitive markets. Today, it is also possible to ask whether and how a number of new ideas, approaches and forms for organizing contracting out can create new changes and directions for the development and reform of the public sector. In an organizational perspective, the differences in approach can be framed as a difference between 'competitive' strategies and 'cooperative' strategies to engagement in and utilization of inter-organizational relations.

Academic studies which measure cost change at the level of individual contracts all find that cost savings has been a result when services are contracted out. In addition, studies which measure cost change at the level of overall budget/spending levels and provide analysis based on statistical analysis of quantitative data do not find any relationship between contracting levels and spending levels. In sum, an academic review finds supportive evidence for an assumption that contracting out in contrasts to in-house provision reduces operational costs for maintenance services. However, no evidence is found in support for the assumption that contracting out should also reduce overall spending levels within the overall service delivery systems. The evidence furthermore suggests that technical efficiency is improved while some long-term problems with allocative efficiency may arise. The evidence also indicates that substantial changes are involved for management, organization and staff. In particular the number of operational staff are reduced, some aspects of management is improved (e.g. 'effectiveness') while new organizational principles are introduced (e.g. 'strategic centralization' and 'operational decentralization').

The findings need to be generalized only with careful reservations. Findings may, for example, be a result equally from contextual particularities or methodological limitations (e.g. confounding factors or 'lurky' variables). Contextual particularities may include policy context, market structure or administrative structure.

6.3.2 Possible impacts on costs and environment by outsourcing

Cost and environment effects from the use of public procurement when public spaces maintenance services are contracted out vary greatly. In Denmark, the INOPS[64] study showed that almost one-half of all municipalities (45%) have gained a reduction in operational cost the last time they procured a park or road maintenance service. The variation was found both between municipalities within an individual country and between the Nordic countries. The average cost change was found to be a cost reduction around 5.5 % (un-weighted mean) for public spaces combined. By contrast, and

[64] Lindholst, A. C. (2017)

according to the INOPS study, in Sweden, the average cost change was found to be a cost reduction around 2.7% (un-weighted mean) for public spaces. 33% of Swedish municipalities experienced a cost decrease. In Norway, the average cost change was found to be a cost increase around 10.3% while only 12% of the municipalities experienced a cost decrease. For the UK, it was found that 77% of all municipalities experienced a cost decrease last time they publicly procured a public space maintenance service. In Denmark, higher levels of cost reduction in operational costs were found in particular to be related to the first or second time (compared to the third time or more) maintenance services were contracted out, an emphasis on a 'low cost contracting strategy', as well as more well-developed contractual framework (transactional dimension). Also, a larger economic size of private sector involvement was indicated to be related with higher levels of cost reductions.
In Sweden, higher levels of cost reductions were found to be related to higher levels of competition as well as a geographical location in the Southern and Eastern parts of Sweden (compared to the Northern parts of Sweden). In Norway, less detrimental cost effects (in terms relatively lower degrees of cost increases) were found to be related to higher levels of competition established by continued use of public procurement. In other words, municipalities which had used public procurements a greater number of times in the past had 'generated' higher levels of competition. According to this study, in the UK, a higher chance of cost reduction in operational costs were found to be related to the lowering of quality standards (but not with a negative influence on managers' satisfaction with provided quality levels) as well as a greater emphasis on a 'low cost contracting strategy'.
Several contextual characteristics of importance were highlighted on another study about contracting out of public space maintenance in Denmark, Sweden, Norway and the United Kingdom[65]; when differences in cost effects were compared across countries. Denmark was found to be characterized by a relatively competitive and 'matured' context for contracting out (evenly distributed across the country). Sweden was found to be characterized by a longer tradition for contracting out and well-developed markets within certain regions while Norway was found to be characterized by generally less well developed markets. In comparison, local authorities in the UK, Danish municipalities, and Swedish municipalities to some extent, have been able to tap directly into already established markets when they procured the last time. In contrast, Norwegian municipalities have been challenged by using public procurement in poorly functioning markets.
Across the four country contexts it was found that a 'low cost contracting strategy' in general has worked out well, i.e. produced cost savings, for municipalities in Denmark and the UK, but not for municipalities in Norway and Sweden. Competition, and in particular a lack of competition, was also found to be important for cost effects.
In terms of environmental benefits, the practice of contracting out public space maintenance services can differ in some extent between municipalities as well as across European countries. The high level of competition between the private companies could lead to avoid environmental concerns. Thus, in order to provide cheaper solutions, many small and medium enterprises sacrifice environmental considerations. By contrast higher levels of collaborative norms as well as more elaborative contractual frameworks could counteract these negative effects on environment[66]. At an aggregate level, local government procurers have adopted a wide range of initiatives to address environment issues. These are condensed into a typology of environmentally friendly supply chain management for the public sector.

6.3.3 Possible impacts on costs and environment by outsourcing

The last decade saw a renewed policy interest in the quality of public spaces. Public spaces have become urban policy tools with a much wider and pervasive significance. This acceptance of a broader role for public spaces, from the iconic parks and gardens to

[65] INOPS Technical Report
[66] Preuss, L. (2009)

the ordinary streets and squares of urban areas, is related to changes in the nature of our understanding of contemporary policy issues in general, and urban policy issues in particular. More to the point, this broadening of policy concerns to encompass public space and its quality is the result of a number of interrelated processes. Foremost amongst these are a renewed concern with the local physical environment and its impact upon the social and economic well-being of its inhabitants. Public realm is a common tool of global and local inter-city competition and as a potential catalyst of urban regeneration, through a demonstrable relationship between the quality of urban life and urban spaces, and the investment decisions and locational choices of business, employment and the workforce.

The concern with those broader linkages between the quality of public spaces, its sustainability and urban policy objectives has been made more urgent by a pervasive perception that public spaces, of all types, lack quality and environmental concerns. Issues here include public space cleanliness and tidiness; graffiti; the dominance of motorcar and the constraints and limitations this imposes on environment and other public space users; as well as a general feeling of discomfort and lack of safety.

This policy agenda has taken shape in a variety of national policy initiatives that have attempted to address the issues of public space and the quality of its management. These encompass:

- changes in legislation giving local authorities formal responsibility for environmental quality through their new powers to promote sustainability and community well-being
- the creation of a task force to report and advise on green spaces
- a public-funded organization to champion green design and the sustainable management of public spaces
- the adoption of auditing regimes for local authorities' street-related services with rewards offered to those performing well
- the institution of funding programmes to support community-based management of public spaces in deprived areas
- the introduction of business improvement district legislation

Two things of concern underpin and unify most of these initiatives. The first is a gradual shift in emphasis from a concern with initial design and implementation, to more attention to the life-cycle of public spaces, in which long-term management and maintenance are seen as paramount. Second, there is a widening of the definition of urban public spaces to encompass also the ordinary streets and squares that articulate the living spaces of communities and neighbourhoods.

Newcastle Envirocall System

This policy attention to more widely defined public spaces and their management has inevitably led to changes, often quite significant, in the organizational structures and practices through which the management of public spaces takes place. New organizational forms have emerged, responsibilities, power and resources have been redistributed within and beyond government structures and new governing arrangements have been formed.

Despite the decrease in operating costs, the practice of tendering out public spaces maintenance services has led in some cases to a lack of ownership of maintenance process, as there might be several layers of management, and reduced responsiveness due to long lines of communication between council management and those actually doing the work. The Envirocall system in Newcastle is a good example on how to overcome such problems by increasing responsiveness and shortening lines of

communication through one point of contact reporting and 45 different public space services. Local authority officers also highlighted barriers to the coordination of maintenance routines and standards in areas where two-tier local government regimes are in place, and between local government and other organizations. To avoid this, some local authorities try to coordinate maintenance between itself and its district authorities by promoting the use of shared contracts.

Furthermore, another British council, Warwickshire, has pioneered potentially one of the most sophisticated systems, a monitoring system called the 'Streetscape Appearance Index' (SAI). This relies on the council and the local community scoring different elements across different types of public space, with the scores being used to highlight where investment is needed. Complementing the SAI is the 'Streetscape Maintenance Log' which identifies responsibilities for spaces, infrastructure and buildings, and helps to ensure that problems on private land are quickly remedied.

The Danish Agency for Palaces and Properties

The Danish Agency for Palaces and Properties and its section for park management in particular has the responsibility of managing, maintaining, and utilizing some of Denmark's most important historical parks and gardens. While first-class design and planning, combined with adequate finance for capital investment and development, are essential for keeping parks and gardens up to date and capable of meeting the diverse demands of the public, it is through the daily provision of public space maintenance that public service facilities, and horticultural and landscape architectural standards are kept up to standard. The Agency's Head Gardeners have the responsibility for managing provisions of green-space maintenance.

Like other Danish public managers exposed to pro-market policies, the Danish Agency for Palaces and Properties (hereinafter the Agency), contracts out the provision of green-space maintenance. Congruently with the New Public Management (NPM) reforms taken in the country and its implied policy of contracting out in the public sector, the Agency arranged its initial approach to contract public spaces management in a standard framework based on the four tenets of specification, pricing, monitoring, and enforcement of service provisions.

Between 1998 and 2004, the Agency achieved remarkable efficiency gains by contracting out virtually all services related to green-space maintenance and thereby abandoning a longstanding in-house arrangement. In 2004, budgets for public space maintenance stabilized at a level 34% lower than in 1998 (measured in 1999 prices), without any experienced decline in standards of work or quality of services. These figures could be explained both by inefficiencies at the outset and by efficiencies achieved by introducing competition.

Despite efficiency gains, government policies continued to force the Agency to consider how further improvements could be achieved. According to the law of diminishing returns to competition, the prospects for further improvements in efficiency by contracting out were limited because competitive pressures were virtually fully implemented. Therefore, the Agency's attention switched to viable alternative arrangements for well-functioning contract design and management of public space maintenance. Fitting in with the emergent partnership approach for public service provisions, the initial objective of improving efficiency through competition came to be accompanied by an objective for improving services through the efficient management of available expertise and resources.

In 2004, the Agency implemented a performance management (PM) scheme to improve the standard framework for managing public space maintenance contracts. The aim of the PM scheme was to address deficits in the standard framework by developing and aligning contractors' behavior and expertise through explicitly acknowledging and (financially) rewarding good performances related to communication and collaboration,

adaptation of services, and rationalization of service provisions. In this way, the PM scheme extended the framework with aspects enabling gardeners, sweepers or garbage men to implement a more holistic and inclusive approach in contract management.

In the first three years of the PM scheme, it was continuously refined in an internal trial and error process and it became an integrated part of the head gardeners or the sweepers' manager contract management practice. As it became routine, the Agency felt a need to evaluate the scheme more thoroughly. In 2006, the Agency agreed to participate in an action research intervention with the purpose of evaluating and improving the PM scheme in a systematic way and thus extracting knowledge that in turn could help other urban public space managers' attempts to improve public space maintenance contracts.

The paper *"Improving contract design and management for urban green-space maintenance through action research"* from the University of Copenhagen[67] has carried out a comprehensive research on this framework for contract management. Since the Agency embodies a case of well-functioning contract design and management, it provides valuable insight into the intricacies and issues in contract design and management for urban public space maintenance. In particular, the case provides insights into how the standard framework for contract design and management can be improved in a situation where urban public space management relies fully on contracting out for the provision of public space maintenance.

As stated above, the Agency had established a standard framework for contract public spaces management based on the four principles of specification, pricing, monitoring, and enforcement of service provisions. Thus, the Agency's first version of a PM scheme was introduced and implemented in 2004 on the back drop of experiences with the standard framework. The reasons for the introduction were three-fold. Firstly, the Agency sought to target issues in established contract management practice that could impede performance but at the same time were difficult to address through the standard framework. Secondly, the Agency sought to improve the value of service provisions by fine-tuning provisions to local needs. Thirdly, the Agency sought to utilize and encourage the professional expertise of contractors to a greater extent by spurring them to produce inputs to planning and the coordination processes. Contractors were also invited to suggest alternative performance items. Finally, the Agency sought to make contracts more attractive for skilled and dedicated staff in a situation with a shortage of skilled staff within the business. The PM scheme was formally organized around three headings:

- Collaboration and communication.
- Service adaptations.
- Rationalizations (i.e. making cost reductions).

A list of performance items and measurement mechanisms was drawn up for each of the three headings. Each heading was specified with several sub-items measured on a scale using the scores: 10, 5, 0, -5, and -10, where 0 was given for the average performance. Only a positive score for the sum of all sub-items was transformed into monetary rewards. The maximum bonus size in the first PM scheme was limited to 2% of the annual contract sum. In later revisions, the maximum was increased to 5%. The PM scheme was gradually refined, and at the time of the intervention it had been extended to cover the Agency's seven major service contracts for public space maintenance.

With the general concept of performance management, the implementation of the PM scheme turned contract management into an integrated process of setting expectations, measuring and reviewing results, and rewarding performance in order to improve overall performance. The standard framework only allowed this process to take place when contracts were renewed. In a broader public policy context, the Agency broke old patterns by implementing performance management as a mechanism internal to the

[67] Lindholst, A. C. 2008.

contract and not as an external mechanism for contract monitoring and accountability as prescribed by the dominant approaches to performance management in the public sector.

6.4 Limitations of the study

As stated above, there has been a lack of comprehensive data for the maintenance of public spaces sector, especially data that divides public space maintenance between services and products for public or private purpose. Furthermore, data related to import and export on maintenances of public spaces services and productions have also been limited in some aspects. Another issue has been that data available in the different studies is very unclear about what is included and excluded in the scope. There are many studies on urban furniture and even with the raise of the smart cities sector; many reports deepen on the capabilities of the public spaces as a trigger for life quality improvement. However, there are a few less specialized on the maintenance of the public spaces and its management procedures. This has, in some instances, led to a high variance of topics without being able to focus strictly on the maintenance issues and its sustainability features. Furthermore, the information provided by the stakeholders did not help to confirm some findings and values.

Despite the lack of information, there is a comprehensive and disaggregated set of data for each Member State in EU-28 (TED dataset). Those countries with highest spend on public spaces maintenance services have been in focus. Therefore, the results are relevant for the overall findings. Specific noted limitations (which includes data gaps):

- Limited European market data on maintenance of public spaces services has been found; most likely because this is a small subsector within the infrastructure, construction, engineering and environment. It is therefore difficult to find out accurate information on this sector.
- Despite according to European Directives on public procurement, notices for procurement procedures of public authorities must be published in the OJ S. There is much information on procurement opportunities which are not published on TED.
- It was found that public space maintenance is managed within a much larger unit taking included under multiple civic departments. However, it was not possible to specify what kind of maintenance services or products they procure for a range of cities across Europe, except for the case of the Barcelona City Council.
- The estimates of market share between large maintenance services companies and SMEs have been also found as limited.
- There are limited data on best practices for the procurement of Green Public Space Maintenance services. The best practices found are related to the public spaces management according to a life-cycle analysis or with a sustainability focus.

Besides, although the CPV system used on the market analysis was identified as the most reliable, its level of accuracy is not total. In light of an estimate the number of correctly coded tenders is only about 90% of all tenders issued. This means that in roughly 10% of all publishing authorities apply a code that does not describe the nature of a tender correctly. Therefore the accuracy of the data provided is subject to mistakes and misinformation. In addition, another problem due to the use of CPV Codes/System was the lack of the supplier's perspective into the analysis. According to many suppliers, the CPV structure does not represent business sectors – which cause inconsistencies for users.

7 Conclusions and preliminary findings

One of the main findings is the fact that these maintenance services are not contracted periodically. By contrast, the volume and number of cleaning activities and services

contracted by the public authorities in each country vary widely between different years. Two specific cases draw a lot of attention. In 2009, Latvia registered a contracting volume of cleaning services and activities of 117 million euros. During the next five years, total public procurement in Latvia for cleaning services was approximately 8 million euros. However, in the year 2015 Latvia recorded a contracting volume of 135 million euros. This irregular periodicity in public contracts can be explained considering the validity of public contracts, being the responsibility of each country to set up their contract terms.

Regarding the market overview, it should be noted that between 2009 and 2015, the total values of the services and activities included under the scope of the study maintained an irregular pattern, exposed to the ups and downs based on budget constraints. However, the business volume of CANs at European level was never below the 1.500 million euros (Figure 23).

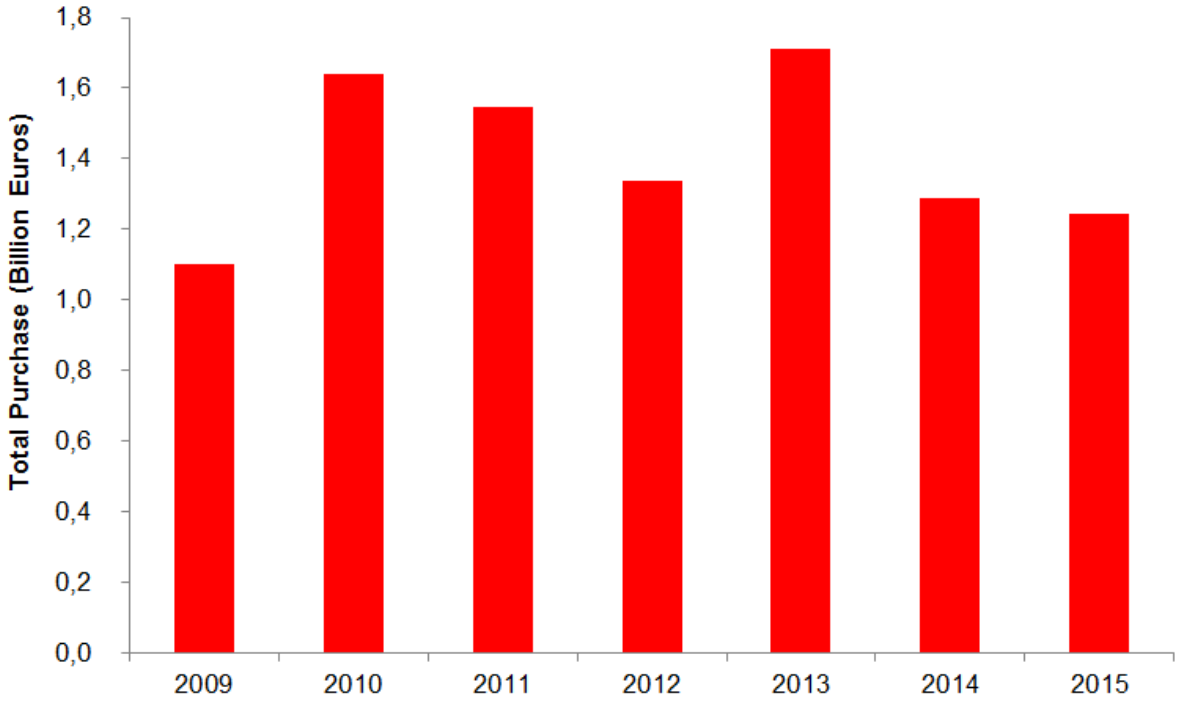

Figure 22: Total purchase of maintenance of public spaces services and activities

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

Furthermore, the evolution of the public expenditure in the European cities shows the absence of periodicity in the purchase of public spaces maintenance services. This absence of regularity at local and national level suggests several key ideas on the structure and the specific characteristics of the maintenance of public spaces sector:

- Public procurement according to specific maintenance based on occasional needs
- Absence of planning in the contracting of maintenance of public spaces services
- Improper use of the maintenance of public spaces sector with electoral purposes
- Counter cyclical economic role
- Public spaces maintenance services purchase based on the public financial situation

Another essential finding is the common typology of European public spaces maintenance between each country. Thus, there is a common typology that serves to explain every country's market. Within each marketplace there are a large number of local small and medium-sized enterprises and a smaller number of large international companies with a large share of the European market. Taking Italy as an example, the production share of the first four operators within the urban furniture market is 30.2%, while the top eight operators in the market account for 45% of the market. Many companies in this sector follow different market strategies such as diversifying or specializing in some of the subsectors of maintenance of public spaces or urban furniture. In this way, few companies are specialized in a unique segment and are able to propose a wide and coordinated offer, which generates a high level of competition.
Most small and medium-sized enterprises work primarily at the local and regional level, and competition is based on price, breadth of product and product innovation policies; these features are mandatory taking into account the current competitive environment. Lastly, the added advantage that companies can provide is the possibility of offering a pre-and post-sale service, with a pre-sale and post-sale service. To adapt and customize the product or service according to the needs of the customer, the maintenance service providers usually work together with the public administration to adapt the needs to the offer.

Besides, the maintenance of public spaces sector is very diverse and rich in typology of companies, business segments and local roots degrees. The heterogeneity hinders integration. The common element for the majority of European countries is the final customer: the municipalities, which have as wells as client / beneficiary of their services the citizens.

Lastly, regarding the contracting out of the public space maintenance services, the academic studies which measure cost change at the level of individual contracts all find that cost savings has been a result when services are contracted out. In addition, the studies which measures cost change at the level of overall budget/spending levels and provide analysis based on statistical analysis of quantitative data do not find any relationship between contracting levels and spending levels. In sum, the academic review finds supportive evidence for an assumption that contracting out in contrasts to in-house provision reduces operational costs for maintenance of public space services.

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Annexes

Annex 1. Public spaces maintenance TED Dataset

Table 7:. Public spaces maintenance, European public contracting volume (2009-2015).

2009-2015	Cleaning	Gardening and landscaping	Repairing and replacement	Temporary elements	Vehicles	Machinery
Austria	12.811.553	56.110.611	2.208.958	1.570.865	73.330.735	0
Belgium	23.916.797	33.448.092	7.125.147	452.196	30.879.367	2.833.511
Bulgaria	34.416.861	16.306.041	3.331.573	930.872	9.982.263	1.585.339
Cyprus	1.854.328	1.382.480	0	0	2.379.284	0
Czech Republic	39.084.214	36.226.819	4.267.098	1.449.690	82.873.701	1.674.481
Germany	447.777.988	90.937.233	12.065.259	73.091.643	131.891.588	30.363.078
Denmark	212.728.885	899.720	21.772.735	793.915	28.025.723	32.986.107
Estonia	82.621.853	16.454.395	1.549.128	640.500	8.823.263	217.497
Spain	605.286.528	627.025.647	51.810.253	1.026.367	38.689.023	4.391.721
Finland	112.321.328	1.859.352	2.560.000	1.624.047	17.232.309	9.941.513
France	338.014.722	159.923.198	264.586.470	24.170.976	91.706.670	34.773.844
Greece	17.874.537	3.746.663	8.215.077	4.832.340	88.101.008	0
Croatia	6.200.527	7.075.145	0	602.552	2.131.914	1.860.674
Hungary	22.061.011	41.191.814	31.184.176	10.985.142	352.903.476	1.555.460
Ireland	4.728.184	650.918	0	1.461.157	4.115.793	0
Iceland	5.380.179	78.528	0	0	892.896	930.344
Italy	515.954.128	282.278.891	40.626.540	5.516.658	288.624.434	4.256.951
Lithuania	23.322.332	8.555.400	3.785.149	580.445	6.784.246	67.887
Luxembourg	1.001.591	262.253	0	219.554	0	578.000
Latvia	259.660.927	283.407	0	0	2.367.403	0
Macedonia	55.020	0	0	0	298.388	0
Malta	759.498	0	0	0	328.253	0
Netherlands	13.906.910	45.643.885	21.963.054	2.475.757	15.758.822	190.000
Norway	35.279.992	9.946.318	12.943.519	1.835.553	10.566.172	1.048.841
Poland	1.999.784.918	146.993.804	53.861.162	13.392.122	77.490.824	2.939.670
Portugal	19.390.869	11.924.280	3.229.300	274.978	21.033.228	5.000.000
Romania	497.039.013	109.810.115	126.320.249	436.161	65.109.742	2.164.475
Sweden	56.948.966	33.859.531	52.296.611		3.117.445	1.831.391
Slovenia	5.838.572	322.943	7.664.322	272.378	4.955.750	2.731.840
Slovakia	16.708.609	15.947.542	18.601.037	1.528.600	84.385.082	0
United Kingdom	404.369.183	798.017.962	570.864.551	445.115.185	292.869.681	102.624.226

Source: TED csv dataset (2009-2015), Tenders Electronic Daily, supplement to the Official Journal of the European Union. DG Internal Market, Industry, Entrepreneurship, and SMEs, European Commission, Brussels. Available at https://open-data.europa.eu/cs/data/dataset/ted-csv. Version 2.1. Accessed on 2017-03-27.

Annex 2. Disaggregated maintenance and improved public spaces expenditure, Barcelona City Council.

The data provided by the Barcelona City Council on maintenance and improving of public spaces is particularly relevant in understanding the structure of public expenditure in a European large city. According to the new transparency policy established, disaggregated data on the local budget and its compliance is published every year. In light of this data, below it the disaggregated expenditure on public spaces maintenance and improving for the city of Barcelona in the year 2014 is presented.

Table 8: Maintenance and improved public spaces, Barcelona City Council (2014).

			2014
Other property investments			16.316.705 €
Replacement investments for infrastructures and assets intended for general use			16.316.705 €
		Public streets Maintenance	2.324.684 €
		Public streets Maintenance	2.255.529 €
		Public streets Maintenance	1.893.496 €
		Public streets Maintenance	1.666.028 €
		City pavement	1.178.318 €
		Public streets Maintenance	1.503.846 €
		Public streets Maintenance	1.408.833 €
		Public streets Maintenance	1.137.950 €
		Public streets Maintenance	1.047.045 €
		Public streets Maintenance	884.048 €
		Public streets Maintenance	870.423 €
		Public streets Maintenance	146.506 €
Current expenditure on goods and services			1.581.078 €
Materials, supplies and other			1.559.423 €
	Works carried out by other companies and professionals		1.281.889 €
		Public roads maintenance	470.675 €
		Other infrastructure maintenance	204.393 €
		Other contracts for municipal services	187.232 €
		Public roads maintenance	71.626 €
		Public roads maintenance	70.203 €
		Public roads maintenance	52.746 €
		Public roads maintenance	64.318 €
		Reporting	5.082 €
		Other contracts for municipal services	4.160 €
		Public roads maintenance	31.397 €
		Other contracts for municipal services	2.760 €
		Technical works	9.281 €
	Miscellaneous		277.533 €
		Services purchase	75.409 €
		Services purchase	87.329 €
		Services purchase	6.806 €
		Services purchase	46.736 €
		Services purchase	0
	Supplies		0
		Other consuming material	0
Maintenance, repairs and conservation			12.499 €
Compensation for services			9.157 €
		Locomotion	9.157 €
Staff expenses			135.459 €
	Government bodies and executive staff		61.934 €
	Basic remuneration and other management remuneration		61.934 €
	Social-security contributions, benefits and expenses paid for by the employer		26.328 €
	Social contributions		26.328 €
	Civil servants		22.981 €
	Complementary salary		13.562 €
	Basic remuneration		9.419 €
	Workers		20.249 €

	Staff	20.249 €
	Incentive program	3.967 €
	Productivity	3.850 €
	Bonus	117 €
Current transfers		7.644 €

Source: Barcelona City Council.

PART III: ENVIRONMENTAL ANALYSIS

Introduction

Nowadays increasing demands from customers and regulators for improved environmental performance and transparency are driving a strong interest in life cycle assessment (LCA) methodology.

Because of the systematic nature of LCA and its power as an evaluative tool, scientific studies are using LCA for the analysis of different products and services to compare different options, highlighting best choices and practices.

Companies are actually increasing the use of LCA to gain a competitive edge for their products, ensuring sustainability and compliance with recent regulations. The use of LCA drives product innovation and environmental improvement and it also supports practices with scientific analysis. However, the use of LCA methodology actually is not always affordable for companies because it is a data and time intensive procedure. To tackle this problem there are a number of user-friendly data banks (e.g. U.S. Life Cycle Inventory Database; CPM LCA Database; European Life Cycle Database) and analytical tools e.g. ecoinvent 3.0; GaBi; SimaPro) that facilitate the comprehensive environmental assessments of products.

The LCA structure is defined and described in the International Organization for Standardization (ISO) 14000 series. ISO 14040:2006[68] provides a comprehensive standard for the conduct of an LCA. LCA is a quantitative method used for assessing environmental impacts associated with all stages of a product's life, from raw material extraction, through manufacturing, distribution, use, maintenance, and the end of useful life.

An LCA may cover all of these steps (cradle to grave) (Figure 23:), or may encompass a subset of the steps in the production and life of a product.

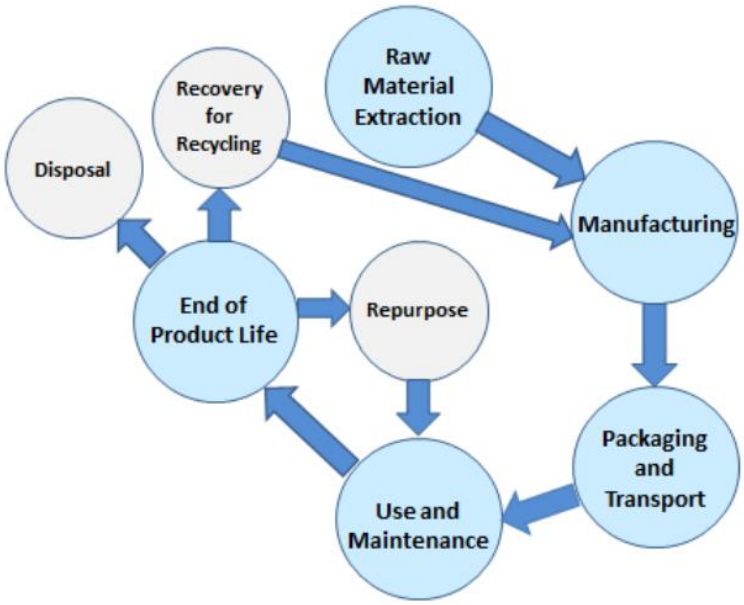

Figure 23: Depiction of "Cradle to Grave" LCA (Hollerud et al. 2017).

[68] ISO 14040:2006. *Environmental Management – Life Cycle Assessment – Principles and framework*. 1 July 2006. Available at: https://www.iso.org/standard/37456.html

The LCA methodology consists of four phases: goal and scope definition, inventory analysis, impact assessment and interpretation (Figure 24).
In the first phase, the purpose of the assessment and the studied systems are identified: goal, scope and system boundary are the factors that represent these choices.
Secondly, the inventory phase (LCI) entails collection of data on the inputs and outputs of the product system, including resources (materials, water, energy), and emissions to air, water and land. The key steps to produce a LCI are: develop a flow diagram of the process being evaluated, identify inputs and outputs at the unit process level, develop a data collection plan, collect the data, and evaluate and report the results. The diagram of the process should be as detailed as possible to have a high level of accuracy.

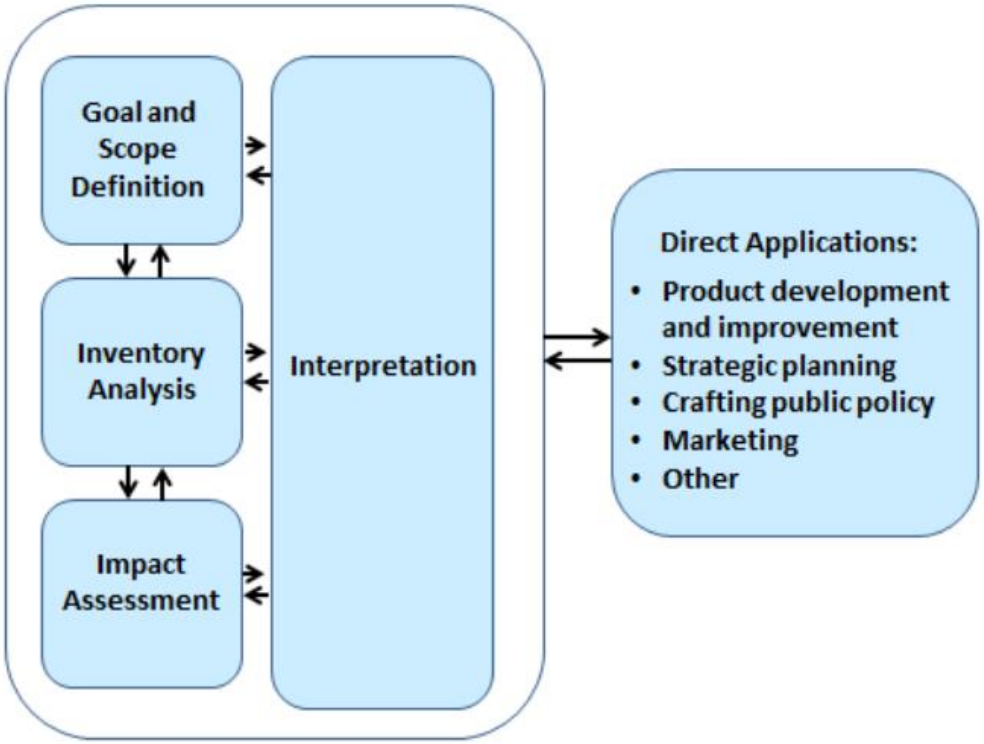

Figure 24: The Four Stages of an LCA (Hollerud et al. 2017)

Subsequently, the impact assessment phase examines data collected in the LCI stage in the context of specific potential environmental and human health impacts. Lastly, the interpretation stage connects the findings from the LCI and LCIA (Life cycle impact assessment) stages back to the goal of the assessment.

The results are presented and evaluated keeping their completeness, sensitivity and consistency in mind. In the evaluation phase, conclusions are drawn and recommendations are given. To test the robustness of the conclusions we use evaluations such as a sensitivity analysis, uncertainty analysis and data quality assessment.

Among different kinds of LCA studies, an Environmental Product Declaration (EPD) is a voluntarily developed document, commonly produced by the production companies, whose purpose is to provide quality-assured and comparable information regarding the life cycle environmental performance of a product. EPDs generally provide information on the environmental impact of raw material acquisition, energy use and efficiency, content of materials and their chemical substances, emissions into the air as well as soil and water, and waste generation. Product and company information is also included.

Each EPD is created and verified in accordance with the International Standard ISO 14025, developed by the International Organization for Standardization (ISO). EPDs are based on a life-cycle assessment according to ISO 14040 and ISO 14044.

EPDs need to be conducted using consistent methodology, responding to specific requirements of the Product Category Rules (PCR). The PCR defines the type of data that must be collected, measured and reported in a life cycle analysis. PCR include instructions for gathering data about the consumption of resources and emissions into air, water and soil. Standard data collection methods defined by PCR allows for a variety of products to be compared based on their environmental performances within specific categories. PCR are developed by organizations like Environdec, IBU, JEMAI, the Green Standard and others.

EPDs provide detailed information about a product's supply chain and allow for the analysis of potential improvements on products' environmental impact. EPD are also useful for companies who can use the information gained from an EPD/LCA to assess ecodesign options (Mieras 2017).

The literature review carried out in this report analyzes different kinds of studies, mostly consisting of LCA studies from peer reviewed papers or EDPs. It also includes information available in Ecolabel reports, e.g. EU Ecolabels (Medyna, Neto, and Wolf 2016; EU Commission 2013; Vidal-Abarca, Kaps, and Wolf 2016; EU Commission 2017a) and Nordic Ecolabel (Nordic Ecolabelling 2016a, 2016b, 2013) which establish foundational knowledge and define environmental requirements for products that are relevant to Public Space Maintenance. Furthermore, relevant studies from research groups or public entities which are not LCA have been referenced to provide useful information about the improvement of best practices (Redust 2012; Layman 2012; Idaea-CSIC 2016).

8 Environmental Analysis

This report focuses on a collection of environmental information necessary to establish environmental clauses and perform assessments of the products/services related to Public Space Maintenance. This information includes environmental profiles for four products/services, as described in the *EU Green Public Procurement for Public Space Maintenance – Part I- section 5.1.*

- Activities are organized around two main categories, which include specific subservices, namely:
  - Cleaning services (including products purchased) for public space maintenance (street-cleaning services, sweeping services, gully cleaning and emptying services, etc.)
  - Gardening & landscaping (including products purchased) (tree pruning, hedge trimming, parks maintenance services, weed-clearance services, grassing services, etc.)

- Equipment, needed to accomplish maintenance activities, which include specific subcategories, namely:
  - Vehicles (gully emptiers, salt spreaders, road-sweeping vehicles, sprinkler vehicles)
  - Machinery (harrows, scarifiers, cultivators, weeders, seeders, planters, lawn or sports-ground rollers, miscellaneous gardening equipment, cleaning machinery)

8.1 Methodology of the literature review

The selection of studies used in this literature review are based on the main topics related with the categories mentioned above and included in the scope of the GPP for Public Space Maintenance.

The research keywords were focused on the collection of LCA studies for groups and sub-groups included in the scope (e.g. LCA for cleaning products and services, dust suppressants, de-icers, fertilizers, soil improvers, vehicles and machinery).

This research produced many results concerning some specific products (e.g. a wide literature is available on cleaning products, de-icer /dust suppressant and fertilizers), services (e.g. winter maintenance, dust suppression, lawn management etc…) or equipment (such as lawn mower).
Through further research on ecolabelled products, some EPD were found about products available on the market, (ISO14025-EPD 2010; ÉCOSÍ 2011) as well as other LCA carried out by companies in order to achieve an ecolabel (Russo 2007).

In a subsequent phase, since the research of LCA didn't provide results for many categories, a further search was carried out using keywords focusing on specific environmental concerns (e.g. PM10 production, dust suppression, organic lawn management, integrated pest control).
Some relevant studies were found for products or services (e.g de-icing, dust suppressant or organic landscaping management) that have been tested to evaluate environmental impacts (Diapouli et al. 2016; Querol et al. 2016; Marshall et al. 2015; Fleisher 2009). This research has also collected some consistent studies reporting an overall literature review on specific topics (e.g. dust suppressant and street sweepers) (F. Amato et al. 2010; Idaea-CSIC 2016).

The research engines used for the research are Google and Google Scholar, Researchgate and Sciencedirect.

In the report, the review of LCA studies is carried out through a specific dissertation aimed to highlight the main categories and structure of the LCA method. For the quality assessment of the selected LCA studies the following categories were reported:
- Goal and scope
- Functional units and system boundaries
- Cut off criteria
- Allocation
- Data quality requirements and data sources
- Impact categories and assessment methods
- Results/findings

Goal and scope
The goal of our study is to provide a solid background of information for determining criteria to guide the purchase of products and services involved in Public Space Maintenance. The scope of our study, as mentioned above, includes cleaning products and services, gardening products and services, and vehicle and machinery involved in Public Space Maintenance.
In order to establish a practical and useful background, different LCA studies have been consulted whose contents are in line with the scope of our study.
A review of LCA literature provides a more comprehensive understanding of common goals and methodologies among a variety of studies. Subsequent comparison will ensure an effective critical review of their conclusions.
Due to the great variety of products, our work reviews a wide variety of LCA studies with a different range of scopes. For that reason, only a few cases presented in the LCA studies could be compared for their results (e.g. use of de-icers for winter maintenance, environmental impact of street sweeping, vehicles, gardening products).

Functional units and system boundaries
According to ISO 14040 and 14044, the functional unit refers to a quantified performance of a product system for use as a reference unit in LCA studies. The system boundary describes which processes are taken into account in the LCA analysis and which processes are not. The choice of the functional unit is key to the LCA and focuses the entire study (Neto et al. 2014).

Cut-off criteria
According to the ISO 14040:2006 and 14044:2006, and the ILCD Handbook, cut-off criteria should be documented in any LCA study, the reasons should be stated and the effect of cut-off decisions on the results should be estimated, because *"this implies that the sensitivities of the elements excluded from the scope of the studies cannot be assessed or estimated."* (Neto et al. 2014)
Within the different studies cut-off criteria are commonly specified.

Allocation
The use of allocation can alter the results of an LCA as different methods are used, but allocation is necessary when a process produces multiple outputs. It is difficult to assess the potential environmental impacts of products/services if no allocation has been conducted, or if it has not been documented. (Neto et al. 2014)
Allocation methods are not always specified among the selected studies and when available, often vary.

Data quality requirements and sources
The time-related, geographical and technological representativeness and data sources, including primary and secondary data of the selected LCA studies, are the primary means to evaluate the quality of an LCA study (Neto et al. 2014).
Consistency and quality as well as quality assurance of data (i.e. review) are important requirements that support valid studies. There is a wide range of potential LCI data sources. The first is primary data sources, which are provided from the producers of

goods and operators of processes and services, as well as their associations. Another source is the secondary data sources which either give access to primary data (possibly after remodeling/changing the data) or to generic data are e.g. national databases, consultants, and research groups. (EU Commission 2010)
Among the selected studies a wide range of data sources are utilized. In the tables provided for each group of product/services, a proper section summarizes the origin of data

Impact categories and assessment methods
The impact assessment (LCIA) has to be performed in the LCI phase, where the resources consumed and emissions in the life cycle of a product or service are documented.
The LCIA is generally built up considering three areas of protection: human health, natural environment, and issues related to natural resource use (EU Commission 2011b).
Impact categories considered in the Life Cycle Impact Assessment (LCIA) include climate change, ozone depletion, eutrophication, acidification, human toxicity (cancer and non-cancer related), respiratory inorganics, ionizing radiation, ecotoxicity, photochemical ozone formation, land use, and resource depletion. The emissions and resources derived from LCI are assigned to each of these impact categories. They are then converted into indicators using factors calculated by impact assessment models. These factors reflect pressures per unit emission or resource consumed in the context of each impact category. Emissions and resources consumed, as well as different product options, can then be cross-compared in terms of the indicators. (EU Commission 2011b).

In the report, a table provides an overview on the impact categories that have been used within the selected LCA studies.
This table has been built up with reference to the list of categories identified by the ILCD method[69].

Additional specific impact categories used in some studies have also been listed in the table.

Results/findings
The overview of the literature on the selected studies gives us a framework for the description of the environmental hotspots of different services/products that characterize Public Space Maintenance. Because of the inconsistency or scarcity of LCA literature in many cases, we cover the lack of information through findings in other studies.

8.2 Relevant life cycle stages and hotspots

In the literature review, according to the *International Reference Life Cycle Data System (ILCD) Handbook - Nomenclature and other conventions*[70] and following the structure of other publications like *Technical Background Reports*[71] (aimed at the study of environmental impact assessment) we analyse the following life cycle stages:

- **Raw material extraction and processing**

[69] Information available at: http://eplca.jrc.ec.europa.eu/uploads/ILCD-Recommendation-of-methods-for-LCIA-def.pdf
[70] *First edition 2010. EUR 24384 EN. Luxembourg. Publications Office of the European Union; 2010.* Available at: http://eplca.jrc.ec.europa.eu/uploads/MANPROJ-PR-ILCD-Handbook-Nomenclature-and-other-conventions-first-edition-ISBN-fin-v1.0-E.pdf
[71] Particularly we followed the Technical background related with Cleaning services, gardening and transport. Available at: http://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm

The key environmental impacts for extraction and processing are related to the depletion of natural resources and climate changes resulting from energy consumed during raw materials processing. Many substances used in products, are taken from non-renewable sources (e.g. derived from petrochemical streams). The release of toxic substances and waste from the processing chain also impacts the environment. (Neto et al. 2014)

- Production phase and packaging
Most manufacturers have large scale facilities that require large amounts of energy to build and run. Production is often associated with energy costs and with the powering of the production chain. Raw materials (including water) will also be transformed, and large factories will require a significant supply.
Moreover, packaging required for the final or end products can also generate negative environmental impacts, "*the three levels of packaging shall be considered: primary, secondary and tertiary packaging"*[72] (Neto et al. 2014). The packaging manufacturing step shall be considered for each packaging material individually. Also, it is included in the evaluation of environmental impacts, mining and extraction of resources, processing of packaging and transportation between the extraction and the manufacturing sites.

- Use stage
The use stage begins when the consumer takes possession of the product, or during the completion of an activity in the case of a service, and ends when the used product and its packaging are discarded for transportation to a recycling or waste treatment facility. Therefore the use stage shall include: the consumption pattern, and the use of energy resources (e.g. electricity and water consumption) (Neto et al. 2014)

- Transport and logistics
The delivery of products also has an associated environmental impact as it involves transportation on a potentially large scale. A fraction of the impacts from transportation activities shall be allocated to the unit of analysis (to the considered product) based on the load-limiting factor. (Neto et al. 2014)

- **End-of-life stage and waste generation**
The environmental issues related with the end of life treatment for products are listed in the *ILCD Handbook* mentioned above. The sub system of this flow of the life cycle assessment are: reuse or further use of products, material recycling, raw material recycling, energy recycling, landfilling, waste collection, waste water treatment, raw gas treatment, other end-of-life services. "*The scenarios to be adopted for the end of life stage shall be representative of the current practices at European level as well as any European country level*." (Neto et al. 2014)

[72] "*Primary packaging (or consumer packaging) is the material that first contains, preserves and protects the product as well as informs the end user. It also includes dosing devices and it is the smallest unit of distribution. Secondary packaging is outside the primary packaging and is often used to group primary packs together to protect them during storage, transport and distribution. Tertiary packaging (or transport packaging) is outer packaging including pallet, stretch wrap, etc. used for warehouse storage, transport shipping. The default form is a palletized unit load"*. (Neto et al. 2014)

9 Environmental analysis of Cleaning activities for Public Space Maintenance

The scope of the sub-group of Cleaning activities for Public Space Maintenance was identified in the *Part I- section 5.1 of this Preliminary Report*. As indicated in this report they include:

Cleaning services:
- Mechanical and manual sweeping of sidewalk, bike lane, road (asphalt, roadbed) and roadside (shoulders, curbs, green areas): CPV code 90610000
- Litter collection services – CPV code: 90511300-5
- Bins' litter collection and sorting: CPV code 90918000
- Mechanical and manual water jet cleaning: CPV code 42924730, and 42924740-8
- Façade/surface cleaning
- Graffiti removal: corresponding to CPV code 90690000, Graffiti removal services
- Snow and ice removal from sidewalks, bike lanes and roads, corresponding to CPV code 90620000, snow-clearing services and 90630000, ice-clearing services
- Beach cleaning: corresponding to CPV code 90680000, beach cleaning services
- Cleaning of fountains, lakes and ponds

Cleaning products:
- All-purpose cleaners- industrial cleaners for outdoor
- Substances for snow and ice removal: salt and sand-and-salt-mixture (called grit), and calcium chloride
- Binding agents for dust control (calcium chloride as a dust binder for street cleaning)

Other supplies/accessories/machinery parts:
- Brushes, rolls

9.1 Characterization of cleaning activities for Public Space Maintenance

Cleaning services

Street Cleaning

Street surface pollution is a source of the deterioration of both water and air quality. Street sweeping is the predominant method of tackling this problem, removing debris and sediment from roads, thus reducing pollutant runoff into the natural environment.
Nowadays, efforts and attention have been directed towards methods of effective reduction of micro-particulate matter (PM10).
During the last decades, there have been significant improvements in the vehicle exhaust emissions due to tightened emission controls, technological development and sulphur- and lead-free fuels. However, these improvements alone have not adequately reduced street dust, and for this reason additional measures need to be implemented to mitigate street dust emissions.
The settlement of fine dusts is the result of many factors, such as environmental pollution, vehicle emissions, tires decay, etc.
In particular during winter, deterioration of the street surface caused by studded winter tires, and the use of traction or sanding materials are regarded as the most significant sources for particles accumulating on the street. After winter, when the ice and snow

melts and the streets dry up, the accumulated street dust is released quickly and often causes very high ambient air particulate concentrations (Layman 2015).
Moreover, in southern European areas, a significant factor in the accumulation of PM concentration is due to the contribution of major natural sources such as: African dust, sea salt and forest fires.
The research from *Estimation of natural source contributions to urban ambient air PM_{10} and $PM_{2.5}$ concentrations in Southern Europe. Implications to compliance with limit values* (Diapouli et al. 2016) provides an overview of the contribution of natural sources in the production of fine dust. As summarized in the article*: "African dust contribution to PM concentrations was more pronounced in Eastern Mediterranean, with the mean annual relative contribution to PM10 decreasing from 21 % in Athens, to 5 % in Florence, and around 2 % in Milan, Barcelona and Porto. The respective contribution to PM2.5 was calculated equal to 14 % in Athens and from 1.3 to 2.4 % in all other cities. High seasonal variability of contributions was observed, with dust transport events occurring at different periods in the Western and Eastern Mediterranean basin. Sea salt was mostly related to the coarse mode and also exhibited significant seasonal variability. Sea salt concentrations were highest in Porto, with average relative contributions equal to 12.3 % for PM10. Contributions from uncontrolled forest fires were quantified only for Porto and were low on an annual basis (1.4 % and 1.9 % to PM10 and PM2.5, respectively); nevertheless, contributions were greatly increased during events, reaching 20 and 22 % of 24 h PM10 and PM2.5 concentrations, respectively."* (Diapouli et al. 2016)

Street sweeping together with water flushing or spreading of binding agents is the main technique in the control of fine dusts.
Concerning the specific characterization of these services, some information is available, for example, on the web site of Barcelona council[73], describing the practice of street cleaning:
"Cleaning services are planned considering the uses and needs of each area. Cleaning tasks are suited to each situation, which is determined by factors such as movement of people and vehicles, commercial and cultural activity, or depending if it is a leisure or recreational area.
Most common cleaning systems identified are:
- *Manual sweep work*
- *Cleaning teams sweep and clean the streets of the city.*
- *Mechanical sweep work (with a brush machine)*
- *Small sweeper trucks brush and vacuum all type of dirty.*
- *Combined sweep work (a combination of the above-mentioned methods)*
- *Along with small sweeper trucks, cleaning teams fully sweep the streets.*
- *Water cleaning*
- *Small trucks clean the dirt from streets using hoses with pressurized non-potable water which come from the phreatic.*
- *Bins are the targets of preventive (repainting, revision, etc.) and corrective maintenance (repairing broken bins, for example). In addition, older bins are gradually replaced with new ones.*

Bins are intensively cleaned four times a year and most often when talking about the most used ones within the city, which are located in the main roads and shopping streets.[74]

Beach cleaning services
From the same web page mentioned above we gathered some technical details for the services related to beach cleaning.

[73] Available at: http://ajuntament.barcelona.cat/ecologiaurbana/en/services/the-city-works/maintenance-of-public-areas/waste-management-and-cleaning-services
[74] Ibid. footnote n.6

Taken from the web page: *"The public beach maintenance is organized according to the influx of users, so frequency and human and material resources increase during the bathing season, especially between the months of June and August. Works are aimed at maintaining the quality of the sand, water, beaches surroundings and hygiene facilities for users (showers and toilets)".*
"Cleaning services in beaches during the peak season include daily cleaning by 21 teams with 40 workers. Besides, there are two cleaning teams during morning and evening shifts for emptying bins, sweeping sand, collecting trash from the bins in beach bars, mechanical sieving of beach sand and cleaning and watering paved areas".[75]

Façade cleaning and graffiti removal
Façade cleaning may refer to different services like removal of dust, dirt and pollution, or graffiti.
Routine façade cleaning is usually conducted using high-pressure jets without the use of chemicals, while for graffiti removal chemicals may sometimes be needed (Nordic Ecolabelling 2016b).
The chemicals are generally sprayed onto the façade undiluted and after 10-15 minutes the product is cleared using a jet washer.
A high-pressure washer should be provided with a separation system whereby the dirty water is recovered (PIANOo 2015). Unfortunately, this kind of machines is quite expensive on the market. This means that usually the wastewater with cleaning agents and residual of graffiti ends up in the municipal waste water. (Nordic Ecolabelling 2016b)
Some more information is available from operational practice of Barcelona council [76] and UK book of cleaning practices (CIWM 2008)

Weed control on paved surfaces
Information about this service and products was taken from the SPP for green space maintenance (PIANOo 2015) .
If weed killers are used, this must take place in line with the most recent valid version of what is called the DOB method (Duurzaam OnkruidBeheer op verhardingen, or "Sustainable weed control on pavements"[77]). This is a requirement stipulated for the performance of the contract.
The DOB sets requirements for, among other things:
1. Registration: the purchase and stocking of weed killers.
2. Administering of weed killers via selective administering techniques.
3. Regulations as to where weed killers may and may not be used on paved surfaces.
4. Taking into account local weather conditions when using weed killers.
5. The annual maximum for the use of glyphosate per hectare/per working round.
6. Conditions for the combined use of weed killers and a sweeping schedule, in which it is not permitted to use weed killers 4 days before or after the area is swept, for instance.
7. Weed control in the event of rain or dew to prevent weed killers from being washed off the plants. The use of glyphosate may in future be linked to required certification on the basis of the statutory use regulation. (PIANOo 2015)

[75] Ibidem.
[76] Available at: http://ajuntament.barcelona.cat/ecologiaurbana/en/services/the-city-works/maintenance-of-public-areas/waste-management-and-cleaning-services/specific-cleaning-treatments
[77] Further information available at: http://www.wur.nl/nl/Onderzoek-Resultaten/Projecten/DOB-verhardingen.htm

Cleaning ponds
From the publication *Good Gardening practices in Barcelona: conserving and improving biodiversity* (Borruel, Punsola, and Garcerán 2016) we could gather some technical information for pond cleaning. As stated in the study:
"Ponds has to be annually cleaned during its period of least biological activity (November to February). Such action will involve:
- Removing organic matter.
- Removing filamentous algae.
- Removing or controlling exotic fauna populations".

"Filamentous algae proliferations will probably require more frequent cleaning initiatives. In such cases action will be taken where appropriate, except during the period between April and July, which corresponds to the amphibians' breeding period, as the filamentous algae may contain their eggs." (Borruel, Punsola, and Garcerán 2016)

"Ponds have to be emptied once a year for cleaning and maintenance work, while preserving their biota and returning it to the pond, as established under Area of Environment Instructions IA/02.02: Managing fauna in ornamental fountains. Note, however, that a thorough monitoring throughout the year, by controlling the various factors that can disrupt the balance of the pond, may make it unnecessary to empty out the pond every year. (Borruel, Punsola, and Garcerán 2016)

"Surface litterfall has to be removed every week with a scoop net. Organic leftovers from food also have to be looked out for and removed. Visitors must be prevented from feeding pond fauna (increased organic matter). Warnings should be bolstered with signage. Trees should not be planted near toy ponds so their leaves do not fall in them. If there are already trees there, they must be suitably pruned." (Borruel, Punsola, and Garcerán 2016)

Winter maintenance
The general goal of winter maintenance operations is to ensure mobility and traffic safety through prediction and friction control on frozen surfaces like roads.
The slippery conditions are commonly produced by:
- the freezing of wet roads
- the condensation of fog
- winter precipitations

Winter maintenance operations are often complicated and unpredictable. The weather forecast is a tool for planning these activities, but it is not always efficient.
The standard activities for winter maintenance are the spreading of anti-icing as well as de-icing and mechanical snow and ice removal. These activities are carried out through the use of special vehicles, which vary in size depending on the kind of road, and the use of thawing products. More information on this group of activities has been given insight in a proper sustainable procurement from the Dutch government[78].

Cleaning products

Cleaning agents
The publication *Industrial cleaning and degreasing agents* (Nordic Ecolabelling 2016b) gives an overview on cleaning products used for Industrial and Institutional trade. This study also covers outdoor use based products.
In professional cleaning operations, the three most commonly used products are:

[78] Available at: *Environmental criteria for sustainable public procurement of Winter Maintenance; available at:* https://www.pianoo.nl/sites/default/files/documents/documents/wintermaintenance-environmentalcriteria.pdf

- Acid based products, which are commonly used to remove hard deposits from water systems. They are mainly hydrochloric acid based and may also be used for cleaning floors, walls, oxidation, rust and algae.
- Alkali based products, which are commonly used to remove grease, dirt or oil from concrete floors.
- Solvent/petroleum based degreasers, which are able to remove grease while not corroding metal.

The main difference between consumer and professional cleaning products is the concentration of some of the materials such as surfactants (>pH values of NaOH or POH of up to 30% compared to typical pH of 13 and 14).
For this reason, in accordance with the Nordic Ecolabel requirements, super-concentrates have a different classification respect to ready-diluted solutions.

More information about cleaning products is available in the *EU GPP Criteria for Cleaning Products & Services*[79], which also covers procurement actions for four categories of products in line with those covered by the EU Ecolabel[80]. Within those categories, the category 'all-purpose cleaning products'[81] could be used to fill information about products related with the scope of public space maintenance. Even if all-purpose cleaners are products meant for indoor use, as stated in the Preliminary Report for Cleaning services (Neto et al. 2014), *"there is great similarity in the substances used in the main generic cleaning products. According to International Association for Soaps, Detergents and Maintenance Products (AISE), the materials used in cleaners and detergents sold to the industrial and institutional sector are around 90% the same as those used in the domestic sector, with identical toxicity characteristics. The key differences are in the concentration and dosage: products supplied to the professional sector can be highly concentrated for maximum efficiency because users often have sophisticated dose control systems to ensure correct dilution during use. Packaging impacts are reduced for industrial and institutional products as they are usually sold in bulk, concentrated and have greater reuse/refill options"* (Neto et al. 2014).

De-icing Products
The winter maintenance materials include chemicals used for anti/de-icing.
The term anti-icing describes the action of applying chemicals to a surface to prevent it from freezing. De-icing describes the act of using chemicals to remove snow and ice that has already bonded with the pavement. (Vignisdottir, Booto, and Bohne 2016)
The most common material in use is salt (sodium chloride). The most common chloride based compound is sodium chloride (rock salt or NaCl); Calcium chloride (CaCl2) and magnesium chloride (MgCl2) are the major products in this category. The first is a product of the ammonia soda process and a joint product from natural salt brines. The second is derived from seawater evaporation.
Other more expensive chemicals, including carbohydrate-based solutions (corn or beet), calcium magnesium acetate (CMA), and potassium acetate, may have less detrimental effects on the environment, and are sometimes preferred in sensitive areas where the application of salt is not appropriate.
The effectiveness of salt spreading is largely dependent on the kind of road, the temperatures and the amount of precipitations[82].
The lower the temperature, the higher the concentration of salt must be.

[79] Available at: http://ec.europa.eu/environment/gpp/pdf/criteria/cleaning.pdf
[80] Available at: http://ec.europa.eu/environment/ecolabel/index_en.htm
[81] Available at: http://ec.europa.eu/ecat/category/en/1/all-purpose-cleaners-and
[82] Information available at: https://www.fhwa.dot.gov/publications/research/safety/95202/004.cfm

Beside de-icers, abrasives used to ensure better friction is a well-established practice in winter maintenance operations.
Typically sand is placed on the road in amounts up to 340 kg per km (Nixon 2001) . The sand may be applied directly, it may be pre-wet with liquid brine, or it may be delivered mixed with salt.

Binding Agents
Dust binding agents are used to controlling the PM10 levels. Traditionally dust suppressants have been used on unpaved roads or in the mineral industry; more recently their effectiveness at reducing road dust emissions has been more widely investigated in a number of European cities, generally as a measure to meet the European daily PM10 limit value of 50 µg m-3 not to be exceeded more than 35 times in a calendar year (Directive 2008/50/EC)[83] (Querol et al. 2016)
Dust suppressants, sprayed onto the road surface, binds the particles of fine dust making them heavier. This prevents them from becoming airborne when agitated by wind, tire action or vehicle turbulence.
Some products form a crust on the surface and others penetrate through the surface.
Efficient dust suppression requires repeated application and treatment over large areas.
As specified in the study *Technical Guide to reduce road dust emissions in Southern Europe* (Querol et al. 2016) in Europe the common dust suppressants in use are:

- Surfactants reduce surface tension and allow particles and aggregates in the surface layer to take on moisture and become wet more efficiently.

- Salts that absorb water when relative humidity exceeds 50 % (i.e. hydroscopic compounds):
  - magnesium chloride (MgCl2);
  - calcium chloride (CaCl2);
  - calcium magnesium acetate (CMA);
  - potassium formate (referred to as KF in some publications).

Salts and Brines are the most common type of dust suppressant; these products allow dust particle on the soil to stabilize and absorb moisture from the atmosphere, so it is critical to have sufficient humidity levels of 20-80% when applying these products.
Concerning CMA, the above mentioned study (Querol et al. 2016) specifies that: *"CMA is commercially available and is marketed under the name 'ICE & DUST AWAY'. It consists of a 25 % by weight aqueous solution of CMA. It contains no additives. A mixture of CMA and potassium formate is also commercially available as 'ICE & DUST AWAY PLUS 50'. This contains 50 % CMA and 50 % potassium formate, and has a lower freezing point than ICE & DUST AWAY. Potassium formate solution is available as Kemdust F."* These products have been awarded with a Nordic Ecolabel and are commercialized by the Nordisk Aluminat[84], who developed them in collaboration with CMA+ research group[85] with LIFE project[86] funding. A complete report on the development of products and on their effectiveness has been produced by the company (Klarskov and Nordisk-Aluminat 2011).
In other regions of the world, other kinds of dust suppressant have been experimented with but some of these compounds have been found to cause strong effects on the ecosystem. In the publication of EPA (US Environmental Protection Agency) *Potential*

[83] Information available at: http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0050
[84] Information available at: http://aluminate.eu/certifications/
[85] Information available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3262
[86] Information available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.getProjects&themeID=2&projectList

Environmental Impacts of Dust Suppressants the main dust suppressant agents in use in the USA are listed (EPA 2014).
These products are:
- Salts and brines: (Calcium chloride, magnesium chloride)
- Petroleum-based organics: (Asphalt emulsion, cutback solvents, dust oils, modified asphalt emulsions)
- Non-petroleum based organics: (Vegetable oil, molasses, animal fats, ligninsulfonate, tall oil emulsions)
- Synthetic polymers: (Polyvinyl acetate, vinyl acrylic)
- Electrochemical products: (Enzymes, ionic products (e.g. ammonium chloride), sulfonated oils)
- Clay additives: (Bentonite, montmorillonite)

In USA, the more used products are chloride salts and salt brine products, ligninsulfonates, and petroleum-based products.
Ligninsulfonate is derived from the sulfite pulping process in the paper industry where sulfuric acid is used to break down wood fiber.
Petroleum Products include used oils, solvents, cutback solvents, asphalt emulsions, dust oils, and tars, they are not water-soluble or prone to evaporation, and generally resist being washed away.

Finally, water can also be used on its own as a dust suppressant. It is commonly used on temporary construction sites. Water is probably the most cost effective short-term solution for dust control (EPA 2014). However, the cost will vary depending on climatic conditions influencing water availability.

9.2 Overview of studies on cleaning activities for Public Space Maintenance

The environmental analysis of this group of services/products has been modelled after the study *Development of the EU Ecolabel Criteria and Revision of the EU Green Public Procurement Criteria for Cleaning Services* (Neto et al. 2014). In addition to the mentioned study we reported a synthesis of ten relevant studies.

About conventional and green cleaning products:
-*Comparative Life Cycle Assessment of Conventional and Green Seal-Compliant Industrial and Institutional Cleaning Products* (Kapur et al. 2012)

One Environment Product Declaration (EPDs) was reviewed:
- *Dichiarazione ambientale di prodotto (EPD) di prodotti per la pulizia e l'igiene di ÉCOSÍ*. (Ecosì 2012)

A MECO[87] environmental analysis for cleaning products:
- *Nordic Ecolabelling of Industrial cleaning and degreasing agents* (Nordic Ecolabelling 2016b)

LCA studies about dust cleaning, winter maintenance and the use of de-icing products and winter maintenance:
- *Life Cycle assessment of Anti-and De-icing Operations in Norway* (Vignisdottir, Booto, and Bohne 2016)

[87] The MECO matrix is a tool to get a concise overview of the environmental concerns evaluating the agents causing environmental problems instead of focusing on the actual environmental impact categories. The areas involved in the analysis are Materials, Energy, Chemicals and Others.

- *LCA for Calcium Magnesium Acetate* (Ritthoff 2011)
- *Environmental Life-Cycle Assessment of Winter Maintenance Treatments for Roadways.* (Fitch, Smith, and Clarens 2013)

Finally, on the topic of dust suppression the studies that have been reviewed are:
- *Road Surface Pollution and Street Sweeping* (Yee 2005)
- *CMA+ - PM10 reduction by the application of liquid Calcium-Magnesium Acetate (CMA) in the Austrian and Italian cities Klagenfurt, Bruneck and Lienz* (Layman 2012)
- *REDUST - LIFE09 ENV/FI/000579 - FINAL Report Covering the project activities from 01/01/2011 to 31/12/2014* (REDUST 2015)
- *A review on the effectiveness of street sweeping, washing and dust suppressants as urban PM control methods* (F. Amato et al. 2010)
-

The last three studies have been published as part of three relevant LIFE funding projects:

- *CMA+ - PM10 reduction by the application of liquid Calcium-Magnesium Acetate (CMA) in the Austrian and Italian cities Klagenfurt, Bruneck and Lienz LIFE07 ENV/A/000003*[88] *(Layman 2012)*

- *REDUST - Best winter maintenance practices to reduce respirable street dust in urban areas - demonstration of best practices, strategy development and implementation LIFE09 ENV/FI/000579*[89]

- *AIRUSE - Testing and Development of air quality mitigation measures in Southern Europe (LIFE11 ENV/ES/000584)*[90] (Idaea-CSIC 2016; Querol et al. 2016; F. Amato et al. 2010)

These studies are particularly comprehensive in their explanation of practices and services related with dust control. Further information and results will be referenced from these studies in the chapter regarding vehicles to specify recommendations regarding the best option on vehicle technologies for street sweeping.

The table below provide a short description of the mentioned relevant studies. In a further section, a deep analysis provides an overview of the quality assessment of the studies focusing on impact categories and highlighting the main hotspots in the products/services life cycle.

[88] Information available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3262

[89] Information available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3734

[90] Information available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=4253#RM

Table 9: Overview of selected studies related to cleaning activities for Public Space Maintenance

Study type	Sub-category	Source	Title	Impact assessment	External critical review	Impact hotspot summary
LCA	Cleaning products	Kapur et al. 2012	*Comparative LCA of Conventional and Green Seal-Compliant Industrial and Institutional Cleaning Products*	ReCiPe 2008 Midpoint (hierarchist perspective) impact assessment methodology	Critical review and peer review pre- publication	Conventional products showed the most dominant impacts in relation to green seal compliant products. The main hotspots for green products occur in the up-stream phase of packaging and distribution, while conventional products show stronger impacts in the use and end of life phase.
EPD	Cleaning products	Ecosi 2011	*Detergents and washing preparations*	Environmental Product Declarations, version 1.0, 2008-02- 29; IPCC - Intergovernmental Panel on Climate Change- 2007 v.1.02; LCA: ISO 14040:2006 and14044:2006; Product Category Rules PCR 2011 :10	PCR review. Independent verification of the declaration and data according to ISO 14025: External Third-party verifier	The main impacts for these products occur in the up-stream phase, while the core and down-stream phase have a lower impact.
LCA	Industrial cleaning and degreasing products	Nordic Ecolabelling 2016	*Nordic Ecolabelling of Industrial cleaning and degreasing agents*	MECO	Not specified	Ecotoxicity and degradability, health impacts, energy depletion (for raw material extraction, packaging production and transportation) stand out as key parameters to be assessed in the setting of new criteria for industrial cleaning products ecolabeling.
LCA	De-icing winter maintenance	Vignisdottir, Booto, and Bohne 2016	*Life Cycle assessment of Anti-and De-icing Operations in Norway*	CML baseline impact assessment method	not specified	Environmental impacts of winter services are highly linked to driving distances and to the amount of spread de-icing material. For these reasons, the optimization of routes and de-icing spreading practices should be focused on.
LCA/ cost-benefit analysis	De-icing products	Ritthoff 2011 LIFE07 ENV/A/000003 2012	*LCA for calcium magnesium acetate. Ecological comparison of CMA, potassium formate and sodium chloride in winter service*	Nowcasting Model" (from the EU Life Project KAPA-GS) with the "INCA-Model"	LIFE07 ENV/A/000003	From the comparison of CMA to sodium chloride, results that the first has a lower abiotic impact but a much higher GWP related with the up-stream phase of production of the material. The advantages and disadvantages concerning the impacts on air and water consumption depend on the application; if CMA is used once in four days for anti-icing, it has advantages in all categories of material intensity. (Ritthoff 2011)

LCA	De-icing products	Fitch, Smith, and Clarens 2013	*Environmental Life-Cycle Assessment of Winter Maintenance Treatments for Roadways*	Oracle Crystal ball modeling plug-in	Not specified	The sodium-chloride based treatment were found to have lower environmental impacts than CMA over the entire life cycle for four of five impact factors; as expected, sodium chloride-based treatments have higher impact for chloride emission to the environment. Most of these emissions occurred as result of the runoff of materials from treated lanes.
Report of results from on street tests	Street sweeping services	Yee 2005	*Road Surface Pollution and Street Sweeping*	-	-	The results of this study show that street sweeping did not effectively reduce pollutant levels. Sweeping reduces the total amount of sediments, but fails to pick up the finer particles. The particles that remain become increasingly fine–grained, intensifying the concentration of metals and nutrients present in road sediment.
Technical report	Road spreading of CMA	Layman 2012	*CMA+ - PM10 reduction by the application of liquid Calcium-Magnesium Acetate (CMA) in the Austrian and Italian cities Klagenfurt, Bruneck and Lienz*	-	-	If applied consistently as a fine-dust suppressant, CM is able to achieve a clearly measurable PM10 reduction in the ambient. Provided that the dose of 10g/m2 is not exceeded and spread on roads in a bad state of repair, no damage is to be expected on public roads. *(*Layman 2012)
Technical report	Dust suppression after winter maintenance	REDUST 2015	*REDUST - LIFE09 ENV/FI/000579 - FINAL Report Covering the project activities from 01/01/2011 to 31/12/2014*	-	-	Up to 25% reduction in the PM10 street dust emissions during spring dust period can be achieved in busy urban traffic locations with improved dust binding and street cleaning actions.
Literature review	Street sweeping services	Amato et al. 2010	*A review on the effectiveness of street sweeping, washing and dust suppressants as urban PM control methods*	-	-	Results about the advantages of street sweeping on PM10 reduction are uncertain. Most studies conclude that water flushing used in combination with sweeping gives good results. However, it has to be considered that this could be the result of a drop of PM levels due to the wetted condition of street surface.

9.3 Analysis of the selected studies

In this section, we present a summary of the mentioned relevant studies.
Concerning the LCA and EPD studies, a table is provided to display the main factors of the quality assessment of the method used for the identification of the environmental impacts.
For the quality assessment of the selected LCA studies the following base parameters were considered:

-Characterization
- Goal and scope
- Functional units and system boundaries
- Cut off criteria
- Allocation
- Geographical and technological representativeness
- Data sources

A further table in a following section will show the impact categories. In the next section, we will just present a summary concerning the other relevant studies identified above, since the quality assessment through the mentioned categories is not appropriate for this kind of studies.

9.3.1 Quality assessment of the LCA studies

Table 9. 1: Quality assessment of LCA studies on cleaning services and products for Public Space Maintenance

Source	Characterization	Goal	Scope	Functional Unit	System boundary	Cut-off criteria	*Allocation*	Geograph.representa-tiveness	Technological representa-tiveness	Data source
(Kapur et al. 2012)	General-purpose, cleaners	Compare the environmental impacts of cleaning products that are compliant with the Green Seal standard to conventional products	Model products of GS-37-compliant, conventional concentrate, and conventional ready-to-use versions	Annual cleaning of 100,000 ft^2 of office space	Cradle-to-grave	Production of cleaning products (i.e. mixing and making of the final products) is not included in the study because of the lack of information from the manufacturer	Allocation procedures for recycling of packaging materials, as per the ISO 14044 (ISO 2006)	North America	Current technological mix of the products sold in the North American market	Specific data for raw materials and production from manufacture companies. Secondary data are collected from Ecoinvent 2.2
(ÉCOSÍ 2011)	General purpose cleaner. Model products of GS-37-compliant, conventional concentrate, and conventional ready-to-use versions of each cleaning product were evaluated	Assess environmental impacts of cleaning products made by Ècosì	Surfaces detergent, detergent descaler (bathroom, glass, and floors), surface disinfectant (x2), detergent for hard surfaces, all-purpose detergent for surfaces and glass (x2), and all-purpose detergent.	1kg of detergent (liquid) packed	Cradle to grave	The building of a production site, infrastructure, production of manufacturing equipment, other capital goods and personnel activities are not included	Not specified	Italy	Current mix of products used in various packing formats and sizes	Specific data are collected in the manufacture company, based on the supply chain from E' Così. For end of life scenario data are based on technique scenarios. Concerning transportation, data on vehicle types are provided from suppliers. Secondary data are collected from Ecoinvent 2.2
(Nordic Ecolabelling 2016)	Industrial cleaning and degreasing agents for (among other uses) façade cleaning, graffiti removal, hard surface cleaning, machinery cleaning, etc..	Assess environmental impacts of products to identify criteria for the ecolabeling	Industrial cleaning and degreasing agents for in-door and outdoor activities	Not specifies	Cradle to grave	Not specified	Not specified	Not specified	Current mix of products used in various packing formats and sizes	Not specified

(Vignisdottir, Booto, and Bohne 2016)	Winter maintenance services	The goal of this study is to map and analyse the activity of anti- and de-icing operations in Norway	Average winter maintenance operations in Norway for winters 2009/2010 through 2014/2015, from now on referred to as winter 2010 through 2015, on national and state roads	Anti- and de-icing operations on national and state roads per km during winter	Material production and transportation as well as storage but also equipment and energy use	The environmental impacts of the de-icing agents after spreading is not included in the estimation	Not specified	Norway	Winter maintenance services in Norway	SimaPro and Ecoinvent database
(Ritthoff 2011)	Chloride based de-icers and CMA for de-icing activities	Comparison of the environmental impacts of different de-icers	Sodium chloride, CMA and potassium formate in winter service	(0.32 kg dolomite and 0.82 kg acetic acid (98%) per kg CMA)	Material flows and resource management	Subject of the screening are the resource consumption and the global warming potential. Other environmental impacts are not covered	Not specified	Europe	They do not represent a specific producer to allow a general material comparison	Wuppertal Institute database. Specific process Information from a producer of CMA
(Fitch, Smith, and Clarens 2013)	1)Application of granular sodium chloride with subsequent application of NaCl 2) Application of brine with subsequent application of NaCl 3) Application of CMA	Comparison of the environmental impacts of different de-icers	Application of de-icer during winter maintenance	100 lane miles	Acquisition-trasportation-storage and application of materials to the roadway-disposal and runoff both from storage site than from the road	Not specified	Not specified	Virginia USA	DOT technologies	Wuppertal Institute database. Specific process Information from a producer of CMA

Table 9. 2 Impact categories of the selected LCA studies related to cleaning services and products

Source	Kapur et al. (2012)	Ecosi (2011)	Nordic ecolabelling 2016	Vignisdottir, Booto, and Bohne 2016	Ritthoff 2011	Fitch, Smith, and Clarens 2013
Impact assessment	ReCiPe 2008 Midpoint (hierarchist perspective) impact assessment methodology	Environmental Product Declarations, version 1.0, 2008- 02- 29; IPCC - Intergovernmental Panel on Climate Change- 2007 v.1.02; LCA: ISO 14040:2006 and14044:2006 ; Product Category Rules PCR 2011 :10	MECO	CML baseline impact assessment method	Nowcasting Model" (from the EU Life Project KAPA-GS) with the "INCA-Model"	Oracle Crystal ball modeling plug-in
Product Sub group	Cleaning products	Cleaning products	Cleaning products	Winter maintenance	CMA/ sodium Chloride	Street sweeping
Climate Change	√	√	-	√	√	√
Ozone Depletion	√	√	-	√	-	-
Ecotoxicity for aquatic fresh water	√	√	-	√	-	-
Human Toxicity cancer effects	√	√	-	√	-	-
Human Toxicity non-cancer effects	√	√	-	√	-	-
Particulate Matter / Respiratory Inorganics	√	√	-	-	√	√
Ionising Radiation – human health effects	√	-	-	-	-	-
Photochemical Ozone Formation	√	-	-	-	-	-
Acidification	√	-	-	√	-	-
Eutrophication – terrestrial	√	-	-	√	-	-
Eutrophication – aquatic	√	-	-	√	-	-
Resource Depletion – water	√	√	-	-	-	-

Resource Depletion – mineral, fossil	√	√	-	-	-	-
Land Transformation	-	-	-	-	-	-
Other impact categories not covered by PEF	- Terrestrial ecotoxicity, - marine ecotoxicity, agricultural land occupation, - urban land occupation, - metal depletion, - cumulative energy demand	- use (material and energy), - waste generation (non-hazardous waste and hazardous waste),		- Marine aquatic ecotoxicity - Abiotic depletion	Material intensity	

The impact categories are not comparable within the different studies due to the difference of scopes and impact methods.
Among the first three studies addressed to cleaning products the study from Nordic Ecolabelling used a simplified method (MECO), where the environmental impacts are discussed through an overall description of the life cycle stages. The study concerning winter maintenance in Norway shows a good coverage of impact categories. While the last two (F. Amato et al. 2010; Yee 2005) studies focused on street sweeping are concentrated just on the emissions of GHGs and particulate matter.

Summary of LCA studies

- ***Comparative Life Cycle Assessment of Conventional and Green Seal-Compliant Industrial and Institutional Cleaning Products Online Resources*** **(Kapur et al. 2012)**

This study compares LCA studies of conventional and Green-seal compliant industrial and institutional cleaning products. Of particular interest for our study is the analysis that the Kapur study carried out about multi-purpose cleaner (green and traditional), and hydrogen peroxide cleaner.
The scope of the study is analysing the cradle to grave cycle of products including packaging and final disposal.

Results

This study examines and compares four types of general-purpose cleaning products:

- Green Seal-compliant (glucoside-based)
- Green Seal-compliant (hydrogen peroxide-based)
- Conventional ready-to-use
- Conventional concentrated

Green Seal cleaning product results have lower impacts across most of the impact categories.
The Hydrogen-peroxide based products have lower impacts for 15 impact categories while glucoside-based products produce lower impact just for 2 categories.

From the research, the formulation stage results in the strongest hotspots, with the main contribution to environmental impacts.
Conventional ready-to-use products show the highest environmental impact. For this kind of product primary packaging and transportation of finished products were the major contributors to environmental impact.
Concentrated products have lowest impacts concerning land transformation.

Figure 3 below shows a breakdown of LCIA results by the life cycle stages of Green seal-compliant products (glucoside-based). When compared to conventional products the Green Seal-compliant perform better for 5 indicators:
- Ozone depletion
- Terrestrial ecotoxicity
- Agricultural land occupation
- Urban land transformation
- Natural land transformation
  (Neto et al. 2014)

When compared to Green-Seal general purpose cleaners, the conventional ready to use (RTU) products performed worse in 13 impact categories:
- Climate change
- Human toxicity
- Photochemical oxidant formation
- Particulate matter formation
- Ionizing radiation
- Terrestrial acidification
- Freshwater eutrophication
- Marine eutrophication
- Freshwater ecotoxicity
- Marine ecotoxicity
- Water depletion
- Metal depletion
- Fossil depletion"
  (Neto et al. 2014; Kapur et al. 2012)

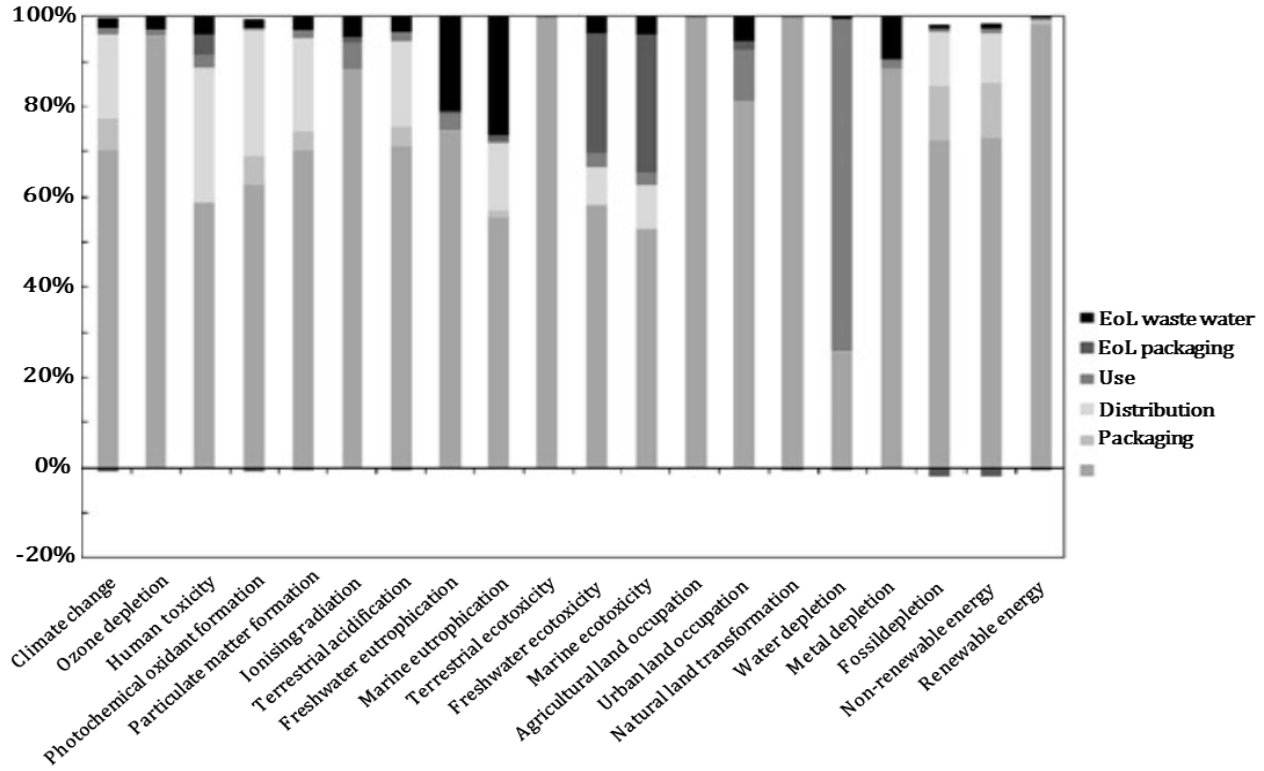

Figure 25: Breakdown of life cycle impact assessment results by life cycle stage for compliant general purpose cleaning products. (Kapur et al. 2012)

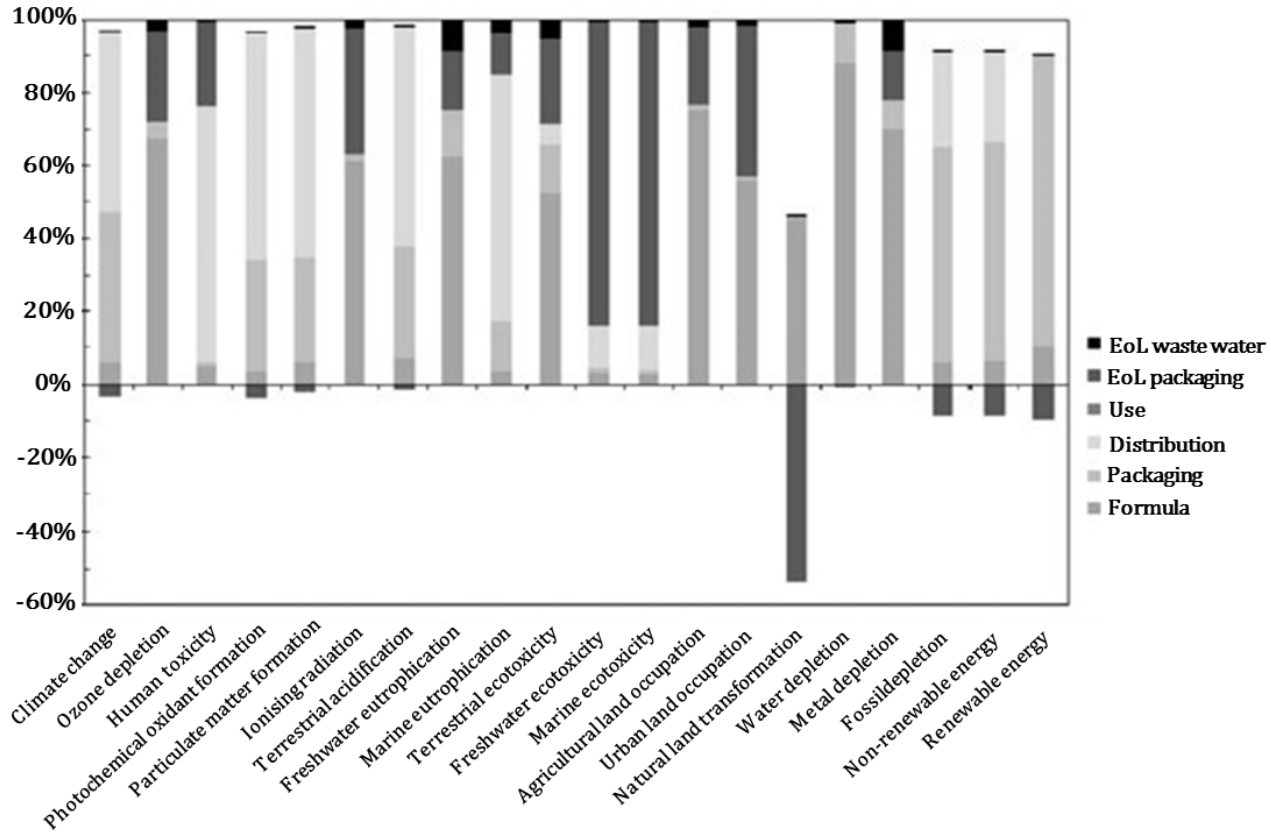

Figure 26: Breakdown of life cycle impact assessment results by life cycle stage for conventional RTU general purpose cleaning products. (Kapur et al. 2012)

- ***Dichiarazione ambientale di prodotto (EPD) di prodotti per la pulizia e l'igiene di ÉCOSÍ*** **(ÉCOSÍ 2011)**

This study has been carried out by the Ecosí company following the requirements of the General Programme instructions for the International Epd® System. Version 2.5 [91].
The assessment is about a cradle to grave environmental product declaration (EPD) study of various cleaning products used in public (indoor) services. The study concerns the life cycle assessment of surface detergents, detergent descalers, surface disinfectants, detergent for hard surfaces and all-purpose detergents.
Even if the scope of this study is not completely in line with the scope of our study, as we explained before, we decided to use it to gather information about all-purpose cleaning products.

Results

Firstly, in the study provided by Ecosí company, the results show potential impacts of products across three modules: up-stream, core module and down-stream module.
Secondly, the results provide some more information on resource depletion, non-renewable resources depletion and waste generation across the three modules mentioned above.

From the study, we can gather as a general trend that the upstream module (formulation of products) give the strongest contribution at environmental impacts.
In the figure below we show the environmental impacts founded for a sample product named 'Cherodal', which is an all-purpose acid-based cleaner, aimed at maintenance and cleaning of hard surface such as concrete or other kind of pavements (ÉCOSÍ 2011).

IMPACT CATHEGORY	UM	10l				50l				1000l			
		TOT.	UP.	CORE	DOWN.	TOT.	UP.	CORE	DOWN.	TOT.	UP.	CORE	DOWN.
GLOBAL WARMING (GWP100)	g CO_2 eq	942	767	90	84	1102	767	90	246	1060	749	90	221
OZONE LAYER DEPLETION (OPD)		-71	-74	0,85	1,86	-103	-107	0,85	2,68	-41	-43	0,85	1,06
PHOTOCHEMICAL OXIDANT FORMATION	g C_2H_4 eq	0,40	0,40	0,01	0,01	0,42	0,37	0,01	0,04	0,44	0,39	0,01	0,04
EUTROPHICATION	g PO_4^- eq	1,50	1,30	0,06	0,14	1,66	1,30	0,06	0,30	1,75	1,46	0,06	0,23
ACIDIFICATION	g SO_2 eq	5,20	4,75	0,20	0,27	5,98	4,76	0,22	1,00	6,11	4,93	0,22	0,96

Figure 27: Potential impacts of CHERODAL in three different packaging: 10l; 50l;1000l (ÉCOSÍ 2011)

- ***Nordic Ecolabelling of Industrial cleaning and degreasing agents*** (Nordic Ecolabelling 2016b)

This background document for the Nordic Ecolabelling contains a description of industrial cleaning and degreasing products and their environmental impacts through a life cycle perspective.
The Nordic Ecolabelling for this branch of products has previously been restricted to only products for indoor use. In this study, the product group has been expanded to include products for outdoor use. The study aims at the identification of criteria for the Ecolabelling. In order to assess which requirement should be set, in the study a simple LCA analysis was conducted using the MECO (Materials, Energy, Chemicals and other characteristics) methodology.

[91]Available at:
http://www.environdec.com/Documents/GPI/General%20Programme%20Instructions%20version%202.5.pdf

Results

The most important factors in assessing environmental impacts in the up-stream phase, are the choice of raw material both for the ended cleaning product than for the packaging. However, the main impact of a product lies in the use phase when the users are exposed to the product. In this phase, dosing and operational practice are crucial for the amount of product consumed and packaging required.

	Raw material phase	Production phase	Use phase	Waste phase	Transport phase
Materials	Materials for product and packaging. Extraction/production of chemical raw materials and packaging materials.	Production of product and packaging.	Properties of the chemicals, dosing, work environment, water use, water temperature during use. Wastewater, emissions directly into the water recipient.	Packaging, emissions from waste management.	Transport relating to distribution of raw materials and products.
Energy					
Chemicals					
Other					

Figure 28: MECO MATRIX (Nordic Ecolabelling 2016b)

In its end of life phase, a product may affect the environment because of contaminants in its waste water. Ecotoxicity, degradability, health impacts, energy depletion (including in raw materials extraction and manufacturing, packaging, distribution) and dosing stands out as key parameters in the Nordic Ecolabelling analysis.

Life Cycle assessment of Anti-icing and De-icing Operations in Norway (Vignisdottir, Booto, and Bohne 2016)

This study addresses the estimation of environmental impacts of production and the transport and distribution of chemicals during winter maintenance services. It particularly focuses on the transportation component of the service and also gives some insight on driving practices and vehicle loading levels.

The goal of the study is to map and analyze the activity of anti-icing and de-icing operations in Norway to provide a framework for effective services and also to provide general data for further LCA studies for the general topic of road maintenance.

Results

The results of this study are presented for 11 impact categories. The impact categories and the origin of the emissions are shown in Table 6 below.

From the results, it can be gathered that *"distribution of salt in Norway is the major contributor to all impact categories, with more than 99% share of total emissions. The only impact category that is slightly different from the others is acidification where freight transport contributes more than to the other impact categories. However, the main source of emissions is, like in distribution, the direct emissions of burning fuel during transport. Towards global warming, the main contributor is the direct emission of burning fuel under transport while the production and maintenance of the truck are almost exclusively the source of abiotic depletion. The production of diesel is responsible for over 84% of the impact towards ozone layer depletion but also the largest contributor towards photochemical oxidation. Surprisingly, break wear emissions from the truck is responsible for approximately 70% of the emissions towards human toxicity."* (Vignisdottir, Booto, and Bohne 2016)

Life cycle stage / Impact category	Production	Freight transport	Distribution	Total emissions
Abiotic depletion [kg Sb eq.]	0%	0%	100%	2.42
Abiotic depletion [MJ]	0%	0.02%	99.98 %	1.4×10^7
Global warming [kg CO2 eq.]	0%	0.02%	99.98 %	8.8×10^5
Ozone layer depletion (ODP) [kg CFC-11 eq.	0%	0.01%	99.99 %	0.16
Human toxicity [kg 1,4-DB eq]	0%	0.01%	99.99 %	4.0×10^5
Fresh water aquatic ecotox. [kg 1,4-DB eq]	0%	0.01%	99.99 %	1.1×10^5
Marine aquatic ecotoxicity [kg 1,4-DB eq]	0%	0.02%	99.98 %	2.7×10^8
Terrestrial ecotoxicity [kg 1,4-DB eq]	0%	0.01%	99.98 %	1.4×10^3
Photochemical oxidation [kg C2H4 eq.]	0%	0.07%	99.93 %	1.5×10^2
Acidification [kg SO2 eq.]	0%	0.11%	99.89 %	3.0×10^3
Eutrophication [kg PO4--- eq.]	0%	0.05%	99.95 %	7.1×10^2

Figure 29: Impact results per kilometer road in Norway during one average Winter (Vignisdottir, Booto, and Bohne 2016)

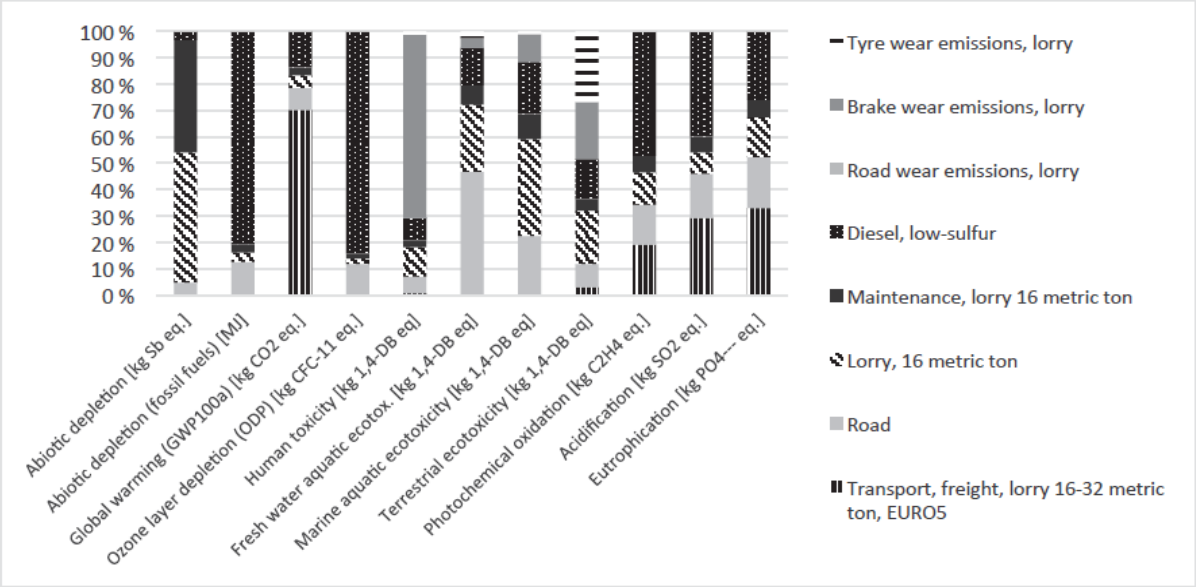

Figure 30: Emission source for the different impact categories. (Vignisdottir, Booto, and Bohne 2016)

-LCA for calcium magnesium acetate (Ritthoff 2011)

This study aims to investigate the environmental impact of CMA and to provide a comparison with the conventional salt used for winter de-icing activities.

As stated in the study, salt is the cheapest option for de-icing activities, but it has a number of relevant disadvantages. It could be harmful for the environment and it has a strong impact on the corrosion of infrastructures, cars and buildings.

Other de-icers commonly used like sand and ash could be harmful because of the increasing PM10 levels, and have to be swept after winter period.

A possible alternative is CMA, which can be used both as de-icing and as a binding agent for fine dust in street sweeping after winter operations.

The study is divided in two parts, the first is focused on the comparison of environmental impacts of salt and CMA on material intensity (MI) and for global warming potential (GWP).

The second part is a review of the corrosive behaviours of the different de-icers.

Results

In this study, from the comparison of the different de-icing products emerges that: *"all de-icers that have been investigated in this study have various impacts but the level and kind of impact depend on the composition of the de-icers but also on many factors beside the de-icer. Relevant aspects are for example the application rate, the winter precipitation rate, the specific road environment of the application and, the traffic volume. Therefore, the various kinds of damages that occur in application of de-icers are by far too complex to generate a valid general comparison of damages through their application in winter service. CMA reduces steel corrosion and groundwater chloride contamination compared to sodium chloride. But substituting CMA for sodium chloride may have unintended consequences in accelerating concrete and asphalt deterioration. Long-term field experiments with CMA are essential in order to determine the effects of long-term use of these de-icers under realistic conditions. Further investigations have to take into account the wide variation of commercially used pavements. Additionally, it should be investigated what happens if NaCl (sodium cloride) and CMA are used alternating. Taking into account the results of the different investigations on corrosion through de-icers it seems to be possible that CMA can increase the concrete deterioration and enable increased reinforcement steel corrosion by NaCl because of reduced steel protection and coverage.*

The reported results on corrosive effects of acetates in general and CMA varies highly. But there are relevant indications that acetates including CMA can lead to corrosion of concrete and asphalt. It seems that the composition of concrete and asphalt has a relevant influence on the resistance to corrosion due to CMA and other acetates. From the studies that have been evaluated it can be concluded that if CMA is used in winter service:

- *The CMA should have a low magnesium content.*
- *It should not be used if the aggregates contain relevant amounts of lime, dolomite or recycled concrete.*
- *Cleaning of the roads after winter can prevent the emulsification of asphalt binder with CMA at higher temperature."* (Ritthoff 2011)

- ***Environmental Life-Cycle Assessment of Winter Maintenance Treatments for Roadways*** (Fitch, Smith, and Clarens 2013)

This study provides a comparison of the environmental impacts of CMA and sodium chloride.

The LCA has been performed in three different scenarios: The first scenario uses the application of conventional rock salt modelled as dry granular NaCl , applied to the roadway following a small accumulation of frozen precipitation on the road surface. Subsequent, further applications of the same material were carried out based on precipitation intensity.

The second scenario was to apply brine of sodium NaCl followed by the application of granular NaCl that had been prewetted with brine. This scenario requires the application of the brine solution just before the storm event to prevent the formation of a bond between the frozen precipitation and the road surface.

The last scenario was a treatment with calcium magnesium acetate solution.

The study was carried out using the technologies and practices of the US Department of transportation (DOTs), which is in charge of winter maintenance.

Results

Winter maintenance using dry salt, brine and CMA were compared over the entire life cycle. The figure below shows the results of this study.

Maintenance approach	Energy use (MJ) × 10^4	GHG emissions (kg) × 10^3	Water use (m^3) × 10	Cl emissions (kg) × 10^3	BOD (kg) × 10^2	Cost ($/storm)
Salt (dry NaCl)	13.2 ± 6.0	10.5 ± 2.9	23.3 ± 5.7	20.4 ± 2.0	0.20 ± 0.07	3,149
Brine (NaCl brine)	8.7 ± 3.7	6.7 ± 1.9	15.0 ± 3.5	13.0 ± 1.4	0.12 ± 0.04	3,343
CMA (CMA brine)	129.3 ± 23.0	40.7 ± 6.9	580.2 ± 6.3	0.53 ± 0.2	135.8 ± 55.2	26,363
Δ_{Brine} (Brine–salt)	−4.5	−3.8	−8.3	−7.4	−0.08	194
Δ_{CMA} (CMA–salt)	116.1	30.2	556.9	−19.9	135.6	23,214

Figure 31: Environmental burden associated with three maintenance approach (Fitch, Smith, and Clarens 2013)

Form the analysis the sodium-chloride based treatment has shown significant lower impacts than CMA for four of five impacts areas. The figure also shows the differences in emissions among the different treatments to highlight the increasing or decreasing of emission cost.
The CMA has a 10 to 15 times higher cost concerning energy required for the delivery. Most of this energy is consumed in the up-stream phase during the manufacturing of the product. This impact also affects largest GHG emissions (four to five times greater than the other two treatments.
Even more pronounced differences between the treatments were observed when considering the biochemical oxygen demand of the treatments. The total BOD emissions associated with CMA production were approximately 600 and 1,000 times greater than for NaCl and brine, respectively. This burden came largely from acetic acid production but also from the runoff following application.(Fitch, Smith, and Clarens 2013)
In regards to water depletion, CMA has a far higher impact because off the water needed for resource extraction.
As expected sodium chloride has a stronger impact on the environment just from chloride emissions.
In conclusion, CMA performs many times worse than the other chloride-based option. *The salt-based treatments consume considerably less water, energy, and generate fewer greenhouse gases and biochemical oxygen demand in receiving waters. Applying the chloride chemicals as a brine rather than in the dry form, results in significant reductions in all environmental impacts over the entire life cycle. This result is consistent for a variety of climate conditions (e.g., representative of coastal, piedmont, and mountain climates) considered for this study, which used historical weather data from Virginia.*
Although the comparison of environmental impacts is strongly dependent on the energy sources available. For that reason, an overall analysis has to be done on the less desirable impact factors (e.g. in some cases it might be preferable to reduce chloride emission risk to a watershed at the cost of increased energy used in the upstream).

9.3.2 Summary of other relevant studies

- ***Road Surface Pollution and Street Sweeping*** **(Yee 2005)**

The objective of this study is to investigate the environmental effects of street cleaning in urban areas.
The study bases its result on the comparison of different urban areas in the cities of Berkeley and Oakland California. Some of the streets were treated with sweeping and

some others remained untreated. Moreover, the different areas are characterized by the variety of morphological characteristics and different traffic intensity.
The results show that differences between opt-out and sweep streets cannot be seen as a whole with all the samples combined, but can only be observed site by site.

Results

Results of the study show that street sweeping in not effective in reducing pollutant levels. The differences observed among the areas between opt-out and sweep streets, depend on many factors.
First the abundance of pollutants on roads is site specific and the effectiveness of sweeping also depends on the pollutants intensity.
If sweeping reduces the total amount of sediment and hence metal and nutrient loads on streets, but fail to pick up the finer particles, the remaining sediment becomes increasingly fine-grained and the concentration, or proportion of metals and nutrients present in road sediment, increases. (Yee 2005)
Also, the operations that use water to suppress dispersion of dust leave behind a layer of dust that increases the binding effect for pollutant.

- ***CMA+ - PM10 reduction by the application of liquid Calcium-Magnesium Acetate (CMA) in the Austrian and Italian cities Klagenfurt, Bruneck and Lienz*** **(Layman 2012)**

This study is a technical report about the 'CMA+' project aimed to improve the air quality in three target municipalities of Sweden by reducing PM10 re-suspension through use of liquid CMA as a dust-binder on roads, construction sites and unpaved roads.
Moreover, the study analyses the quality of CMA as de-icer in comparison with sodium chloride.
The target of the project was to reduce re-suspension by up to 30% and PM10 levels in the ambient air by up to 10% (related to the annual mean) around roads. In addition, the project aimed to reduce PM10 levels by up to 50% around construction sites or unpaved roads.

For this purpose, the CMA was used as binding agent on road surfaces. Pollution measuring campaigns were carried out to determine the effect of CMA on PM, capturing PM10, NOx (nitrogen oxides) taking in consideration meteorological parameters and traffic conditions.
For the application of CMA as a de-icing agent, the target of the project lay down in the improvement of friction potential of CMA. The result was a new product obtained by the mixing of 10% potassium and 90% CMA. The environmental impacts of the new products were compared with the impacts of sodium chloride.

Results

From the application practice of the CMA it is stated that: *"if applied consistently as a fine-dust suppressant, CMA is able to achieve a clearly measurable PM10 reduction in the ambient air at curbside measuring stations (up to 30% relative to the daily average, 10%–20% in the winter months, 5%–10% on an annual average).*
Provided that the dose of 10g/m2 is not exceeded and spread evenly and provided that bends, roundabouts, intersections, pedestrian crossings, slippery roads or roads in a bad state of repair remain untreated, no negative impacts on traffic or consequential damage are to be expected on public roads. (..) The time when CMA should ideally be applied depends on factors such as the level of PM pollution, air humidity, temperature, precipitation and traffic volume. If PM pollution is clearly below the limit values, in case of high air humidity (above 80%) or if precipitation is to be expected, there is no need to

apply the fine-dust-glue. CMA is very effective as a de-icing agent, albeit only as a preventive measure. The combined use as a fine-dust glue and as a de-icing agent is therefore possible and so is its combined use with road salt. As a de-icing agent, application is recommended in pedestrian zones and sensitive areas to avoid environmental damage resulting from the use of conventional road salt.
CMA:KF MIXTURES ARE MORE EFFICIENT AS REGARDS BOTH THEIR DE-ICING AND THEIR FINE-DUST-BINDING EFFECT, WHICH ALSO LASTS LONGER COMPARED TO THE PURE CMA PRODUCT. THE OPTIMAL EFFECT IS ACHIEVED IF CMA AND KF ARE MIXED AT A RATIO OF 50:50. HOWEVER, THIS HAS NOT BEEN FIELD TESTED YET. A VERY GOOD AND LONG-LASTING DUST-BINDING EFFECT (AT LEAST -50%) IS ACHIEVABLE ON UNPAVED SURFACES AT A CMA DOSE OF AT LEAST 100-200 G/M2." (LAYMAN 2012)

-REDUST - LIFE09 ENV/FI/000579 - FINAL REPORT COVERING THE PROJECT ACTIVITIES FROM 01/01/2011 TO 31/12/2014 (REDUST 2015)
The use of traction control materials and winter tires are the main environmental factors leading to street dust accumulation during and after winter.
In particular during spring, with decreasing precipitation and humidity levels, and the rise of temperatures, street dust becomes a significant air quality issue in Finnish cities.
The spring dust season typically lasts for approximately two months between March and May.
With this in mind, the aim of REDUST project was to find the most effective winter maintenance practices in the fields of traction control, dust suppressing and street cleaning and accelerate their implementation to reduce levels of breathable PM10 street dust in urban areas.

The project was divided into six Actions:
Action 1: Demonstrations of best practices to reduce PM10 street dust by means of winter maintenance
Action 1.1 Traction control practices (winter tires, traction sanding)
Action 1.2 Dust binding practices (dust binding solutions, dispersion techniques)
Action 1.3 Street cleaning practices (mechanical & vacuum sweepers, street scrubbers, combinations)
Action 2: Emission estimations and mitigation potential of the practices
Action 3: Total PM10 emissions, reduction potential and cost estimations of the measures to support the strategy development
Action 4: Development and implementation of the feasible winter maintenance strategy to reduce street dust emissions compared with current state
Action 5: Communication and dissemination
Action 6: Project Management & Audit (REDUST 2015)

Results:
The REDUST project confirmed that dust emissions from newly studded tires were higher compared to winter tires without studs on clean roads. This finding supports the hypothesis that reducing the number of studded tires would decrease street dust originating from pavement wear.

The use of traction sanding was also found as a main issue for dust emissions, especially if the quality of the rock material used for traction sanding was sub-optimal. For that reason, the use of not-sieved sand should be avoided. For the purpose of removing the fine grain sizes (<1-2mm) the practice of wet-sieving has been found to be the most effective.
However, the use of traction sanding should be reduced as much as possible and should target areas with a high need for traction, e.g. junctions, bus stops, hills and traffic lights.

Concerning the use of dust bindings, the study found that its application is only effective as a short-term method of dust mitigation. For that reason, the schedule of treatments should be optimized in order to prevent peak of dust loads in the street environment.

For the tests, the dust binding solution used was a 10% CaCl2.

In order for dust binding to be considered an efficient method of street cleaning, improved air quality must show a relative reduction of PM10
Modern street scrubber (PIMU) was found to be the most effective street cleaning technique. It was especially efficient when used on very dusty streets, which had high load of fine street dust material.
Traditional vacuum sweeper alone was not efficient at reducing PM10, better performances were measured combining the operation of traditional sweepers with a separate washing lorry, which flushed the street with high pressure water sprays (combination cleaning).

In conclusion, based on the REDUST studies it may be estimated that up to 25% reduction in the PM10 street dust emissions during spring dust period can be achieved in busy urban traffic locations with improved dust binding and street cleaning actions.

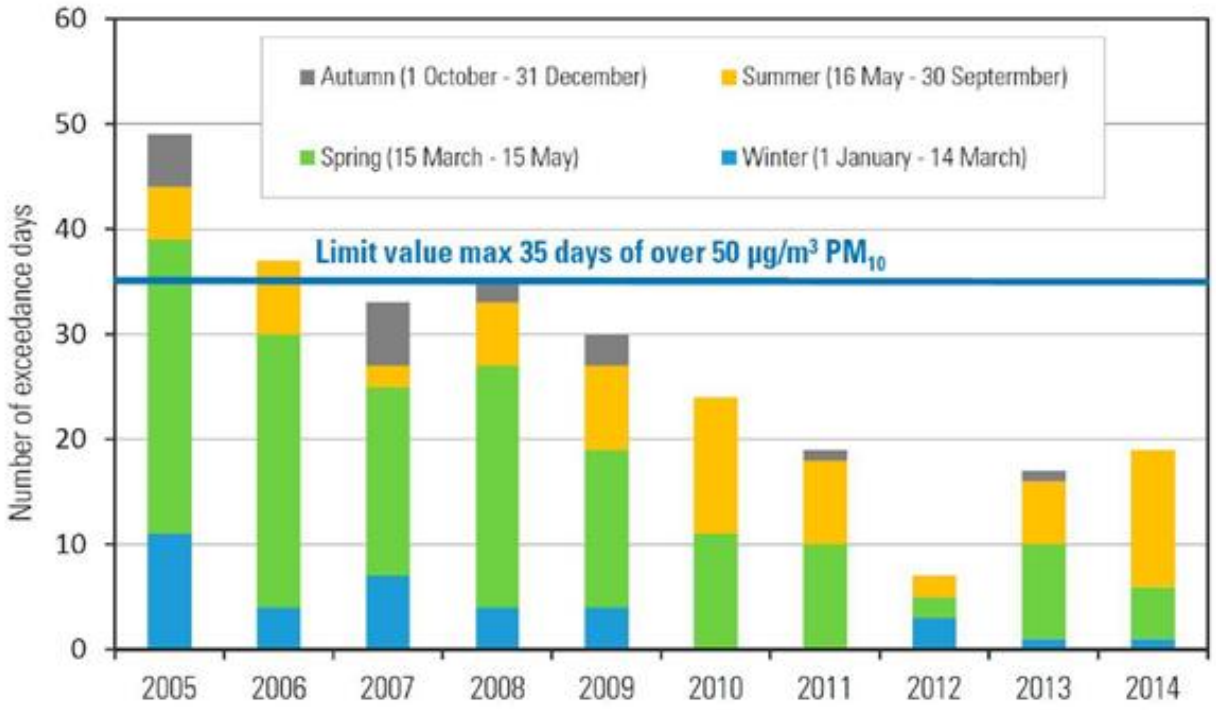

Figure 32: The number of daily limit value exceedance days at Mannerheimintie (Helsinki Centre). The number of exceedance days of PM10 daily limit value level (50 µg/m3). The limit value has not been exceeded after 2006 and the trend of spring-time exceedance days (green bar sections) is clearly declining. Positive development continued during REDUST years 2011-2014. During the year 2012 weather conditions were very favourable for street dust mitigation, which led to exceptionally low number of exceedance days. (REDUST 2015)

In the figure, the relevant results achieved in 2012 are due to exceptional mild and humid weather conditions. In 2013 the concentrations were somewhat higher than in 2012, but the overall downward trend remained.
In particular the positive trend over the years seems to be related to the improved strategic street maintenance actions, such as dust binding and improved street cleaning actions.

Moreover, dust binding practices were found to be a very fast and cost-efficient measure to decrease PM10 resuspension from busy and dusty streets.
Typical costs were for
1) dust binding targeted to street kerbsides 40 €/km,

2) traditional cleaning with vacuum sweeper often complemented with water spraying 400 €/km, and
3) improved cleaning with modern street scrubber 600 €/km.

In considering the evaluation of costs, these processes are not comparable since best practices require the combination of different methods.

Of course, lower cost efficiency can occur after rain precipitation, in concomitance of lower traffic rate and when the operations are carried out too late in spring.
In the REDUST experiments, the lowest costs (8−17 €/kg) were achieved in the Helsinki routes, where the frequent use of dust binding in busy streets decreased costs per reduced dust.

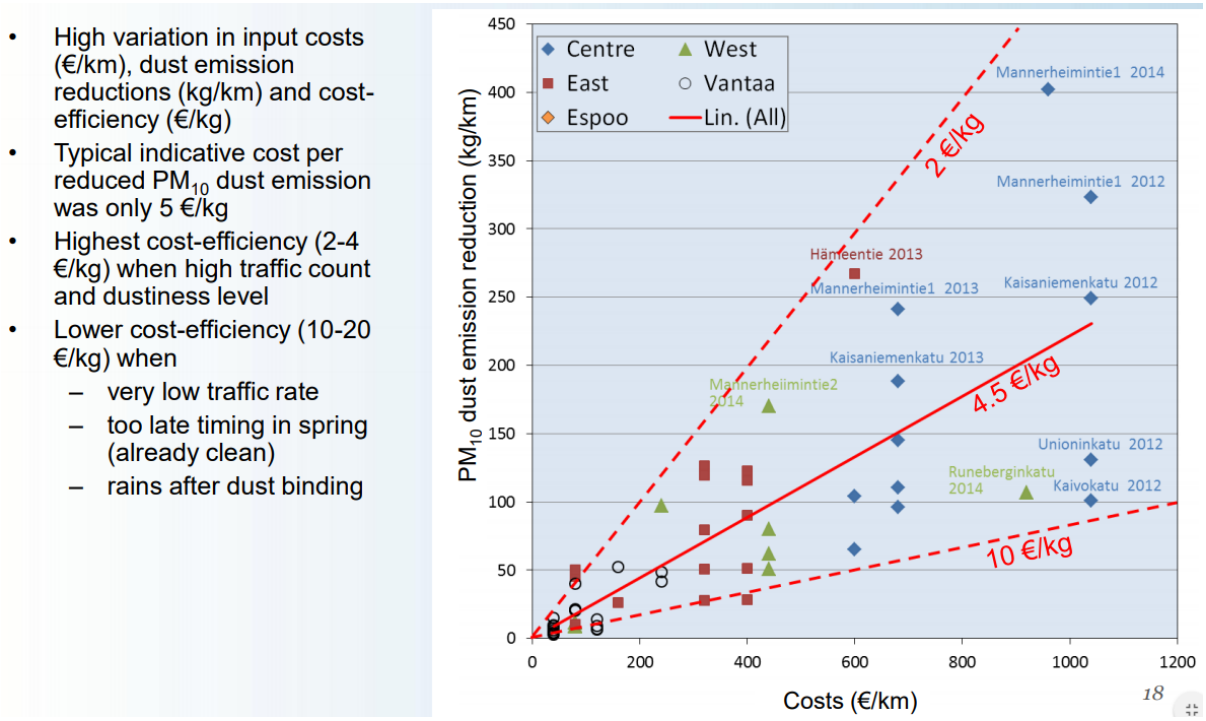

Figure 33: Cost-efficiency of dust binding (Niemi 2014)

- ***A review on the effectiveness of street sweeping, washing and dust suppressants as urban PM control methods (F. Amato et al. 2010)***

Sweeping, water flushing and use of chemical suppressant are the common method to try to diminish the accumulation of fine dust in urban areas. Evaluating the effectiveness of the techniques is a difficult task because the results depend on many factors.
This study provides a literature overview of the main research on the field of street sweeping to the contention of environmental impacts related with PM10.
In the first part, the study gives an overview of the technical characterization of current technologies and products.
In the conclusion, it explains the real effectiveness of the current technologies with respect to sediment removal and reduction of ambient air PM levels.

Results

Results for the effectiveness of street sweeping are confusing. From the literature review; in general, mechanical broom sweepers can easily pick large particles and debris, while the regenerative-air sweepers are recommended for fine dust.

A part from the kind of vehicle in use, many factors influence the effectiveness of street sweeping, these factors include: environmental conditions, particle size, sweeping frequency and time, surface type, moisture and quality state and the presence of parked cars on the street lane.
The study concludes that the best practice is a tandem operation, where the street is first cleaned with a mechanical street cleaner, followed by a regenerative-air street cleaner to remove particles.
In an average normal climate condition, it is recommended to sweep just on the lane of the street, in fact it is demonstrate that the dirty and dust is mostly concentrated at 2m from the extreme lane.
However, concerning the main purpose of the study which is the effectiveness of street sweeping for dust reductions, it shows that street sweeping alone was ineffective in reducing PM10 concentration.
When water flushing is combined with the sweeping the results seems to be more encouraging; although this could be just the results of the adherence of dust at the street surface due to wet conditions.

9.4 Overview of environmental impact hotspots of cleaning services

Literature identification, review and selection have given us an understanding of the environmental impacts of different types of cleaning activities, providing a framework for the identification of the main hotspots of the Life Cycle of services and products.

A summary of the quality and availability of environmental impact assessment literature for cleaning services is provided below:
Literature availability – Existing studies on the environmental impact of cleaning services for public space maintenance present a comprehensive knowledge base on street sweeping practices and winter maintenance, including environmental performances of related products such as dust binding and de-icing agents. Less material has been found on the specific topic of cleaning products for open space activities, being most of the literature dedicated to cleaning products for in-door use.
Impact category coverage – only a few selected studies have adequate coverage of impact categories, moreover due to the variety of topics that have been treated it was not reasonable to carry out a comparison of the environmental impacts of the different service/products that have been analyzed.
Representative study for cleaning services – There is expansive precedent work in line with the scope of our study. This literature allowed for emphasis on specific environmental impacts and improvement areas along the life cycle of different services / products, as well as identifying best practices in the field of cleaning services for public space maintenance.
The following section is a summary of the prevailing environmental concerns as reported in the referenced literature results.

Production phase

Raw materials
The production phase of cleaning agents or of de-icing/binding agents could have significant impacts for terrestrial ecotoxicity, land occupation, land transformation, ozone depletion and metal depletion.

The ingredients of cleaning products are important contributors of environmental impacts. *"Of all ingredients, the major part of the environmental impact is caused by the*

surfactant ethoxylated alcohol, which is commonly found in general purpose cleaners (Kapur et al., 2012).
"Surfactants are of mixed origins, i.e. both oleo chemical origin (palm and coconut resources) and petrochemical, which has an effect on both natural land transformation and agricultural land occupation. For the impacts related to ozone depletion and metal depletion, the ingredient ethylene glycol diethylether caused the largest share of the environmental impact." (Neto et al. 2014)
Polymers and solvents tend to come from fossil raw material that are also no renewable.
Renewable raw material may also constitute an environmental problem if related with the destruction of tropical rainforest in favour of plantation. (Nordic Ecolabelling 2016b)

As found in the review of previous studies, surfactants and polymers are also used as binding agents; for that reason, the environmental impact of the up-stream phase of these products must also be considered in order to evaluate the life cycle of dust control operations.
Furthermore, in the up-stream module, also CMA is found to have a strong impact for gas emission, energy and water depletion because of the energy needed for extraction and manufacturing of product. (Vignisdottir, Booto, and Bohne 2016)

Manufacturing
Impact for human health, energy and water depletion.
The majority of cleaning products come in liquid form, they are diluted with water and solvent.
During production, there is a risk for employees to being exposed to the raw materials.

Packaging
Significant impacts for climate change and energy consumption should also consider the use of petrol-based materials related with the production of packaging.
The selected LCA studies have confirmed that primary product packaging is a key environmental impact hotspot for cleaning products. *"By reducing packaging material or even avoiding via the use of return or refill system, the environmental footprint of a product can be reduced. For conventional general-purpose cleaners, primary packaging can be amounted for about 40% of the climate change impact. The environmental impact of packaging is most significant for ready-to-use products because they require higher volume of primary packaging."* (Neto et al. 2014)
Plastic for packaging comes from fossil resources, it also could be produced from renewable resources such corn and sugar cane.
In the market of industrial cleaning products, the amount of recycle material used for packaging remain small.

Transport
Significant impacts on climate change, energy consumption, fossil fuel depletion and particulate matter emissions are related to the distribution and transport of cleaning products as well as binding and de-icing agents.
Due to the nature of cleaning services as part of public space maintenance, the transport of a great amount of materials (e.g. during the spreading of binding agents or de-icing products) is a significant factor, therefore the transportation associated with these services must also be considered.
Aside from the efficiency of routes travelled, the environmental impact of emissions related to transport is highly dependent on the weight of the load the vehicles carry. Product distribution methods should be reassessed to highlight potential changes that could decrease environmental impacts. Emphasis should be placed on diluted cleaning products, because of the difference in weight and volume from the added water.

Regarding winter maintenance and dust control operations, transportation of salt or diluted products such as binding agents is an important factor, since the distances travelled are very significant. The transportation of salt is especially significant because it

starts from the excavation point, continues through distribution, and includes the use and spreading of the salt. (Vignisdottir, Booto, and Bohne 2016)

Use phase

Significant impact for water depletion, freshwater eutrophication and ecotoxicity, human toxicity, marine ecotoxicity, ionizing radiation and urban land occupation are related to the use of chemicals and materials from cleaning services for public space maintenance.

"Water is used for product dilution and rinsing. The use phase of cleaning products, mainly associated with the product dilution, accounts for up to 88% (water depletion) of impact contribution." (Neto et al. 2014)

In the branch of cleaning products for professional application, ecotoxicity and the degradation of the products' chemical composition has the strongest environmental impacts.

Industrial products often come concentrated, so a great amount of water is needed for dilution; however, in most cases the water does not need to be heated so there is minimal processing.

The increase in environmental impact could also be related to excessive and unnecessary use of products. An increased demand and consumption of products leads to a higher rate of extraction of raw materials, as well as an increasing amount of packaging, and a higher emission of chemicals into the sewerage system.

Nevertheless, the impact of industrial cleaning and degreasing agents is of greater importance, as is dust bindings and de-icers, which are usually applied using machinery equipped with measured dosing systems. The usage of these kinds of products has to be consistent and portioned before their application. The correct dosage must be determined as a result of technical evaluation and assessment of efficiency, and must be subsequently measured before proceeding with their application. This will make a significant difference in the environmental impact of both dust suppressant and de-icer spreading.

End of life

The end-of-life stage of cleaning products, de-icing and binding agents is considered directly following their application as they are left to release particles into the environment. Their release could mean significant impacts for freshwater and marine eutrophication, material intensity and ecotoxicity.

Kapur (et al. 2012) shows that the end-of-life stage of cleaning products in the sewage system has significant impacts on the freshwater and marine eutrophication. In addition to the residues of cleaning agents, waste water may also contain residues of oil and dirt from the surfaces that are being cleaned.

In outdoor cleaning operations, waste water doesn't always runoff into the sewage system, although a consistent amount of material may runoff in the soil or in other water ecosystems, generating a strong environmental impact on the biological life, as it may alter the pH level, salt level and environmental toxins. (Nordic Ecolabelling 2016b)

The release of salt during winter maintenance operations and dust control operations also has an impact on water ecosystems and soil, moreover the use of salt leads to the deterioration of metals.

"During winter, road salt is released into nature in waves, which can lead to a rapid change of salt in the surface water. This rapid change can have deteriorating effects on the water quality. It has been shown that chloride levels in roadside stream increase dramatically and is carried downstream. With a continued build-up of chloride in lakes, it can have serious effect on the use of the water in the future. Additionally, a large proportion of the salt can leach into the groundwater where drinking water supplies can be affected by the chloride concentration. Salt contaminated run-off water main impact surface water in several ways. It can alter both physical and ecological characteristics of lakes with insufficient mixing of denser deeper layers and fresher upper layers. Seasonal mixing is essential for oxygen transfer in the lake that is necessary for continued animal and plant life in lakes. Toxic metals in sediments can also be release as a result of high

salt concentration in water bodies. Release of toxic metals such as mercury can lead to lake stratification which again effects animal and plant life.
The effects of salt on soil are not as serious as the effects on water. However, it has the potential to increase overland flow, surface runoff and erosion while decreasing soil permeability and aeration. The impact of salt can therefore be assumed to potentially increase emissions that contribute to categories like fresh and marine water aquatic ecotoxicity and terrestrial ecotoxicity." (Vignisdottir, Booto, and Bohne 2016)

The release of other products in the environment, such as CMA for dust suppression or de-icing operation has less environmental impact on water and soil ecosystems, but it can affect concrete structures.

CMA is less corrosive against steel and other metals compared to sodium chloride, but due to the diffusion of corrosion protection for cars, this is no longer of high relevance.
Studies found that even a low concentration of calcium magnesium acetate can cause measurable damage to concrete that results in loss of material (Ritthoff 2011).
Beside damages to concrete there are some concerns about acetate as it relates to the deterioration of asphalt. Loss of asphalt pavement structure and elasticity has been noted in other studies that attribute the cause to emulsification mechanisms (Ritthoff 2011).

In addition to a comprehensive review of existing literature focusing on the complete Life Cycle of de-icing products, a wide variety of literature is available on a diverse range of environmental issues and specifically related to the use of salts or acetates such as calcium magnesium and potassium[92].
Analysis of ecotoxicological characterization with different bioassays found that CMA were more toxic than inorganic salt (Joutti et al. 2003). In particular, it has been found that KF was the most toxic, and that the ranking of toxicity was KFo > KAc > CMA > $CaCl_2$> NaCl > $MgCl_2$, with potassium formicate at the lower end of the scale as the worst performing chemical composition, and the Magnesium chloride the best.
The negative effects of the application of de-icers are far too complex to generate a valid general comparison of damages by application in the winter season (Ritthoff 2011). Results from these studies can be conflicting, while some are critical of salt's strong environmental impacts (Vignisdottir, Booto, and Bohne 2016; Blomqvist 2001), others underline its economic and environmental convenience, charging CMA as being a worse alternative (Fitch, Smith, and Clarens 2013; Ritthoff 2011).

Finally, the use of traction sand on the street surface during winter maintenance operations is another environmental concern. This practice seems to have a strong contribution to the production of PM_{10} after snow and ice melting. PM_{10} is a significant factor that can be detrimental to the population's health, and it is a very difficult pollutant to control (Nixon 2001; Layman 2015).
The extent of the production of fine dust from traction sand is dependent on the quality of material. Lower dust emissions were measured for wet sieved traction sanding material from which the finest size fractions (<1–2 mm) were removed. The choice of traction sanding material and quality control will help mitigate street dust emissions (Kupiainen 2016).

9.5 Environmental improvement areas

In this section, we investigate the potential of the services and products analysed above, in order to identify possible environmental gains.

[92]Main publications on the effect of de-icing chemicals on ground water: http://www.syke.fi/en-US/Research__Development/Research_and_development_projects/Projects/Migration_of_alternative_deicing_chemicals_in_aquifers_MIDAS/Main_publications_on_the_effect_of_deicing_chemicals_on_ground_water

Cleaning products

1. Use of cleaning products with lower environmental impact

As stated in the PRC (Neto et al. 2014), cleaning services that use products with low environmental impact have lower overall impact.

"Ecolabels provide a reliable and easy way for cleaning service providers to identify cleaning products with improved sustainability performance.
For example, products carrying the EU Ecolabel for all-purpose cleaners are guaranteed to have the following merits:
- *a reduced total quantity of chemicals,*
- *limited substances harmful to the aquatic environment,*
- *increased biodegradability,*
- *less packaging,*
- *an efficient wash,*
- *carry reliable consumer information.*

Cleaning service providers who aim to improve the sustainability of their operations should make conscious effort to use ecolabelled cleaning products." (Neto et al. 2014)

However, the environmental consequences of both fossil and renewable materials are crucial, and it is important that raw materials come from a sustainable production chain as more as it is possible.
Products containing raw materials with low eco-toxicity and good degradability, affect the environment to a lesser degree than conventional products with non-readily degradable and toxic row materials.

Regarding graffiti removal, recommendations can be gathered from the document on good practices in garden maintenance related to the city of Barcelona (EU Commission 2014) and in the SPP from Netherland (PIANOo 2011). As it is specified in these documents, chemical or abrasives for graffiti removal should be applied carefully without interfere to plant life.
The use of machines with water collection systems should be preferred if it's possible, otherwise, chemicals should be used as a last resort for removing graffiti. Treatment with pressurized water or sand is recommended.

2. Cleaning product concentration

As found in many studies, the weight and load levels of vehicles during transportation have a strong impact on the environment. For cleaning products, it is recommended in the PRC (Neto et al. 2014) that: *"Transporting concentrated cleaning products is preferable in environmental terms as it avoids the need to transport the water used for product dilution. Concentrated products also reduce the amount of packaging per dose, further reducing environmental impact by saving materials and weight. Key types of transport-related environmental impact reduction include reduced fuel consumption, greenhouse gases emissions and particulate matter emissions."* (Neto et al. 2014)
"*For cleaning service providers, the best practices for cleaning product procurement and logistics include:*
-Purchase concentrated cleaning products to transport them in concentrated form and delivery in bulk
-Posterior dilution at sites" (Neto et al. 2014)

However, industrial cleaning agents often come in large packs with a relatively small quantity of packaging per dosage, thus in this case there is no need for particular requirements.(Nordic Ecolabelling 2016b)
In professional cleaning services, products are used in large volumes, and so effective practices are of main importance. Products that are dosed correctly reduce consumption which lowers costs and lowers environmental impacts.

Cleaning machines commonly use automatic dosage systems, providing an opportunity to reduce overdosing the product.

3. Recycled materials in cleaning supplies

The use of recycled materials reduces the environmental impact of products by reducing the need to extract and process virgin materials. Cleaning equipment and brush and bin bags should be done with recycled materials to reduce environmental impact. (Neto et al. 2014)

In outdoor activities, the application of cleaning products is carried out mainly with the use of machinery or vehicles. Also for this branch of products there is strong improvement potential in the use of recyclable parts and materials. These aspects will be explored further in the proper chapters dedicated to machinery and vehicles.

4. De-icer products

De-icers are essential to wintertime road maintenance. There has been a growing concern about the environmental effects (e.g. in Northern Europe) from de-icing due to the use of road salts (NaCl, $CaCl_2$ and $MgCl_2$), especially in groundwater (Joutti et al. 2003). Alternative new organic de-icers, for example potassium formicate, potassium acetate, and calcium magnesium acetate, have been tested to determine if they have less harmful impacts on soil and groundwater (Joutti et al. 2003). Nevertheless, the convenience of CMA is still debated. For example, CMA has a lower abiotic material intensity but a much higher GWP compared with sodium chloride (brine and salt)(Fitch, Smith, and Clarens 2013). Other advantages and disadvantages for the categories air and water consumption depend on the application (Ritthoff 2011).

Due to the corrosive properties of CMA against concrete and asphalt it seems that the composition of those materials can influence on resistance to corrosion.

From the studies consulted it can be concluded that if CMA is used in winter service, the best practices to follow are:

- *The CMA should have a low magnesium content.*
- *It should not be used if the aggregates contain relevant amounts of lime, dolomite or recycled concrete.*
- *Cleaning of the roads after winter can prevent the emulsification of asphalt binder with CMA at higher temperature.* (Ritthoff 2011)

Moreover: *"if CMA is used once in four days for anti-icing, CMA has advantages in all categories of material intensity* (Ritthoff 2011).

However, according previous research, the use of salt based de-icing or the use of potassium based (CMA) has to be carefully managed with respect to many general conditions.

On average, we can conclude that:

- Since the main impacts of CMA are related to the UP-stream phase (Fitch, Smith, and Clarens 2013) with a strong impact on energy depletion, the availability of alternative energy sources is a good scenario for the implementation of CMA application.
- Since the main impacts associated with salt based application occur in the down-stream phase, its application should be managed carefully with particular care given to the water runoff scenario (Ritthoff 2011). The proximity of water ecosystems, the possibility of water precipitation, and the absence of sewage systems are all factors to take into account for the planning of salt operations.

5. Binding agents

In addition to de-icing agents, the previously conducted studies on the use of salts and acetates for dust suppression show discordant results.
A useful summary of European state-of-the-art experiments and practices on dust control practices has been provided from publications curated by the research group of the AIRUSE project (Querol et al. 2016; F. Amato et al. 2010).

Based on a review of most relevant European literature, the AIRUSE study (Querol et al. 2016) concludes that in Northern and Central Europe dust suppressants are effective where the road dust load is high, such as in region where the use of studded tires and de-icing agents lead to high PM10 concentrations when the snow melts in the spring. The study also underlines that the effectiveness of dust suppressant has been noticed in regions with relatively wet climates (Sweden, Norway, Finland, Netherlands, UK, Germany, Austria and North Italy).

In short, the conditions that contribute to the effectiveness of binding agents are:
- High dust loading (studded tires, road sanding)
- Low solar radiation
- High humidity

For Southern Europe, where solar radiation is higher the AIRUSE project demonstrated that street washing is a more effective method for dust suppression compared with binding agent spreading.

6. Packaging
"Packaging is used in large quantities for transporting and storing cleaning products. The environmental analysis has identified packaging as an environmental hotspot for cleaning products and consequently it has significant environmental implications for cleaning services. Cleaning service providers should look for cleaning products that use packaging materials with a lower environmental impact." (Neto et al. 2014)

The following list includes examples of how the sustainability of packaging can be improved by altering raw materials:

-Avoid chlorinated plastics such as PVC
-Use recycled content and recyclable materials
- Use mono-material (single material) parts that can be separated and easily collected for recycling.
- Reduce packaging sizes
(Neto et al. 2014)

Cleaning operations

1. Dust control
From the literature, street sweeping alone is not being found effective in reduction of fine dust in urban areas.
The results of tests on practice depend on many variables.
As concluded from the literature review we can consider the following more effective practices:
- the use of tandem operations, with a previous cleaning of the street with a mechanical sweep cleaner to remove the large particles, leaf and debris, followed by a regenerative-air street cleaner to remove the finer particles (F. Amato et al. 2010)
- the use of biding agents like CMA:KF which is a mixture of 10% of potassium and 90% of CMA.(Layman 2012)
- water flushing in combination with street sweeping.

Water washing can reduce the mobility of dust load deposited on street surfaces, decreasing the possibility of suspension and transport, especially since the coherence of wetted particles often persists after the water has evaporated due to the formation of aggregates.
Water flushing can be integrated in a street sweeper or manually applied by means of hosepipes. Street sweeping alone has not proven to be effective in the reduction of fine dust in urban areas over the short-term, though they may show more effective results over the long-term. These results were not excluded (Querol et al. 2016).
Nevertheless, even though the studies register a reduction of pollutant dust in the air due to the practice of sweeping on a wet street, the result cannot be considered absolute. The improved results in air pollution is due to the 'displacement of particles' from the ambient to the wet street surface (F. Amato et al. 2010). This phenomenon results in a strong intensity of fine pollutant materials at street surface and in the production of sludge (Yee 2005).

Furthermore, from previous studies we can assume that the recovery of dust emission after cleaning operations or binding spreading is very fast (on average 70-99% depending on weather conditions). Evaporation is the principal element in measuring the collection of road dust emissions. Based on these results it can be concluded that road washing activities and the spreading of binding agents should be performed in the first hours of the morning (5-6 am), in order to minimize the morning peak of emissions (7-9 am). For the same reason, it is also recommended to establish a continuous light but frequent moistening of roads instead of an intensive occasional cleaning (Ritthoff 2011; Fulvio Amato et al. 2012)

2. Winter maintenance

Concerning the best practice of de-icing operations, the study of Fitch et.al (2013) on the comparison of LCA of three de-icing options (salt, CMA and brine) conclude that: "*of the three approaches the use of brine appears to be the best option. This option requires less total energy, releases fewer GHGs, consumes less water, and emits less BOD (biochemical oxygen demand) than either CMA or dry salt. The benefits of using brine over using dry salt were significant, typically on the order of 30–40%. The storm conditions were found to have an important effect on the savings that could be realized by using brine.(…) For regions where storm intensities tended to be relatively mild, the benefits associated with using brine were even more significant. (…) The volume of water needed for brine production was extremely small compared to the total water used for the salt mining process. (…) A switch to using salt brine as a treatment method, rather than rock salt, enhances efficiency and reduces total energy use, water use, and greenhouse gas emissions without requiring a significant financial investment."* (Fitch, Smith, and Clarens 2013)

The storage of de-icing products is also an important concern of LCA for winter operations. For that reason it has to be carefully planned due to the risk of producing runoff in water courses (Vignisdottir, Booto, and Bohne 2016).
Road salt or sand/salt stocks should always be protected from precipitation or surface runoff. The storage facility should preferably have an asphalt pavement to prevent loss of materials in the soil (Vignisdottir, Booto, and Bohne 2016).
Permanent storage structures afford the best protection, however where storage facilities are not available, the use of polyethylene sheets and spray coating are certainly a better alternative to open storage.
Considering noise levels and general aesthetic conditions, salt storage areas should be located away from residential zones.

Finally, for best winter maintenance practices the control of the quality of traction sand material is an important concern, best practices from Northern Europe indicate that only washed and sieved gravel should be applied, with grain size of 1 to 5.6 mm for driveways and 3 to 5.6 mm in pedestrian areas with the mixing of some salt to prevent clogging (Ritthoff 2011). The amount of salt used varies between 5-60 g/m2 (minimum for a dry condition, maximum for a wet, snow fall condition). Salt is mainly used moistened, but sometimes also as a brine solution (Ritthoff 2011).

3. Water use in cleaning services

Water use in cleaning services has been identified as an environmental hotspot in the environmental analysis. Water is used in significant amounts in cleaning services, for dilution and washing and rinsing; its usage is particularly high for street cleaning. The professional cleaning service industry has demonstrated that the use of innovative cleaning equipment provides alternative cleaning solutions that require a lower amount of water. Staff training on efficient cleaning practices can also reduce water use in washing and rinsing.

4. Energy use

From the literature review no information has been found on the topic of energy depletion during the use phase of vehicles and machinery for cleaning services.

In general, we can consider that this factor is strongly dependent both on the energy source technology available from the grid as well as from the specific technology of battery and powertrains of machinery and vehicles.

These aspects will be further commented on in the proper chapters dedicate to vehicles and machinery.

5. Emission of air pollutants

Road transport in the cleaning services for Public Space Maintenance is dominated by the need to move equipment and products and also from the technical characteristics of the service itself. Winter maintenance and street sweeping or bins cleaning are characterized by the movement of equipment and people covering long distances. These transports for long distances generate significant environmental impacts because of energy use and emissions to air. To minimize these impacts, cleaning service providers should use vehicles with good fuel economy and environmental performance.

Dust generation during sweeping:

In the sweeping service, the air pollutant emission of vehicles is largely dependent on the technology of powertrain. Besides this, some sweeping vehicles produce a dust cloud from the brooms or from sweeper air discharged from the unit, although those emissions are considered as not significant (F. Amato et al. 2010).

Concerning winter maintenance, efforts to reduce the impact are focused on vehicle and fuel technology. Fuel efficiency combined with the optimization of de-icing practices, routes and the load of vehicles are key factors. However, it should also be kept in mind that winter maintenance especially through anti-icing operations is beneficial as it makes mechanical snow removal easier, thus we can say that de-icing operations reduce emissions from the phase of mechanical snow removal. (Vignisdottir, Booto, and Bohne 2016).

Operational management

1. Solid waste collection, disposal and recycling

Key factors of solid waste collection are the empting of bins, manual street sweeping, leaf collection and beach cleaning.
Cleaning services have to manage the collection/disposal practice and provide infrastructures and machineries adequate for the task.
It is the cleaning services responsibility to ensure that recyclable materials are separated from other waste to maximize recycling efficiency. Thus, cleaning service providers should ensure a streamlined waste collection and categorization process before moving on to the disposal and recycling. (Neto et al. 2014)
To guaranty the quality of the waste collection operations the cleaning services should ensure the proper training of its staff.

Concerning leaf collection, the study *High-Quality Solid Fuel Production from Leaf Litter of Urban Street Trees* provide a framework for the potential of this kind of organic waste to be used for ecofriendly fuel generation. The total cost of the practice, both from an economical and an environmental point of view is not described. This means there is potential for improvement in the operation of leaf collection.

In winter maintenance, the operation of salt spreading precedes the sweeping of debris and salt from the street surface. The literature review provided in our study didn't bring any information about the disposal of used salt or the disposal of snow from mechanical removal.
This has to be considered as an important factor in order to ensure the protection of the environment.
In the case of precipitation, according to the literature review, the environmental impact of snow disposal from mechanical removal is not clear.
Collected snow may be contaminated with salt, sand, litter, and automotive pollutants such as oil, for that reason, its disposal on the site has to be avoided as much as possible, in order to reduce potential contamination to wetlands, water supplies, and bodies of water.
Municipalities and winter service providers should identify and map appropriate upland snow disposal locations.

To ensure the effectiveness of disposal the following maintenance measures should be undertaken for all snow disposal sites:
- A fence should be placed securely on the down gradient side of the snow disposal site.
- It is recommended to place site separate from bodies of water, and in any case, filter the pollutant out of the melted water.
- Debris should be cleared from the site prior to using the site for snow disposal.
- Debris should be cleared from the site and properly disposed of at the end of the snow season[93].

2. Wastewater discharge

Wastewater inappropriately discharged in the end-of-life phase of cleaning services can have a large environmental impact.

[93]Further information is available at: http://www.mass.gov/eea/agencies/massdep/water/regulations/snow-disposal-guidance.html

Concerning the use of cleaning products during the activities of hard surface cleanings, bins cleaning, façade cleaning or graffiti removal, the run-off of water may represent an environmental impact. The inappropriate discharge of this waste water can lead to severe consequences such eutrophication and ecotoxicity. This impact can be mitigated by using sustainable products with less toxic values.
As explained before, the use of machinery with water collection system is a good strategy. In any case waste water containing cleaning products or debris should be always discharge in a waste water treatment system.

After street cleaning operations and winter maintenance operations the production of waste water could raise important levels. Not always this amount of water run-off in the public grid of water treatment. Mitigate these environmental impact is strongly dependent from good operational practices, that ensure the lower use of products and the lower production of sludge.

3. Technology tools

The specific operational routines of the cleaning services for public space are characterized by the needs of moving vehicles, staff and products for use in large distances relative to urban areas. These transports have economic and environmental consequences that have to be planned and managed in order to reduce these costs.
Many practices and documented events from municipalities provide examples of the improvement potential of technology tools associated with the cleaning services and in the rationalization of routes.
For example, in winter maintenance services we see the use of technology that can provide multi-level solutions for intelligent winter road maintenance management[94] (Hyyrönmäki 2016; Roosa 2011; Kociánová 2015; Layman 2012).
Systems are usually based on the monitoring and the forecasting of weather conditions and road surface conditions through the use of weather stations, which provide early warnings about dangerous situations on the road.
From the processing of this data, together with forecasting models and date from weather radars and satellites, it is possible to have information support for the right maintenance decision and for effective and timely treatment of roads in the winter.
Furthermore, dynamic systems, which provide on-line fleet monitoring and management, enable the winter services staff to ensure optimization and timely intervention.

Improvement potential of new technologies has also been shown in the field of street sweeping and cleaning.
Many municipalities are implementing the use of GIS technologies to carry out a continuous monitoring of their operations, providing informational support aimed at saving energy, improving comfort and reorganising maintenance services.
Many practices are documented by USA municipalities (e.g. Chicago, Oakland, Maricopa county[95]), likewise in Europe we can follow interesting practices on street cleaning such as the management models documented by municipalities of the region of Catalunya (Barcelona[96], Prat de Llobregat[97])
The case of Prat de Lobregat is of particular interest due to its multi-level implementation of GIS technology as information support. The main levels of the information support are focused on:

[94]Information available at:
http://tapahtumat.tieyhdistys.fi/site/assets/files/1344/talvitiep_iv_t_2016_esitelm_julkaisu.pdf
[95] Information available at:
http://www.esri.com/news/arcnews/spring11articles/better-street-sweeping-management.html
https://data.cityofchicago.org/browse?tags=street+cleaning
https://www.arcgis.com/home/item.html?id=3277a7ea7db845f799b5dd4410b9f96e
[96] Information available at: http://cargocollective.com/juanjo_vidal/following/juanjo_vidal/Barcelona-Mobility
[97] Information available at :http://www.elprat.cat/urba/residus-i-neteja/neteja-viaria

- The display of different data sets, providing a complete inventory of many element objects of the service of cleaning and maintenance (e.g. trees, plants pots, bins, etc).
- A map system that follows staff operations and their fleet
- A free mobile application that uses citizen participation for the identification and communication of incidences in the city.

Through these three tools, GIS technology enables the maintenance staff to manage interventions in real time, ensuring both the effectiveness of the service and the rationalization of routes (Boscadas 2014).

9.6 Cost considerations

The fulfilment of cleaning services for Public Space Maintenance is mostly associated with the use of sweeping vehicles or water jet machinery using pressurized air or sand. That means that economic incidence from the purchasing of cleaning products is low and does not significantly affect the total cost of the service. The main factors in the total cost of public space cleaning services are the cleaning machines and the cost of the staff.
Little information is available concerning the comparison of green cleaning services and traditional cleaning services. In spite of that, we can gather some conclusions about cost considerations from best practices among the European contest.
It is clear that much could be done to improve green practices in cleaning services for public spaces that could lead to important environmental and economic advantages.
A good practice in the field of technology supporting cleaning services of public space maintenance is shown by the case study of Prat de Llobregat [98](Bcn).
In this case, bin collection, street sweeping and maintenance of extra-ordinary incidences are planned through the support of a GIS application that enables the maintenance service to combine inventory map information with the incidences reported by citizens thanks to a free mobile application. This practice shows that efficient green cleaning services will result in savings of environmental and economic resources. Concerning the use of cleaning products for professional out-door use, not much information is available concerning the cost of products, even though, as mentioned, the economic incidence of these products in cleaning activities of Public Spaces is negligible.

With respect to street cleaning and dust suppression, the cost efficiency of operation is related with the higher rate of PM_{10} mitigation, which can be achieved in concomitance of peaks of dust load. The studies found that frequent operations before of high dust load events are more effective option. (REDUST 2015; Querol et al. 2016). Concerning the use of CMA as dust binding, some results are available from the research *+CMA -PM_{10}* (Layman 2012) where a Cost-Benefit Analysis was undertaken that shows that applying CMA on the main roads in Klagenfurt would lead to savings in the health sector greater than the cost of CMA application (Idaea- CSIC 2016).

When it comes to winter maintenance, the accurate planning of routes and services carried out with the support of technologies will prevent unnecessary loss of de-icer products and unnecessary transportation. Finland as an example shows that sustainable winter maintenance could be supported by proper procedures and technology, assisting winter services in their organization and ensuring efficient operations (Redust 2012).
In recent years, new de-icers have been introduced as a result of a growing awareness of the damage from traditional salt-based de-icers. The new products generally based on formates and acetates, show fewer environmental impacts, but unfortunately, they are also more expensive, which is why their use is still confined to airports, bridges, certain municipalities and private spaces.

[98]Further information available at:
http://www.elprat.cat/urba/residus-i-neteja/neteja-viaria?lan=en#googtrans(ca|en)

New de-icer products are covered by a Nordic Swan Ecolabel that steers the market of these products; in fact, although Swan-labelled products remain more expensive than road salt, there has been a reduction in price compared with the situation in the past when road salt was 15-30 times cheaper (Nordic Ecolabelling 2016a).

Market availability of environmental friendly products

Regarding cleaning agents, the rate of environmentally friendly products on the market is increasing, as we can gather from the reports from Ecolabelling organizations. There is not a lot of information available at a national level for the market penetration of professional cleaning products. As an example, a rough estimation for Germany, obtained through one stakeholder, suggests that the use of ecolabelled cleaning products (I&I) within commercial cleaning services is about 3-5%. (Neto et al. 2014)
However, the number of signatories to charters (e.g. AISE Sustainable Cleaning Charter) or voluntary schemes (e.g. EU Ecolabel or Nordic Swan) indicates that there is a market and interest for sustainable products and services.

For example, the International Association for Soaps, Detergents and Maintenance Products (AISE) estimates that cleaning product manufacturers and distributors signed up to their Sustainable Cleaning Charter scheme represent 85% of the industry's volume output in Europe (A.I.S.E 2013). The charter is addressed mainly to household products; even though it also includes supplies for non-domestic market and for Industrial & Institutional (I&I) e.g. technical cleaning products (for transportation care, workshop cleaning, industrial plant, storage, equipment cleaning, metal products cleaning, degreasing, chemical treatment delaquering, etc.). Out of the 216 cleaning product companies that have signed up to the AISE charter, the majority are providers to households while just 23 provide solely to the I&I sector and 47 provide both.
Moreover according to EU Ecolabel Work Plan for 2016 -2018 (Ecolabel 2016), a total of 2,772 products for all-purpose cleaners and cleaners for sanitary facilities were awarded with the EU Ecolabel, and Spain being (ES2 In the Ecolabel 2016) the country with highest number (53) of Ecolabelled all-purpose cleaners (ES2 In the Ecolabel 2016).
Concerning the *Nordic Swan*, the official ecolabel of the Nordic countries, the *Nordic Ecolabeling, Annual report 2015* shows an implementation of the green market products, but does not give further information about the number of products eco-labelled (Nordic Ecolabeling 2015).

Concerning cleaning services, a type of Ecolabel for companies is provided by EMAS. The *EU Eco-Management and Audit Scheme*[99] (EMAS) is a premium management instrument developed by the European Commission for companies and other organizations to evaluate, report, and improve their environmental performance. The website of the organization gives information about the trend of inscription to the EMAS membership; however, the number of organizations specialized in street cleaning is not specified.

[99] http://ec.europa.eu/environment/emas/index_en.htm

10 Environmental analysis of gardening activities for Public Space Maintenance

As stated in the *Part I- section 5.1* of this *Preliminary Report*, for general landscaping services, the statistical categories used as reference correspond to: 77313000, parks maintenance services, 45112710, landscaping works for green areas, 45112711, landscaping work for parks, 45112712, landscaping work for gardens, 45112713, landscaping work for roof gardens, 77311000, ornamental and pleasure gardens maintenance services.

Gardening and landscape services include:

- Pruning: corresponding to CPV code 77341000, tree pruning
- Trimming: corresponding to CPV code 77342000, hedge trimming
- Planting and plant and tree replacement corresponding to CPV code 77330000, floral display services: 03121100, live plants, bulbs, roots, cuttings and slips: 03440000, forestry products: 03441000, ornamental plants, grasses, mosses or lichens: 03451000, plants: 03451100, bedding Plants: 03451200, flower bulbs: 03451300, shrubs: 03452000, trees: 77314100, grassing services: 77315000, seeding services
- Fertilization
- Weed control and pesticides use: partially corresponding to CPV code 77312000 weed-clearance services
- Lawn replacement
- Manual & automated irrigation

Gardening products include:
- Soil improvers
- Ornamental plants
- Herbicides and pesticides

The published material about *EU GPP criteria for Gardening Products and Services*[100] (EU Commission 2012) and the *Gardening Products and Services Technical Background Report* (TBG) (EU Commission 2011a) provide a wide background for this group of products/services.
The scope of the GPP is completely in line with the scope of this sub-group for Public Space Maintenance. Even though the GPP include as well criteria for design of green spaces, while our study is especially focused on maintenance of public spaces (as specified in the above-mentioned *Section I*)

To expand upon the topic of gardening activities, a literature review has been carried out for the different sub-groups included in the scope of our study.
Regarding gardening activities and practices, the web page of Barcelona council: *Parks and gardens management*[101]*,* and the related publication: *Good Gardening practices in Barcelona: conserving and improving biodiversity* (Borruel, Punsola, and Garcerán 2016) were consulted. These sources provide good technical information for the characterization of the activities.
On the topic of soil improvers, background information is available the EU Ecolabel[102], particularly the preliminary report for these criteria gives a framework for the characterization of the product and provide a wide literature review.

[100] Available at: http://ec.europa.eu/environment/gpp/pdf/criteria/gardening.pdf
[101] Available at: http://ajuntament.barcelona.cat/ecologiaurbana/en/services/the-city-works/urban-management/coordinating-improvement-measures-in-public-areas/parks-and-gardens-management
[102] Available at: http://susproc.jrc.ec.europa.eu/soilimprovers/stakeholders.html

Concerning fertilizer, a proper web page by the EU commission describes the state of art for this product among Europe[103], including evaluation and the scientific robustness of the concept of plant bio-stimulants (du Jardin 2012).
Moreover, on the topic of controlling weeds, pests and other alien species we can refer to the web page of EU Commission. In this case as well, the EU Commission gives a broad background on the product[104], on sustainable practices[105], as also on biocides and its sustainable use (EU Commission 2016).

10.1 Characterization of Gardening activities for Public Space maintenance

Gardening services

Maintenance of green elements
Gardening services involve a wide range of activities including; maintenance of green areas and parks and maintenance of green lines or tree lines in the city as well as flower pots.
Gardening services require a continuous maintenance during the year.
The purpose of this service has both aesthetic objectives as well as to preserve the condition of vegetation in terms of structure and phytosanitary state.
Every park, garden, lawn, tree line or other vegetal element is different and, therefore, they require specific maintenance. Some parks are full of trees and in some shrubs or plant fences represent an important part of vegetation. Surfaces of lawns vary, as well as the number of groups of flowers and, of course, the species of each one of these green areas.
That is the reason why specific maintenance plans are needed for each one of these spaces or elements. Special attention, for example, has to be paid to the historical parks since they are much more fragile than the rest, and their original landscape structure must be preserved.
The web page on maintenance practices for the green spaces of Barcelona council[106] provides a description of the main activities included in gardening services. These activities concern:

- **Trees and palms:**
Maintenance of trees and palms in gardens and roads consist mostly of pruning, whether in terms of training, cleaning or crown lifting, and, in the case of palm trees, cleaning dried leaves. As well regular preventive phytosanitary treatments have to be scheduled.

- **Lawns:**
A lawn can be part of a park or of a smaller green area within the city. They are a type of green facility which requires great efforts through the year in order to maintain their quality, especially taking into account that grass needs a lot of moisture.
Currently lawn species are selected according to their tolerance to drought situations and high summer temperatures.
Lawn mowing is carried out throughout the year as well as trimming the borders of flower-beds in parks and gardens in order to keep their structure.

- **Covering plants and perennials**
Covering plants are often used to cover horizontal surfaces as an alternative to lawn.

[103] Deep information available at: http://ec.europa.eu/growth/sectors/chemicals/specific-chemicals/
[104] Information available at: https://ec.europa.eu/food/plant/pesticides_en
[105] Information available at: https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides_en
[106] Ibidem

These species usually require pruning and pinching work, which are usually performed in winter, early spring and late summer.
During spring plant replacement and planting, soil is loosened and preventive phytosanitary treatments are used.
Throughout the year, perennial plants require pruning, pinching and trimming. Soil loosening, fertilization and preventive pesticide treatments are necessary when spring approaches. Plants are usually cleaned of dried flowers in early summer and early autumn.

- **Borders**
These fences made of shrubs can have different functions like aesthetic decoration as well as distribution within green areas.
Borders require pruning and maintenance, along with trimming in early winter and early autumn when the plant has stopped growing and after sprouting. Usually, when spring approaches, the planting soil is loosened and preventive phytosanitary treatments are carried out.

- **Groups of flowers**
Flowers are usually seasonal plants, which must be renewed several times a year.
Maintenance work consists of preparing the soil before planting, usually three times in a year; at the beginning of spring, summer and autumn.
The maintenance of planting soil in flower groups includes weeding in order to aerate it. Also, preventative phytosanitary treatment has to be planned during the planting months. Three times a year dried flowers needs to be eliminated in order to maintain the quality of the groups of flowers (Borruel, Punsola, and Garcerán 2016).

- **Flower pots**
The maintenance work basically consists of pinching at the end of summer in order to have thicker sprouts in spring, removing dried flowers and fertilization.

Watering
Irrigation of green areas and vegetal elements can be carried out both manually and automatically thanks to the use of irrigation systems. Manual irrigation can be carry out through pipes connected with the urban grid, or often with the support of water tank.
In both cases irrigation practices need to be calibrated during the year according to the real need of each vegetal species.
Beside irrigation activities, the scope of our study includes the maintenance of irrigation systems; this service is of great importance in order to ensure the contention of water losses.
Nowadays the use of water is a sensitive topic due to environmental issues associated with its depletion. Globally, the diffusion of policy about *Integrated water resources management*[107] is providing frameworks for a responsible use of water. Moreover, EU commission consultations[108] have stressed the importance of extending EU minimum quality requirements to the irrigation of sport fields and the irrigation of urban green spaces. Southern countries are the most willing to consider an expansion of EU minimum quality requirements to other types of uses.

[107] Information available at: http://cordis.europa.eu/project/rcn/78473_en.html
[108] Information available at: https://circabc.europa.eu/sd/a/2917fa78-d319-4063-966d-dc60b48f5438/Workshop%20on%20EU%20public%20consultation%20on%20Water%20reuse_Background%20document.pdf

Gardening products

Fertilizer, soil improvers and mulch

Fertilizers are material of natural or synthetic origin that are applied to soils or to plants to supply one or more nutrients to promote growth.
Together with nitrogen and potassium, phosphorus is one of the three key components of fertilisers and its main source consists in reserves of phosphate rock.
Within fertilizers, organic fertilizer are those derived from animal matter, compost and crop residues, peat, manure, slurry and guano.
Fertilizers release their nutrient in the soil very fast increasing the risk of leaching into the soil and bodies of water.
Therefore, slow nutrient releasing compounds are recommended over fertilizer, e.g. soil improvers. Therefore, only soil improvers with a high percentage of compost should be added to the soil.
Soluble chemical fertilizers contain mineral salts that plant roots can absorb quickly. However, these salts do not provide a food source for soil microorganisms and sometimes they will even repel them because they turn the soil acidic. Over time, soils treated only with synthetic chemical fertilizers lose organic matter and the all-important living organisms that help to make up a quality soil.
Many organic materials serve as both fertilizers and soil conditioners.
Concerning the group of products including soil improvers, growing media and mulch, the EU Ecolabel provide definitions and technical characterization(Quintero et al. 2013).
In general soil improvers are materials added to soil to improve its physical properties such as: water retention, permeability, water infiltration, drainage, aeration and structure. The goal is to provide a better environment for roots.
Organic mulches reduce evaporation and runoff, inhibit weed growth, and create an attractive appearance. Mulch is a protective cover, placed over the soil that can be either organic or synthetic, it is used to adjust soil temperature by helping soil retain more heat in spring and autumn, and by keeping soil cool and even out temperature swings during the hot and variable summer conditions
Soil improvers must be thoroughly mixed into the soil, while mulch is left on the soil surface. Organic mulches may be incorporated into the soil as amendments after they have decomposed to the point that they no longer serve their purpose.
There are two broad categories of soil improvers: organic and inorganic. Organic improvers include peat, wood chips, grass clippings, straw, compost, manure, biosolids, sawdust and wood ash. Inorganic include vermiculite, perlite and tire chunks.
Compost is a mixture of organic and inorganic amendment and there are three broad categories: peat based, loam based and peat free.
Due to the specific properties of mineral materials, these are often applied in professional media. The availability and price of organic materials other than peat, i.e. bark or coir, often determine their utilization. Bog peat is still the overall predominant growing medium constituent in the EU, and this is also true for member states without domestic peat production. Peat-free growing media are highly esteemed by some stakeholder and user groups but still play an overall minor role in industrial production of growing media. (Schmilewski 2009)
It is estimated that peat represents 86% of all constituents used in the professional horticultural sector and 69% of the constituents used for the hobby growing media market. (Schmilewski 2008)
Peat is an accumulation of decayed vegetation or organic matter. It forms when plant materials are inhibited from decaying fully by an acidic condition. Even though peat has a biological origin, due to the slow regeneration rate it is considered no renewable material. Because of that, and also for the lower amount of nutrients compared to other compost, the use of peat should be minimized (EU Commission 2011a).
The word compost also defines another kind of organic material which is the result of the "composting" of organic waste. Nowadays many municipalities have facilities to process compost and provide it for horticulture uses.

Growing media constituent	General description	Use as a growing media constituent
Bark 	Bark from one or more tree species. (Non-composted bark is used in this study.)	Used as the sole constituent in orchid cultivation or as a constituent in potting mixes for tree nurseries and floriculture.
Coir pith 	Product obtained by mechanical processing of the mesocarp of coco palm fruits. It is primarily imported from the Far East (Sri-Lanka, India, Philippines). The material is locally pressed into sheets, blocks or briquettes and then shipped in containers.	Esteemed for its good wettability and peat-like colour. Mixed with other constituents in mixes for sowing, propagating and potting; also as the sole constituent of grow bag mixes in vegetable and flower cultures.
Green compost 	Solid particulate matter resulting from controlled decomposition, by thermophyllic microorganisms, of biodegradable materials such as arboreal wastes, grass clippings and other material from gardening and landscaping maintenance activity.	Used in mixes for all segments of horticulture; important constituent of growing media for organic growing.
Mineral wool (picture shows mineral wool flakes) 	Product obtained by melting basalt and limestone after addition of coke at 1600°C followed by spinning and granulation. Binders for firmness and wetting agents are added for the production of mineral wool mats, which are referred to in this study.	Mineral wool mats are used in the production of fruity vegetables (e.g. tomatoes or egg plants), cut flowers, etc.
Black Peat 	Strongly humified (decomposed) peat (H6-10 on the Von Post scale) sedentarily accumulated in bogs consisting mainly of peat moss residues and residues of cotton grass, shrubs and other typical bog plant species with hardly to non-recognizable plant structure and dark brown to almost black in colour.	Used in all horticultural segments. Second most important constituent of growing media throughout Europe.

White Peat 	Weakly to moderately humified (decomposed) peat (H1-5 on the Von Post scale) sedentarily accumulated in bogs consisting mainly of peat moss residues and residues of cotton grass, shrubs and other typical bog plant species with visible plant structure and yellowish brown to dark brown in colour	Used in all horticultural segments. Main constituent of growing media throughout Europe.
Perlite 	Manufactured from naturally occurring hydrated volcanic rock (perlit), expanded by heat to form a cellular structure.	Usually mixed to improve the flowability, increase the air content and improve the water uptake of mixtures.
Rice hulls 	Residue obtained in the rice manufacturing industry and mainly consisting of rice paleae; steamed.	Can be added to mixes to improve air capacity. Constituent of less importance.

Figure 34: Growing media characterization. (EPAGMA 2012)

Ornamental plants

The maintenance of green public spaces requires the continuous replacement of plants. The practice of plant selection is an issue of strong importance. Currently, policies are doing efforts to boost the biodiversity in urban green areas[109].

The selection of plant species not only affects the ecosystem, but also irrigation water needs and pesticide o fertilizer use.

Pesticides and herbicides

Concerning pest control practices, the EU sets rules for the sustainable use of pesticides to reduce the risk and impact on people's health and the environment. Moreover, the EU is boosting the Harmonization of *Integrated pest management*[110] among Europe countries, to promote low-pesticides-input management including no chemical methods.

The criteria of Cleaning services for Public Spaces from Netherland (PIANOo 2015), include the basic principles of sustainable pest management, that includes:

- Have knowledge of the kind of pest
- Have knowledge of the environment measuring nuisance
- Having knowledge of measures to be taken and bring forward these measures: *temporary measures (capturing, using pesticides); semi-structural measures (nest control, contraception); structural measures (influencing the environment, influencing the food supply)*
- Preventing further development and invasion of pest through: *mechanical control, biological control, chemical control*
- Monitoring and inspecting
- Training and raising the awareness of the employees

[109] Information available at http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm
[110] Information available at: https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides/ipm_en

Pesticides are products aimed to prevent, destroy, or control a harmful organism ('pest') or disease. Pests could include: plants, weed, animals, insects etc… Thus, the term Pesticide includes: herbicides, fungicides, insecticides, acaricides, nematicides, molluscicides, rodenticides, growth regulators, repellents, rodenticides and biocides.
Within pesticides, plant protection products are pesticides that protect crops or useful plants. They are aimed at protecting plants against pest and disease, influencing the life process of the plant, and preventing growth of diseased plants. While plant controls are meant for food and feed plants, biocides regard substances for non-food and feeding purpose.
Pesticide effectively is due to active substances, which are chemical, plant extract, pheromone or micro-organisms (including viruses).
The use of active substances for pest control is regulated and approved by the EU Commission[111].

Beside pesticides, biological pest control is a method of controlling pests using other organisms. The method relies on predation, parasitism, herbivory, or other natural mechanisms. It can be an important component of integrated pest management (IPM) programs
The main strategies within biological pest control are:

- Importation, in which a natural enemy of a pest is introduced in an ecosystem.
- Augmentation, in which locally-occurring natural enemies are released to improve control.
- Conservation, in which measures are taken to increase natural enemies.

Against pests, natural enemies include predators, parasitoids, pathogens, and competitors. While biological control agents against plant or weed diseases include seed predators, herbivores and plant pathogens.
Biological control is a sensitive method that has to be managed carefully due to the possibility of unwanted effects on biodiversity through attacks on non-target species.
Further information about technical characterization of biological pest control is available in the publication about Good Gardening practices of the city of Barcelona (Borruel, Punsola, and Garcerán 2016).

10.2 Overview of studies on gardening activities

A lot of information is available on the topic of gardening products and in particular for soil improvers (EU Commission 2013), fertilizer[112] and pesticides[113] even if the literature review shows that the studies are mainly focused on agricultural activities.
With the aim of covering different products and services included in the scope of gardening activities we selected nine relevant studies.
Some of them are developed through the methodology of Life cycle assessment; others provide the evaluation of specific environmental impacts through different methods; others give an overview on current publications about specific topics.

The reviewed studies are:
About Environment Product Declaration (EPDs):
- *Dichiarazione ambientale di prodotto di fertilizzanti organo minerali granulari*. (Scam 2012)

[111] Information available at: https://ec.europa.eu/food/plant/pesticides/approval_active_substances_en
[112] Information available at: http://www.fertilizerseurope.com/media/publications/
[113] Information available at: http://www.pan-europe.info/media/press-releases

LCA on specific products:

- *Dall'analisi del ciclo di Vita dei fiori al marchio ecologico Ecoflower* (Attanasio et al. 2007)*and related insight: Analisi del Ciclo di Vita dei Fiori.Risultati delle analisi di LCA sulle aziende floricole.* (Russo 2007)
- *Comparative life cycle assessment of horticultural growing media based on peat and other growing media constituents.* (EPAGMA 2012)
- *A preliminary assessment of the greenhouse gases associated with growing media materials.* (DEFRA 2008)
- *Environmental inventory modelling of the use of compost and peat in growth media preparation.* (Boldrin et al. 2010)

LCA about services:

- *Environmental Assessment of Garden Waste Management*. (Boldrin 2009)
- *Energy use and carbon footprint from lawn management. A case study in the Uppsala region of Sweden* (Wesström 2015)

A literature review on the environmental impacts of the up-stream phase of fertilizers.

- *A Review of Greenhouse Gas Emission Factors for Fertiliser Production*.(Cowie and Wood 2004)

A literature review on the environmental impacts of pesticides:

- *Environmental effects of pesticides. An impression of recent scientific literature.* (PAN EU 2010)

Even if it is not an LCA study, we present a summary of the report concerning the experiments carried out from the research group of Prof. Fleisher in 2008, aimed at supporting the practices of organic landscaping management of green areas within the Harvard University Campus.

- *Harvard yard soils restoration project summary report* (Fleisher 2009)

The table below provide a short description of the mentioned relevant studies.
In a further section, a deeper analysis provides an overview of the quality assessment of the studies focusing on impact categories and highlighting the main hotspots in the products/services life cycle.

Table 10: Overview of selected studies related to gardening activities for Public Space Maintenance

Study type	Sub-category	Source	Title	Impact assessment	External critical review	Impact hotspot summary
EPD	Fertilizer products	Scam 2015	*Dichiarazione ambientale di prodotto di fertilizzanti organo minerali granulari.*	IPCC 2013 (global warming) di CML-IA baseline method January 2016 (eutrophication and photochemical oxidation) e CML-IA Non-baseline method (acidification fate not included) January 2016.	PCR review Independent verification of the declaration and data according to ISO 14025: External Third party verifier: Certiquality S.r.l	Not specified. The report presents only data set and results of the tests
LCA	Flower crops	Russo 2007	*Analisi del Ciclo di Vita dei Fiori. Risultati delle analisi di LCA sulle aziende floricole*	LCA: ISO 14040:2006 and14044:2006;	ENEA	Main environmental impacts in the use of energy for the heating of the green house. Important impact with the use of PVC and polystyrene for the packaging. Important environmental impacts due with the strong use of fertilizer. The research shows differences in energy and water use between soil crops and out-soil crops
LCA	Peat and other growing media constituents	EPAGMA 2012	*Comparative life cycle assessment of horticultural growing media based on peat and other growing media constituents.*	IMPACT 2002+; ReCiPe LCIA method	Critical review was performed by a third-party panel of experts	Normally, for all the areas of application, the growing media that have the highest impact on the Climate change and Resources indicators are the mixes containing peat. This is due to land use changes during peat harvesting and production stage as well as GHG emissions during peat decomposition in the use and end-of-life stages.
LCA	Growing media	Defra 2008	*A preliminary assessment of the greenhouse gases associated with growing media materials*	PAS2050 (BSI) LCA (offset approach)	Not specified	*In terms of total GHG emissions the LCA approach supports the use of UK and Irish peat, and coir as growing media material, however, if the carbon neutrality of short-term materials and potential sequestration is taken into account then the opposite is true and compost, timber products and coir are the preferred materials.* (DEFRA 2008)

LCA	Garden waste management	Boldrin 2009	*Environmental Assessment of Garden Waste Management.*	Material Flow Analysis (MFA) and Substance Flow Analysis (SFA). The LCIA was performed based on the EDIP (Environmental Design of Industrial Products)	Michael Hauschild, Arina Schrier and Elke Meinken	*Garden waste management system based on windrow composting generates rather small potential impacts on the environment.* *Furthermore, the chemical analyses showed that the compost produced from garden waste contains low amounts of contaminants and it is suitable for organic farming. (*Boldrin 2009)
LCA	Lawn management	Wesström 2015	*Energy use and carbon footprint from lawn management. A case study in the Uppsala region of Sweden*	Not specified	Not specified	The results showed that greens had the largest carbon footprint and energy use per hectare followed by tees, fairways, roughs, utility lawns and meadow lawns. Mowing, irrigation and manufacturing of fertilizer were the management activities consuming most energy. The activities with largest carbon footprint were mowing, manufacturing of fertilizer and soil emissions from application of fertilizers
LCA	Fertilizers	Cowie and Wood 2004	A Review of Greenhouse Gas Emission Factors for Fertilizers Production.	Not specified	Not specified	This study provide greenhouse gas (GHG) emission factors associated with the production of a range of nitrogen, phosphate and multi-nutrient fertilizers, for use in agricultural and forestry Life Cycle Assessments
Literature review	Pesticides	PAN EU 2010	*Environmental effects of pesticides. An impression of recent scientific literature*	Not specified	Not specified	The study describes environmental effects of pesticides on: - Soil contamination - Water contamination - Effects on organism - Effects on farming practices and biodiversity
Technical Report	Lawn Management	Fleisher 2009	*Harvard yard soils restoration project summary report*	-	-	The comparison between conventional lawn management and organic management allowed for 2 million gallons of water from reduced irrigation, and $45,000 in waste removal fees from on-campus composting.

10.3 Analysis of the selected studies

In this section, we present a summary of the mentioned relevant studies.
Concerning the LCA and EPD studies, a table is provided displaying the main factors for the quality assessment of the method used for the identification of the environmental impacts.
For the quality assessment of the selected LCA studies the following base parameters have been considered:

-Characterization
- Goal and scope
- Functional units and system boundaries
- Cut off criteria
- Allocation
- Geographical and technological representativeness
- Data sources

A table in a following section will show the impact categories.

Concerning the other relevant studies identified above, in the next section we will just present a summary, since quality assessment of the mentioned categories is not appropriate for this kind of study.

10.3.1 Quality assessment of the LCA studies

Table 10. 1: Quality assessment of LCA studies on cleaning services and products for Public Space Maintenance

Source	Characterization	Goal	Scope	Functional Unit	System boundary	Cut-off criteria	*Allocation*	Geograph.representa-tiveness	Technological representa-tiveness	Data source
(Scam 2012)	Granular organo-mineral fertilizers	Quantification and evaluation of the environmental impacts of Granular organo-mineral fertilizers produced by SCAM in 2015, through the identification of energy use, of the used materials and waste released into the environment throughout the product life cycle.	Granular organo-mineral fertilizers produced by SCAM in 2015	1 t of product packaged	1. Upstream module, including the production of the ingredients and the fertilizers packaging production, 2. Core module, including the manufacturing phase 3. Downstream module, including use (emissions into air and water after fertilizers spreading) and distribution	Fertilizer packaging end - of -life treatment was excluded from the boundaries of the system.	Not specified	Not specified	Actual tech used	Specific data are collected by SCAM according with PCR 2010:20. Secondary data are retrieved from Ecoinvent 3.1
(Russo 2007)	Rose and cyclamen crop production in the geographic area of Terlizzi.	Evaluate: - potential impacts on the environment caused by production processes; - the environmental effects of different production processes of the same type of flower; - energy consumption in different forms, water and non-renewable resources	Typical floricultural productions in the Terlizzi district	100 rose stems and 6 cyclamen plants	Cradle-to- gate	The 7 companies where data collection was performed are located in the floral district at the north of Bari. (Terlizzi, Molfetta, Giovinazzo, Bisceglie and Ruvo di Puglia)	Not specified	The production technologies representative of the productive reality of the Terlizzi (Italy) area	Primary Data from private companies of the floral sector. Secondary data from GaBi4 database.	The companies where data collection was performed are located in the floral district at the north of Bari. (Terlizzi, Molfetta, Giovinazzo, Bisceglie and Ruvo di Puglia)

(EPAGMA 2012)	Peat based growing media for five areas of application: fruity vegetables, pot plants, young plant production using loose-filled trays, tree nursery stock, and hobby market	Understanding of environmental impacts of peat and comparing popular growing media made partially or totally of black and white	Growing media mixes produced by EPAGMA	To provide 1 m3 (EN 12580) of growing media for five areas of application: fruity vegetables, pot plants, young plant production using loose-filled trays, tree nursery stock, and hobby market	Cradle to grave	Potential impacts from reutilization of growing media after their first use is not estimated	Different allocation factors for bark, coir pith and rice hulls	Not specified	Composition of growing media for the following five areas of application: -fruity vegetables - pot plants - young plant production -tree nursery stock -hobby market	-Suppliers -EPAGMA -Ecosystem 2.2
(DEFRA 2008)	Growing media constituent	Reduce the horticultural use of peat in order to meet the UK Lowland Raised Bog Habitat Action Plan	Assessed the carbon footprint of selected GM constituents, comparing GHG emissions (CO_2, CH_4 and N_2O)	Metric ton (t), at end-use stage of the life cycle. (100-year time horizon)	Cradle to grave	Excludes all the GHG emissions associated with capital goods	The approach used in PAS2050 is to allocation emissions to co-products where possible and this approach is used in this study	Not specified	Current technology of composition growing media in Europe	-Official UK sources. - DEFRA - Peer reviewed literature
(Boldrin 2009)	Garden waste management including windrow composting, thermal treatment and home composting	Environmental assessment of six scenarios of garden waste generated in Århus. Evaluating windrow composting, incineration, and home composting as treatment technologies	Management of garden waste, including windrow composting, thermal treatment and home composting	Ton of waste treated	Upstream and downstream processes linked to garden waste management	Not specified	Environmental emissions defined for Århus (Denmark) composting plant	Environmental assessment of six scenarios of garden waste generated in Århus. (Denmark)	Windrow composting of garden waste from public gardening services	Inventory of data regarding windrow composting of garden waste has been established using Århus composting plant as a case study
(Wesström 2015)	Lawn maintenance for three kinds of green areas:	Improve lawn management practices	Evaluation of energy use and carbon footprint from urban lawn managements with different intensities.	The management of 1 ha of lawn during one year	Lawn management; maintenance of equipment and production of purchased inputs e.g. fuel, fertilizer and pesticides	Environmental impacts from production of equipment, construction of lawns, waste management and end of life treatment of equipment was not included	Collection of inventory data was geographically limited to the Uppsala region, Sweden	Sweden	Not specified	Primary data from municipality Secondary data from peer reviewed literature

Table 10. 2: Impact categories of the selected LCA studies related to gardening services and products

Source	*Scam 2015*	Russo 2007	EPA GMA 2012	DEFRA 2008	Boldrin 2009	Wesström 2015
Impact assessment	IPCC 2013 (global warming) di CML-IA baseline method January 2016 (eutrophication and photochemical oxidation) e CML-IA Non-baseline method (acidification fate not included) January 2016.	LCA: ISO 14040:2006 and14044: 2006;	IMPACT 2002+; ReCiPe LCIA method	PAS2050 (BSI) LCA (offset approach)	Material Flow Analysis (MFA) and Substance Flow Analysis (SFA). The LCIA was performed based on the EDIP (Environmental Design of Industrial Products)	Not specified
Product Sub group	Fertilizer products	Flower crops	Growing media	Growing media	Garden waste management	Lawn management
Climate Change	√	√	√	√	√	√
Ozone Depletion	√	√	-	-	-	-
Ecotoxicity for aquatic fresh water	√	-	-	-	√	-
Human Toxicity cancer effects	√	-	-	-	√	-
Human Toxicity non-cancer effects	√	-	-	-	√	-
Particulate Matter / Respiratory Inorganics	-	-	-	-	-	-
Ionising Radiation – human health effects	√	-	-	-	-	-
Photochemical Ozone Formation	-	√	-	-	√	-
Acidification	√	√	-	-	√	-
Eutrophication – terrestrial	√	√	-	-	√	-

Eutrophication – aquatic	√	√	-	-	√	-
Resource Depletion – water	√	-	√	-	-	-
Resource Depletion – mineral, fossil	√	√	√	-	-	-
Land Transformation	√	-	-	-	-	-
Other impact categories	Biogenic GWP Photochemical oxidizing transformations				Material intensity	

Impact categories are not comparable within the different studies due to the difference of scopes and impact methods.

Summary of LCA studies

- ***Dichiarazione ambientale di prodotto di fertilizzanti organo minerali granulari*. (Scam 2012)**

The products covered by the study are granular organo-mineral fertilizers produced by SCAM in 2015. Organic minerals in Italian legislation (Legislative Decree 75/2010) are products obtained by reaction or by mixing one or more organic fertilizers with one or more mineral fertilizer.
The calculation of potential environmental impacts from the products was carried out using the Life Cycle Assessment (LCA) methodology, using the factors of CML-IA baseline method January 2016 (eutrophication and photochemical oxidation) and CML-IA IPCC 2013 (global warming) non-baseline method (acidification fate not included) January 2016.

Results

This study doesn't provide a summary on environmental hotspots in Products Life Cycle, so can just show the results of the Environmental impact assessment.
The environmental parameters are declared for each module of the life cycle of the mineral organic fertilizer.
1. Upstream module, including the production of ingredients and the fertilizers packaging's production
2. Core module, including the manufacturing phase
3. Downstream module, including use phase (emissions into air and water after fertilizers spreading) and products distribution.

MEDIUM ORGANO-MINERAL FERTILIZER					
IMPACT CATEGORY	udm	UPSTREAM	CORE	DOWNSTREAM	TOTAL
GLOBAL WARMING	$kgCO_{2eq}$	1004.40	140.08	467.91	1612.40
GWP BIOGENIC		49.56	2.65	5.89	58.95
PHOTOCHEMICAL OXIDATION	$kg\ C_2H_{4eq}$	0.35	0.03	-0.35	-0.07
EUTROPHICATION	$kg\ PO_{4---eq}$	2.24	0.23	1.38	3.66
ACIDIFICATION	$kg\ SO_{2\,eq}$	7.52	1.12	2.07	9.51

Figure 12: Potential environmental impacts for the medium organo-mineral fertilizer. (Scam 2012)

FERTILIZZANTE MEDIO OM						
CATEGORIA IMPATTO		udm	UPSTREAM	CORE	DOWNSTREAM	TOTAL
RISORSE NON RINNOVABILI MATERIALI		kg	**773,30**	**5,12**	**3,59**	**782,00**
	Sali potassici	*kg*	*265,24*	*0,00*	*0,00*	*265,24*
	Torba	*kg*	*202,70*	*0,07*	*0,02*	*202,79*
	Dolomite	*kg*	*119,08*	*0,01*	*0,00*	*119,09*
	Fosforo minerale	*kg*	*48,86*	*0,00*	*0,00*	*48,86*
	Altro	*kg*	*137,41*	*5,04*	*3,57*	*146,02*
RISORSE NON RINNOVABILI ENERGETICHE		kg	**446,88**	**54,95**	**28,10**	**529,94**
	Petrolio	*kg*	*146,42*	*18,06*	*22,64*	*187,12*
	Carbone	*kg*	*164,55*	*11,84*	*4,08*	*180,47*
	Gas naturale	*kg*	*135,06*	*25,00*	*1,35*	*161,41*
	Altro	*kg*	*0,85*	*0,06*	*0,02*	*0,93*
RISORSE RINNOVABILI MATERIALI		kg	**0,07**	**<0,00**	**<0,00**	**0,07**
	Legno	*kg*	*0,07*	*<0,00*	*<0,00*	*0,07*
	Altro	*kg*	*<0,00*	*<0,00*	*<0,00*	*<0,00*
RISORSE RINNOVABILI ENERGETICHE		MJ	**332,85**	**63,50**	**7,59**	**403,95**
	Idroelettrico	*MJ*	*280,84*	*39,54*	*6,47*	*326,85*
	Eolico	*MJ*	*51,27*	*9,21*	*1,08*	*61,56*
	Altro	*MJ*	*0,74*	*14,76*	*0,04*	*15,53*
RIFIUTI NON PERICOLOSI		kg	**0,05**	**2,13**	**0,00**	**2,18**
RIFIUTI PERICOLOSI		kg	**0,00**	**0,02**	**0,00**	**0,02**
RIFIUTI RADIOATTIVI		kg	**0,00**	**0,00**	**0,00**	**0,00**
CONSUMO DI ACQUA		m^3	**5,76**	**0,38**	**0,09**	**6,23**
di cui diretto		*m^3*	*-*	*0,148*	*-*	*0,148*

*Figure 35:*Resource depletion, waste production and water depletion for an average Fertilizer (US=1t)

As we can gather from the tables the strong impact for an average product from Scam affect the Global warming in the UP-stream module (raw material extraction and manufactures).

- ***Dall'analisi del ciclo di Vita dei fiori al marchio ecologico Ecoflower*** **(Attanasio et al. 2007)** ***and related insight: Analisi del Ciclo di Vita dei Fiori. Risultati delle analisi di LCA sulle aziende floricole.*** **(Russo 2007)**

The research presented in this document is part of the project *Ecoflower Terlizzi - Demonstration Project for the Environmental Declaration of Product: Terlizzi Flowers and the Local Eco-Label* funded by the European Union LIFE04 ENV / IT / 000480. The objective of the project is to establish a coherent development of good environmental practices and to promote the efficient use of resources in the production of flowers in the Terlizzi productive area characterized by a strong use of water, fertilizers, pesticides, energy, growing substrates, plant material and building materials.
To establish the environmental impacts of floricultural production, an LCA study was conducted on selected crop's companies with the aim of evaluating:
- Potential impacts on the environment caused by the production processes in question
- The environmental effects of different production processes of the same type of flower
- Energy consumption in different forms, water and non-renewable resources.

Results

Within this LCA study the environmental hotspots have been analyzed with respect to the following components:
For the companies that produce rose stems:
- fertilizers
- packaging
- pesticides
- structure and installations (including cover materials)
- transplant plants
- heating oil
- energy used

For the companies that produce pot cyclamen:
- fertilizers
- packaging
- pesticides
- structure and installations (including cover materials)
- seedlings and plastic pots
- energy used

The heating of the greenhouses is shown to have strong weight on environmental impact categories.

Energy consumption of fossil fuel has a big impact on all environmental assessment indexes for the cultivation of roses. A reduction is recommendable, but this advantage is shown to be counterbalanced by the greater use of pesticides.
Particularly, roses must be raised in a greenhouse with a night-time temperature of 16-18° C and daytime of 24-26° C. These temperatures are obtained thanks to the operation of heating; the increase in air temperature allows for a reduction of the pesticides in crops.

Transplant plants are mainly responsible for environmental impacts of the cyclamen crops due to the heating fuel used in nurseries as well as the use of PVC pots and Polystyrene for the plateau.

By comparing the values of crops in and out of soil, it has been found that out-soil crops have a smaller environmental impact, even if they have a greater energy need, which in any case correspond to a better result in the production of flowers in respect both to the number of units and the size of the flower.

Both for the production of roses and cyclamen the structure of the green houses has certain effects on environmental impacts generated by floricultural production. In particular, the structures with glass coverage more strongly affect the environmental impact categories than those with plastic film coverage. (Russo 2007)

- **Comparative life cycle assessment of horticultural growing media based on peat and other growing media constituents. (EPAGMA 2012)**

This study carries out a comparison of different growing media produced by EPAGMA.
EPAGMA has commissioned Quantis to carry out this study.
EPAGMA represents a large part of the peat and growing media industry in the European region. The company acts as the interface for peat and growing media companies with EU institutions since its members represent 18 European peat and growing media companies who wish to be informed of political decisions that affect their day-to-day business.
Through the study EPAGMA aims to contribute to higher environmental standards and practices in peat extraction, mixing and transportation.
The objective of this life cycle assessment was to compare the environmental impacts of peat-based growing media, media composed of peat in combination with other constituents, and one peat-free medium.
The materials, other than peat, assessed in this project were: bark, coir pith, green compost, mineral wool, perlite, rice hulls, and wood fiber.
More specifically, as declared in the study, their objectives were:

- *To characterize the environmental impacts over the life cycle of the chosen growing media constituents*
- *To compare the environmental impacts over the life cycles of the chosen and defined growing media within the same areas of application*

- *To identify the key parameters of the study and provide an assessment of their overall environmental impact through a sensitivity analysis* (EPAGMA 2012)

The study is carried out as a cradle to grave LCA, in the figure below the flow considered in the study are specified.

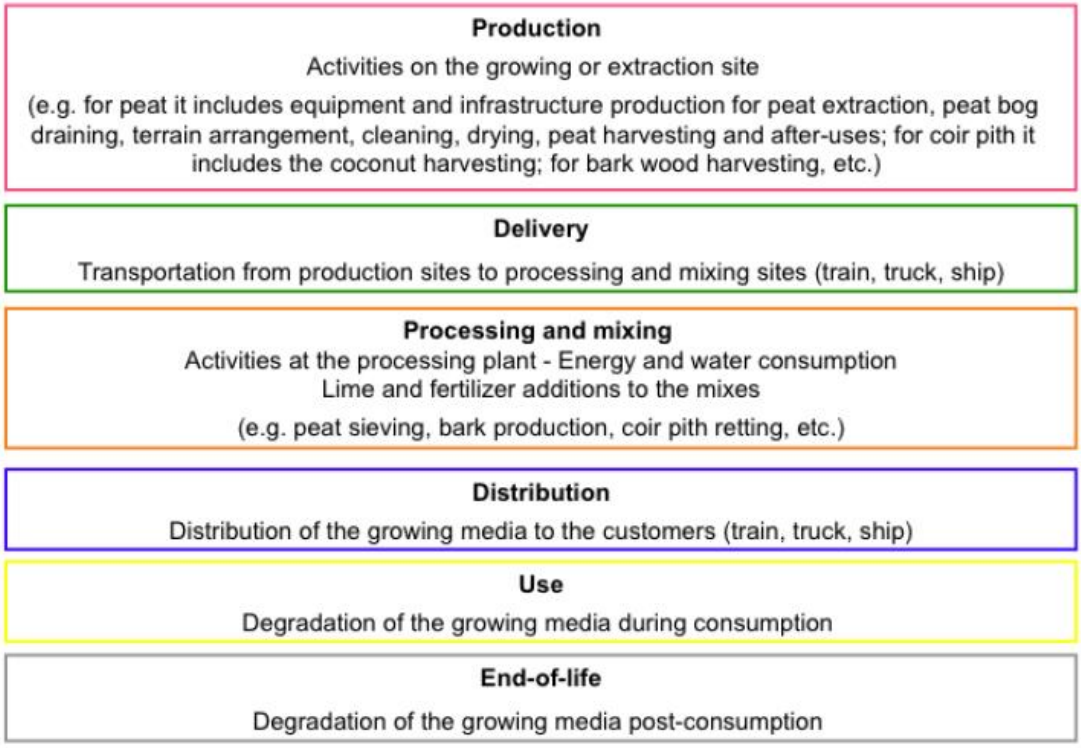

Figure 36: Product system description for the LCA of the systems studied. Common processes (excluded in the growing media comparison) are not included in this figure. *(EPAGMA 2012)*

The study covers a large range of primary data from the supplier. Information regarding production, transformation and distribution of the different growing media constituents, including manufacturing processes, distances of immediate suppliers, distribution distances and transportation modes, was collected directly from EPAGMA members.
Secondary data describing background processes (e.g., electricity generation) mainly from the *Ecoinvent* inventory database (version 2.2) are based on adapted *Ecoinvent* processes.

For the use stage of the products, the following 5 areas of application were identified:
- Growing media for fruity vegetables (e.g. eggplant, tomato, pepper, cucumber)
- Growing media for pot plants (i.e. green plants)
- Growing media for young plant production using loose-filled trays
- Growing media for tree nursery stock (i.e. container-grown plants)
- Growing media for the hobby market (potting mix)

For each area of application an expert from EPAGMA defined different kind of mixtures.
All mixtures related to a specific application were required to be comparable from a functional point of view (the same function for all the mixtures).
Specifically, for peat production in the up-stream phase, a wide range of data was considered:
- Dynamic GHG emission profiles for peat
- Reference scenarios – before site preparation

- Harvesting stage
- After-uses of extracted peatlands
- Use and end-of-life stage

For the production and processing of the component forming growing mixture, the production and processing phase was considered for the following components:
- Coir pith
- Green compost
- Mineral wool
- Perlite
- Rice hulls
- Wood fibers

Moreover, following stages of life cycle were also considered:
- Mixing processes
- Growing media distribution
- Use stage for the growing media
- End-of-life for the growing media constituents (other than peat)

In this study, the use phase of growing media is assumed to take place while plants are growing. Moreover, emissions occurring during the subsequent years were included in the end-of-life stage.
Since current LCA methodology does not consider the timing of when emissions occur, all the emissions of a given pollutant are summed up into a single aggregated value. As stated in the text: *the global warming impact is then calculated by multiplying the aggregated emission of each gas by the respective global warming potential (GWP) for a given time horizon (20, 100 or 500 years). Finally, the life cycle impact for the global warming category in kg CO2 -eq is given by the sum of the impact of each GHG.* (EPAGMA 2012)
The study is also aware that temporary carbon storage has value only if a time horizon is chosen over which impacts are calculated, so that delayed emissions have an impact over this time period, which the current LCA methodology cannot evaluate.
Therefore, the preferred solution is adopting a dynamic LCA approach instead of the traditional LCA approach to compare the impacts of different product systems over a consistent time frame, including the GHG emissions dispersed over several years.

Results
As can be gather from this study:
For the different constituents, the key parameters playing an important role in the cradle-to-gate environmental assessment (excluding mixing processes and distribution to the customers) are described as follows:
- For bark and wood fibers, the dominant processes for Climate change, Resources and Human health are electricity consumption for sawing and processing (about half of the impacts) and transportation. Land occupation during wood harvesting contributes to Ecosystem quality impacts. The same conclusions also apply for wood fibers.
- For coir pith, more than half of the impacts on Climate change and Resources are due to transportation to the mixing plant due to CO2 and CH4 emissions and diesel consumption. The rest of the impacts are due to electricity consumption for processing and calcium nitrate for buffering. Land occupation during coconut harvesting contributes to Ecosystem quality impacts (70% of the total impact) while transportation contributes mostly to Human health (80% of the impact is due to transportation to the mixing plant) because of particulate matters and NOx emissions. (EPAGMA 2012)

For green compost, processing emissions (ammonia and N2O) and transportation contribute to Ecosystem quality impacts, Human health and Climate change impacts (respectively, about 80% and 20%).
- For mineral wool, processing energy for expansion contributes to 70% of the Ecosystem quality impacts and to more than half Climate change and Resources. Half of the impacts on Human health are related to basalt extraction (because of particulate matter emissions during extraction), while 30% are due to transports.
- For perlite, the energy consumption for expansion contributes to 70% of the Climate change impacts, while for Ecosystem quality blasting contributes more than half of the impacts and for Human health the transports and processing stages are the most impacting.
- For rice hulls, rice cultivation contributes to Climate change, Resources and Ecosystem quality impacts (70% of total impacts) through CH4 emissions from land and fertilizers, while transportation contributes to Human health impacts. (EPAGMA 2012)

The environmental profile of peat is characterized by three dominant processes, depending on the considered impact categories: distribution to the final customer, end-of-life, and peat extraction. Black peat is in general more impacting than white peat above all because its higher density. More precisely:
- The distribution of peat is a contributor to almost all the indicators (between 80% and 30%), in particular for Human health, Aquatic acidification and Aquatic eutrophication, because of particulate matters and NOx emissions during transports.
- The end-of-life, i.e. the peat decomposition, represents about 50% of the Climate change potential;
- Peat extraction, because of peat oxidation in situ, represents up to 60% of the impact for the Resources indicator. The extraction stage also contributes more than 30% of the Ecosystem quality impact (similar to distribution), because of the land use change over 50 years due to the extraction activities.
- Less important than the three above-mentioned processes are the processing stage, which contributes between 10% and 25% of the overall impacts. The highest relative contribution is for Ecosystem quality because of the electricity consumption of the machinery. (EPAGMA 2012)

The study concludes that peat based mixes have a higher impact on climate change and resources than non-peat mixes.
Concerning constituents of growing media, we observe that:
- Coir pith has the highest impacts on Ecosystem quality
- Mineral wool has the highest impacts on Human health
- Peat has relatively the highest impacts on climate change and resources.

Among growing media, peat based products have a higher impact on climate change and resources than non-peat mixtures.
Particularly, the extraction of raw material was found to have the highest impact on resources.
Black peat has a stronger impact on transportation than white peat, probably due to its higher density, which influence the environmental impact of transportation.
For climate changes, the most impacting stage is the end-of-life, the reason being that peat decomposition takes approximately 200 years, with the strongest emissions in the first 100 years.
Black peat end-of-life impacts are higher than for white peat due to the higher carbon content and density[114].

[114] Conclusions gathered from the literature review of EU Ecolabel (EU Commission 2013)

- ***A preliminary assessment of the greenhouse gases associated with growing media materials.*** **(DEFRA 2008)**

The main aim of this study was to assess the carbon footprint of selected growing media materials, comparing GHG emissions (CO2, CH4 and N2O) in their production, processing, transport and use phase.
This study uses average moisture content for peat, composts, forestry materials and coir but perlite and vermiculite are reported on a dry weight basis.
The research highlights a number of difficulties that exist when assessing the GHG emissions of organic materials. The report assumes that organic materials added to the soil decompose at the end of their life cycle, and that mineral materials remain in the soil.
For organic materials, it is assumed that 80% of the carbon decomposes within the IPCC 100-year time line and is emitted as CO2 while the rest 20% is retained into the soil carbon store. As a result, the CO2 emitted within the 'end use' stage dominates the results[115].
As stated in the study, primary data on all aspects of the supply chain was difficult to find. Therefore, the inherent variability in the composition of the organic materials made the calculation of a precise carbon footprint a difficult task since a single parameter, for example, bulk density, introduces variability into the results.
If it is necessary to calculate the GHG emissions from goods and services to PAS2050 standards then the offset approach is correct.
In the study GHG emissions were used as an environmental indicator and they are expressed in kg of CO2 equivalent.
The method that has been used for impact assessment is the 'LCA' carbon footprint where all emissions are included in the final total and also an 'offset' carbon footprint which excludes emissions of carbon dioxide from biogenic materials and deducts emissions associated with stored carbon.

Results

Concerning greenhouse gas emissions in the Life Cycle of growing media, the study found that coir, both UK and Irish, emit the least GHGs.
Also, the study is aware of the relativity of the results, for example, an offset approach gives a completely different perspective to the same data.
Peat, perlite and vermiculite have large carbon footprints while green compost, coir and wood products have low carbon footprints.
The study has considered the materials in their own right and made no calculations on the different mixtures which are normal in the commercial market where such mixtures of materials are common and quality and production are essential. Thus, to obtain a better understanding of the GHGs associated with those products, further studies should focus on specific market products (not materials).
In conclusion, the LCA approach supports the use of UK and Irish peat, and coir as growing media material, however, if the carbon neutrality of short-term materials and potential sequestration is taken into account then the opposite is true and compost, timber products and coir are the preferred materials. Therefore, the study underlines the fact that reduced peat use should remain its 'non-renewability' and potential for long-term in-situ carbon storage rather than its emissions of GHGs.

- ***Environmental Assessment of Garden Waste Management*. (Boldrin 2009)**

This PHD thesis provides an environmental assessment of a range of treatment schemes for the management of garden waste. The study includes windrow composting, thermal treatment and home composting. Even if the scope of the study is not completely in line with the scope of gardening, the part related to waste management through windrow composting has interesting findings relevant to our study. As explained in the study:
The results presented in this thesis are based on a study performed in Århus Kommune. The activities included comprehensive field-sampling campaigns for characterization of

[115] These summary conclusions have been collected from (EU Commission 2013)

garden waste and quantification of gaseous emissions during windrow and home composting.
During the waste characterization campaign, different properties of garden waste were defined, including unit generation rates, material fraction distribution and chemical compositions. Samples of waste were collected several times during the year, according to a low-cost sampling method developed and validated specifically for garden waste. The results confirmed that both material fraction and chemical compositions of the waste have a clear seasonal variability and suggest that diversion of garden waste to alternative treatments could be done on a seasonal basis. Furthermore, the chemical analyses showed that garden waste contains low level of pollutants. (Boldrin 2009)

Results
The Århus case study showed that a garden waste management system based on windrow composting generates rather small potential impacts on the environment. *These impacts are in the order of a few mPE per tonne of waste treated: -1 to 0.5 mPE tonne-1 of ww for the non-toxic categories and up to 18 mPE tonne-1 of ww for the toxic categories. Furthermore, the chemical analyses showed that the compost produced from garden waste contains low amounts of contaminants and it is suitable for organic farming.* (Boldrin 2009)
Therefore, as it is shown, that this kind of garden waste management is gathered to have a positive environmental impact.

- ***Energy use and carbon footprint from lawn management. A case study in the Uppsala region of Sweden*** **(Wesström 2015)**

The maintenance of lawns requires frequent maintenance activities, such as mowing, irrigation and fertilization, which result in energy depletion and cause greenhouse gas emissions. The goal of the study lies in the evaluation of energy use and carbon footprints from urban lawn systems with different intensities through a life cycle perspective.
The objectives of the study are to evaluate:
- the total energy use per hectare for each lawn type and energy use between the different management activities
- the carbon footprint per hectare for each lawn type and how it is portioned between different activities
- the total required carbon sequestration to obtain a carbon neutral lawn management
- improvement potential of maintenance practices to reduce the energy use and the carbon footprint

The lawns included in the study consist of utility lawns and meadow lawns, with management under Uppsala municipality, and two golf courses Upsala GK and Sigtuna GK.
The energy use and carbon footprint was determined by an inventory of the existing lawn management practices found in data from suppliers, green keepers and municipality. Secondary data was mainly collected from literature reviews.
The studied system boundary included lawn management, maintenance of equipment and the production of purchased inputs e.g. fuel, fertilizer and pesticides.
Transport of equipment between sites was excluded, except for the scenario related to golf courses.
The impact categories chosen for environmental assessment are global warming and energy use, while the functional unit is stated as the management of 1 ha of lawn during one year.
For the evaluation of the carbon footprints, data from inventory and previous studies were used regarding the different activities performed during lawn management. Emissions of CO2, N2O and CH4 were calculated and converted to CO2e. The energy use

was determined similarly, by using the inventory results and existing energy data of primary energy derived from other studies.
As mentioned, the study includes the use of lawn mowers and machineries in the estimation of environmental impacts.
The studies consider as source the Swedish electricity mix; the energy in the Swedish electricity mixture is taken mainly from nuclear power and hydropower.
Concerning petrol production and distribution, data was retrieved from existing publications.
While concerning fertilizers, data were collecting both from publications and from the European Fertilizer Manufacturers Association (EFMA).

Results
The study takes in consideration different kinds of lawns. Within them the results shown that greens (golf courses) have the largest carbon footprint and energy use per hectare followed by tees, fairways, roughs, utility lawns and meadow lawns.
Within the management activities, mowing, watering and the manufacturing of fertilizer were those with the largest carbon footprint.
The energy use was determined for the utility lawns and meadow lawns, where respectively 3 and 0.5 GJ ha-1 year-1 were required for the lawn management.
The carbon footprint of utility lawns is estimated to be 210 kg CO2e ha-1 year-1 and meadow lawns of 30 kg CO2e ha-1 year-1.
In conclusion, a recommendation for improvement is to reduce the applied amounts of nitrogen fertilizer, in particularly on fairways. Another suggestion is to increase the documentation of used resources, which will consequently improve the internal environmental work.
In the municipality, one possible improvement is to increase the environmental requirements for the procurement, for instance by demanding hybrid or electrical mowers. These types of mowers can be suitable since mowing was one of the management practices with the largest climate and energy impact.

10.3.2 Summary of other relevant studies

- ***A Review of Greenhouse Gas Emission Factors for Fertiliser Production*(Cowie and Wood 2004)**

The production of fertilizers requires much energy and generates considerable greenhouse gas (GHG) emissions.
This report represents a literature review on recent studies and collects published greenhouse gas (GHG) emission factors associated with the production of a range of fertilizers, for use in agricultural and forestry Life Cycle Assessments.
In particular it provides data of greenhouse gas emission factors for:
- Nitrogen Fertilizer Production and emission factors (Ammonia, Nitric Acid, Ammonium Nitrate, Calcium Ammonium Nitrate and Other Nitrogen Fertilizers)
- Urea and Urea-Ammonium Nitrate production and emission factors
- Phosphate Fertilizers production and emission factors
- NPK Fertilizers production and emission factors

As stated in the study, emission factors provide a useful shortcut for use in LCA, avoiding the need for detailed calculations of emissions. This factor is highly accurate in estimation of GHGs released to the atmosphere per unit of activity, and in this case, per unit weight of fertilizer produced (i.e. g CO2-e / kg fertilizer).
Concerning the assessment of impacts in line with international greenhouse accounting practice (IPCC 1996a), emission factors are expressed as carbon dioxide equivalents per unit mass of fertilizer product (eg. *g CO2-e / kg fertilizer*) or element (eg. *g CO2-e / kg N*).

Through the literature review this study enables the estimation of GHG emissions during extraction of resources, transportation of raw materials and products, and during fertilizer production processes.
The report also considers environmental impacts of key processes involved in the production of each type of fertilizer.

Results
This study is a literature review with the aim to estimate Greenhouse Gas Emission Factors for fertilizer production. There were few published studies that present GHG emission factors for fertilizer production and, with the exception of one study from the US, all were based on fertilizer manufacture in Western Europe.
In the literature review, data on Ammonia and Nitric Acid is widely available of data.
Concerning GHG emissions, nitrogen-containing fertilizer shows higher values in the production stage. In this phase, the strong emission is related to carbon dioxide (CO_2) emitted when natural gas is combusted as part of ammonia synthesis, and nitrous oxide (N_2O) emitted during nitric acid production.
For Phosphate Fertilizers, the higher emission of CO2 happens during the consumption of fossil fuels used in the various production processes. Transport of raw materials was an important contributor to phosphate fertilizer GHG emissions.
The study also underlines that these results vary within the different studies considered in the literature review. *This variation is due to differences in plant design and efficiency, emissions control mechanisms and raw material inputs. Differences may also be attributed to assumptions made by the analysts during the calculation of the emission factors, particularly in relation to the interpretation of energy and emissions credits and transport considerations.* (Cowie and Wood 2004)
A further understanding of these factors is required to ensure better decision on the improvement potential of fertilization practices.

- ***Environmental effects of pesticides. An impression of recent scientific literature.*** **(PAN EU 2010)**

Pesticide Action Network (PAN) is a network of organizations and institutions of over 60 countries worldwide aimed to minimize the negative effects of hazardous pesticides and to replace their use with ecologically sound alternatives[116].
The report we selected in our literature review represent a literature review itself its aim is to provide a broad framework of the environmental impacts related with the use of pesticides (including biocides) across different compartments.
In particular it shows the environmental impacts of pesticides:
- soil contamination
- water contamination
- effects on organisms
- effects on biodiversity

Results
The study presents a literature review on the environmental impacts of pesticides on different compartments.
Concerning soil contamination, the study shows that the main factors are related to the persistence of pesticides in soil, which can vary from few hours to many years in case of OC pesticides. Despite these pesticides having been banned in many countries, their presence is still detected in soils (Ferencz and Balog 2010).
Moreover, the impact of pesticides on soil is due to their absorbtion. Pesticides bound to soil organic matter or clay particles are less mobile, bio available but also less accessible to microbial degradation and thus more persistent. The addition of organic matter to soil can enhance sorption and reduce risk to water pollution. The amount and composition of

[116]Information available at: http://www.pan-europe.info/eu-legislation/directive-sustainable-use-pesticides

organic matter has had a large impact on pesticides sorption. Meaning that soil rich on humus content are more chemically reactive with pesticides than non-humified soils (Farenhorst 2006).
Although bound residues are considered of low significance because they are inactive and non-available, there also exists evidence that some organisms, e.g. plants and earthworms, can uptake and remobilise old tightly bound residues.

Concerning water contamination, pesticides can get into water via drift during pesticide spraying, by runoff from treated areas or leaching through the soil. Also some practices utilize the direct spray of pesticides onto water surface e.g. for control of mosquitos.
Rapid transport to ground water may be caused by heavy rainfall shortly after application of the pesticide to wet soils; the contamination depends also on the distance from the application site to water source. *In general, the compounds most frequently detected were currently used pesticides (herbicides Atrazine, Simazine, Alachlor, Metolachlor and Trifluralin, insecticides Diazinon, Parathion methyl, and organochlorine compounds due to their long persistence (lindane, endosulfan, aldrin, and other organochlorine pesticides).*

Pesticides also affect soil microorganisms. The ecosystem is essential for maintenance of soil structure, transformation of organic matter, and the making of nutrients for plants. The inhibition of species which provide key processes in terrestrial ecosystems mean a strong impact; fungicides were found to be the strongest pollutant in respect to the microbiological ecosystem of soils (Liebich, Schäffer, and Burauel 2003).
Further information is available in the study about the impacts of pesticides on microorganism ecosystem, particularly concerning, nitrification bacteria, symbiotic mycorrhizal fungi, soil invertebrates as well as other non-target species or animals.

Finally, the study analyses the effect of pesticides on biodiversity. Studies have brought alarming evidence of the negative effects of agricultural intensification on the diversity of wild plants, carabid and bird species.
As recommended in a study carried on in UK[117] the pressures of agricultural changes may be reduced by:
- minimizing loss of large habitats,
- minimizing permanent loss of agricultural land,
- maintaining habitat diversity in agricultural landscapes in order to provide ecosystem services,
- minimizing pollution from nutrients and pesticides from the crops themselves.

- ***Harvard yard soils restoration project summary report*** *(Fleisher 2009)*

The Harvard Yard Soils Restoration Project is a pilot effort modeled on the fully organic landscape maintenance program successfully operating at Battery Park City Parks (BPCP) developed by Eric T. Fleisher. Project Team also included: FAS Physical Resources and Planning, Facilities Maintenance Operations (FMO), Professor Michael Van Valkenburgh, from the Graduate School of Design, and James Sotillo of Treewise, Inc., a New York-based arborist specializing in organic care practices.
The project started in March 2008, when Harvard University converted a 1-acre plot of conventionally managed turfgrass into organic lawn.
The aim of the project was to reduce or eliminate the use of all inorganic fertilizers, chemical pesticides, fungicides, and herbicides, and significantly reducing the use of organic nitrogen fertilizers in the lawn maintenance programs.

The experiment was carried out over the course of 8 months between March and October 2008 and passed through 5 steps:

- Eliminate all use of toxins: pesticides, herbicides, fungicides and insecticides.

[117] Information available at: http://rstb.royalsocietypublishing.org/content/363/1492/777.full

- Test existing soil conditions to determine current biological, textural, and nutrient requirements.
- Develop specific compost teas and application schedules to balance soil biology and restore natural nutrient cycling. Reduce irrigation requirements and minimize need for nitrogen applications.
- Measure root growth, bi-weekly through November 1st, and compare results to the Control Plot.
- Adjust amendment program based on findings and analysis.

The early tests on existing soils showed an inefficient natural nutrient cycle system.
Therefore, the experiment forecasted an amendment strategy focused on properly balancing soil microbial population and activity for optimal nutrient cycling capacity. Also, specific compost tea[118] formulations were designed to boost the number of protozoa (Amoeba and Flagellates) and increase fungal colonization.

Results
Tests on the soil structure showed significant improvement in the natural nutrient cycling system. These results are also supported by the evidence of improved root growth, nitrogen levels and reduced need for irrigation. Root growth in the Test Plot increased by 3" to 5" over the Control Plot.
Concerning the Nitrogen levels, retesting of the Test Plot in September revealed that available nitrogen had increased to a healthy range, between 100 to 150 lbs per acre. These results were achieved thanks to the increasing of fungi and bacteria, which effectively immobilized the nitrogen in the root zone, particularly the rhizosphere (a 1mm zone immediately around the roots), preventing it from leaching away from the plant and making it available for consumption by the predator populations.

Concluding, as a result of the switch from conventional to organic landscape practices the university noted a first-year savings of 2 million gallons of water from reduced irrigation, and $45,000 in landscape waste removal fees from on-campus composting (Raver, 2009).
Currently the internal landscape department maintains 65% (52 acres) of Harvard properties, which have been managed organically since 2008; however, landscape managers hope to convert all 80 acres of Harvard University to organic practices.(Marshall et al. 2015).

The project is still ongoing, and the research group keeps updating information with regards to organic landscaping management.
From the website[119] of the project, it is possible to gather technical information in order to improve sustainable practices concerning:

- Organic Soils Management
- Soil Testing
- Composting
- Pest and Disease Control
- Irrigation
- Proper Planting & Pruning Techniques
- Plant Selection and Placement

[118] Compost tea is an aerated solution made by extracting and replicating the beneficial biology in compost into a liquid form.
[119] Information available at: http://www.energyandfacilities.harvard.edu/facilities-services/landscape-maintenance/organic-maintenance-program

10.4 Overview of environmental impact hotspots of Gardening Services

A summary of the quality and availability of environmental impact assessment literature in regards to gardening activities is provided below:

Literature availability – The number of studies related with gardening products such as fertilizers (Lammel and Brentrup 2003; Berthoud et al. 2012; Hasler et al. 2015), soil improvers and mulch (Schmilewski 2008; Ceglie et al. 2015; Verhagen and Boon 2008; EPAGMA 2012; DEFRA 2008), pesticides (Liebich, Schäffer, and Burauel 2003; Ferencz and Balog 2010; PAN EU 2010; Farenhorst 2006) is very wide due to the connection of this product with agricultural activities and the production of food. Also, all these products are the object of many EU regulation for fertilizers[120] or pesticides[121] and ecolabeling criteria for soil improvers (EU Commission 2013).
These publications provide a huge framework for the identification of environmental impacts and hotspots across the stages of their life cycle as well as identify hazardous substances or better practices.

Also, many publications are available on the environmental impact of crops in general even if many studies are related with agricultural production. However much literature is also available on floricultural production (Rikken 2010) as also for the production of ornamental plants (Russo 2007; Attanasio et al. 2007), both from the Eu Commission[122] .
Less information is available on the topic of gardening services regarding the activities of management of green areas, such as pruning trimming etc. However, a more detailed information is available on the topic of lawn maintenance, due to the stronger environmental impacts related with this maintenance service. In particular great awareness is currently increasing on the topic of sustainable management of lawn with the aim of reducing the use of chemicals and water and energy depletion associated with irrigation and lawn trimming activities[123].

Impact category coverage – Among the selected studies, most of them are specially focused on environmental impacts related with GHG emissions and climate change. The study from EPAGMA is the one which covers the wide range of impact categories.

Representative study for gardening activities – the studies that have been selected for the literature review are in line with the scope of our study and have been useful both for investigating issues related with gardening products as well as gardening services.

Regards the identification of the hotspots within gardening activities, The *Gardening Products and Services Technical Background Report* (TBG) (EU Commission 2011a) provide a good background. Moreover, the literature review that we have carried out, enables us to add some more insight on the topic. Below a summary of the main hotspots that we have identified:

Production phase

Raw materials extraction, manufacturing and transportation
There is significant impact for terrestrial climate change, acidification, eutrophication, important for photochemical ozone formation and mineral fossil resource depletion.

Fertilizers :

[120] Information available at http://ec.europa.eu/growth/sectors/chemicals/specific-chemicals/
[121] Information available at: https://ec.europa.eu/food/plant/pesticides_en
[122] Information available at: https://ec.europa.eu/agriculture/flowers_en
[123] Information available at: http://www.energyandfacilities.harvard.edu/facilities-services/landscape-maintenance/organic-maintenance-program

Production of fertilizers cause high values of climate change in the impact categories, as well as fossil fuel depletion and acidification, whereas resource depletion is dominant for production and transportation.
As gathered from the study on Granular organo-mineral fertilizer (Scam 2012), the main environmental impact of fertilizers are on global warming and rise in the Up-stream module which correspond with extraction of raw materials and the processing stage.
Moreover from the comparison of different fertilizer production chain (Cowie and Wood 2004), we see that that the strongest emissions of CO2 are associated with the production phase of nitrogen-containing fertilizer, emitted during nitric acid production
Concerning Phosphate Fertilisers production chain, GHG emissions are mainly associated with the consumption of fossil fuels used in the various production processes, and particularly during transportation.

Concerning growing media:
From the study on horticultural growing media (EPAGMA 2012) it is possible to gather the same results about fertilizers, being the extraction of raw materials as the highest hotspots for its impact on climate change, ecotoxicity and human health.
In the case of peat, beside the strong impact on climate change due with the extraction of basalt, the environmental impact during its transportation and end-of-life stage also represents some strong hotspots.
In any case, peat seems to have strong environmental impacts within soil improvements. The same conclusion can be gather in the TBG (EU Commission 2011a) which recommended to minimize the use of peat based soil improvers.
In the study carried out from Defra some different results have been provide.
In particular, the study shows that the extraction of peat from UK and Ireland peatland produces a low GHG emission.
While surface mining of perlite ore and vermiculite involves great changes in land use, removing the rock and soil in the mining process of steel increases emissions of both CO2 and N2O.
Crude perlite rock contains embedded water which when quickly heated to above 871°C, causes the crude rock to expand as the water vaporizes. The expanded particles are moved out of the furnace and cooled, graded and packed.(DEFRA 2008)
For that reason, the perlite and vermiculite production chain means strong CO_2 emissions due to the need of heating the rocks to a high temperature in gas fired furnaces for expansion.

Ornamental plant:
As shown in (Russo 2007) and in the TBG (EU Commission 2011a) in relation to plant suppliers, the main impacts are related to the growing practices, materials and resources used in the nurseries, particularly, water and energy consumption used for irrigation and for the heating of the greenhouse and high use of chemical for fertilizers and pest control.

In this review, no information on the production chain of pesticides was available.

- **Packaging**
About the suppliers of ornamental plants, as gather in the study on LCA of floricultural activities (Russo 2007), the use of non-reusable compostable PVC pot and polystyrene for the plateau, which are used for the delivery of nurse plants, contribute for 20% of the total environmental impact of the life cycle of flower nursery crop.

Use phase

Gardening products:

-Pesticides
The strongest impacts associated with pesticides occur in the use phase.

Pesticides are characterized by a high persistence in the environment, low water solubility and accumulation in water sources, soil and bioaccumulation in food chain.
Moreover the use of pesticides is also associated with loss of biodiversity both of vegetal species, microorganism and animals. (PAN EU 2010) (information on environmental effects of pesticides is available in this publication)

- **Fertilizers and soil improvement**

The main environmental impacts in the use phase of fertilizer are associated with Acidification and Eutrophication.
The acidification process occurs as a result of NH3, NOx, and SO2 emissions. Ammonia and nitrogen oxide appear both during production and after the fertilizer is applied. *Ammonia losses range from 1 to 15% of the nitrogen mass in the fertilizer and are the greatest following application of urea* (Skowroñska and Filipek 2014).
Nitrogen oxide emissions result increases in the efficiency of nitrification and denitrification processes following application of mineral fertilizer, as well as ammonia volatilization (about 10% ofammonia from agriculture is oxidized to NOx in the atmosphere) (Skowroñska and Filipek 2014).
The highest emission, expressed as the percentage of nitrogen in the fertilizer, following application of urea (3.2%); in the case of ammonium nitrate, it was only 0.7%.
The acidification process AP grows with increased nitrogen application in the form of NH4NO3, mainly due to ammonia volatilization. (Skowroñska and Filipek 2014).

Concerning the Eutrophication process two subcategories have to be distinguished: terrestrial eutrophication and water eutrophication. As application rates of nitrogen fertilizers increase, changes in the terrestrial eutrophication potential will have a similar pattern as in the case of acidification (Skowroñska and Filipek 2014).
Analysis of the aquatic eutrophication potential indicates that when nitrogen fertilizer application rates exceed 144 kgNha-1, changes in AEP are mainly determined by the amount of nitrate leaching; phosphorus, which mainly comes from phosphorus fertilizer production, accounts for only 9% of AEP even when the fertilizer is applied at the highest rates (Skowroñska and Filipek 2014).
Studies shows that mineral fertilizer application rates that are either too high or too low reduce the eco-efficiency of crop production, mainly due to eutrophication in the former case and to inefficient land use in the latter (Skowroñska and Filipek 2014).

The literature review doesn't show relevant impacts from the use-phase of soil improvers.

Gardening services:

- **Lawn management**

The literature shows strong impacts from the maintenance of lawn. The impacts are related to the high rate of water and energy resources needed for operation of watering and lawn trimming. The using of machinery in these phases is also associated with fuel depletion and emissions.
Moreover, in this phase the environmental impacts are also related with the use of fertilizers and pesticides for lawn maintenance.

End of life

As gathered from the TBG (EU Commission 2011a) plant delivery can generate considerable amount of waste. *"Plants are normally delivered in flower pots or containers that are either single-use plastics pots or reusable containers that nursery do not take back, ending up most of time in landfill sites or incinerators."* (EU Commission 2011a)

For the end of life of gardening products the environmental impacts derived from the 'abandon' (EPAGMA 2012)of products in the soil and their accumulation in the ecosystem means a strong impact for the environment. The word 'abandon' refer to the act of

releasing products such as fertilizers, pesticides or soil improvers in the environment. This release results in a progressive accumulation of pollutant, heavy metals or chemicals both in soil and in water ecosystems.

10.5 Environmental improvement areas

The increasing awareness about the improvement potentials of landscape management has boosted the implementation of sustainable practices.

Organic landscaping care is being adopted more widely and studies found that organic management programs resulted in fewer herbicide and insecticide treatments than conventional programs, and thus a reduction in annual maintenance costs, with comparable aesthetic qualities to a conventionally managed system (Alumai et al. 2009; Marshall et al. 2015).
As stated on the web page[124] of the research group from Harvard University dedicated to sustainable landscape management: "*The foundation of an organic program requires the plants and soils to be viewed as extensions of one another, existing in a perfect symbiotic relationship. This holistic "bottom up" focus contrasts with the conventional maintenance mindset of treating specific plant health conditions from the "top down" through the application of synthetic chemicals*. *Sustainable landscape management encourages the systems created by nature: healthy soils supporting healthy plants.*"

In this paragraph, we will present a synthesis of the improvement areas for gardening services and products that we gathered from the literature review, furthermore the information provided on the Harvard web site mentioned above is included as a useful resource for a basic understanding of potential improvement for gardening services and products, along with the results and findings from the LCA studies presented.

Gardening products

1.Fertilization and soil improvement
A way to reduce the impacts of growing media is to optimize the impacts of individual constituents over their respective life cycles, particularly the distribution of growing media to the final customer.
The peat industry has developed different strategies to lower the environmental impact of peat harvesting. Some examples are:

- *Setting criteria for choosing bogs to harvest (for instance, focus peat production on drained peatlands with high greenhouse gas emissions). There is a need for a simplified methodology to determine/estimate emissions from individual sites.*
- *Developing new production technology allowing harvesters to:*
  - *Reduce the amount of residual peat to reduce emissions from the after treated area (in the case of afforestation);*
  - *Reduce the moisture content of the extracted peat: the drier the peat, the lower the fresh peat density, and consequently the lower the emissions from transport;*
  - *Shorten the harvesting time as much as possible.*
  - *Starting the after-use as soon as possible after harvesting. The choice of after-use will depend on many factors. Restoration, rehabilitation or afforestation should be the preferred peatland after-uses.* (EPAGMA 2012)

Some more recommendations about the use of fertilizer are available in another study about different fertilizer product types: "*appropriate use of fertilizer in crop production to limit the environmental impact is essential for sustainable agriculture. While much is*

[124]Information available at:
http://www.energyandfacilities.harvard.edu/facilities-services/landscape-maintenance/organic-maintenance-program

known about the environmental impact of fertilizer production only a limited amount of data is available covering the whole fertilizer supply chain".(Hasler et al. 2015)
Other studies found that calcium ammonium nitrate based fertilizers are a sustainable choice the reduction of phosphorus application rate according with a fertilizer strategy with a balanced nutrient formula. On the other hand, as nitrogen application rates strongly affect the LCA results, it is essential that the right amounts of N are used and that for N fertilizer production the best available technique should be installed. (Hasler et al. 2015)

The main concern in organic landscaping management is the restoration and maintenance of the natural nutrient cycling system. It is possible to improve nutrient and moisture availability and retention, aeration and degradation of harmful pollutants through non-chemical or synthetic methods.
Moreover, significant improvements in the natural nutrient cycling system of the soil are strongly related to improved root growth, which allows a better water and nutrient retention and also result in healthier plants that require less water and are less vulnerable to disease.(Fleisher 2009)

Therefore, as recommended in the Harvard Report, fertilization and plant management practices should be focused on improving roots growth more than foliage growth.

2. Ornamental plants
There is technical information available from the TBG on improvement areas for the suppliers of ornamental plants.
As stated there: *"organic cultivation should be applied to ornamental flowers and plants. Organic production must respect natural systems and cycles. Sustainable production should be achieved insofar as possible with the help of biological and mechanical production processes, through land-related production and without the use of genetically modified organisms. In organic farming, closed cycles with the use of internal resources are preferred to open cycles with the supply of external resources."* (EU Commission 2011a)
Some findings about improvements from the plant suppliers can be gathered in the study on floricultural crops (Russo 2007). As stated in this study, due to the strong impact in energy depletion caused by the heating of green houses, the use of renewable energy sources in these systems of production is recommendable.
Furthermore, possible interventions to get lower environmental impacts are:
- Roof covering layers and/or thermal screens on the green house structures
- Use of renewable energies as solar, photovoltaic and/or wind power
- The use of biomass for the cogeneration and trigeneration
- Use of methane instead of traditional fossil fuels

The use of pots and containers of seedlings made with resultant material and/or recycled material would reduce the environmental impact, as well as the recycling of rain water for crop irrigation.

For ornamental plants, a lot of information can be gathered from the publication (Borruel, Punsola, and Garcerán 2016). This guide gives information about the sustainable choice of plant variety and also on the kind of invasive species to avoid.

Gardening operations

1. Pest control
The use of plant protection products in the EU is highly regulated; the only products currently approved for the European market are those which risks are considered acceptable. Moreover, the EU Commission boosts the diffusion of Integrated Pest Management (IPM) in order to enhance low pesticide-input management including non-

chemical methods. Professional users will have to apply general principles of IPM from 1 January 2014[125]; therefore, national authorities are working at Nation Action Plans[126] in order to adapt their laws to meet these goals.

IPM is a system of management of green areas that involves a combination of biological and chemical measures that aims to provide a cost effective and environmentally sound management of diseases, insects, weeds and other pests.
IPM strategy comprises three main activities:
- Prevention of pest build-up through use of appropriate cultivation methods.
- Monitoring of green areas to observe pest levels, as well as the levels of beneficial species that can provide natural control mechanisms.
- Intervention where control measures are deemed necessary.

IPM practices and policies have been adopted in publicly managed green spaces; one example is the municipality of Barcelona which service of garden maintenance shows the commitment of the Municipality to ensure the use of practices and products that create fewer risks to people's health and the environment. The Commission for Ecology, Urban Planning and Mobility gave its unanimous approval to eliminating the use of glyphosate and other toxic herbicides in Barcelona's green areas, streets and squares. The City Council coordinates its works of garden maintenance following the criteria and regulations set out in the Barcelona Green and Biodiversity Plan and the Barcelona Street-Tree Management Plan. In particular their strategy involves "*fighting against alignment-tree pests and diseases through their natural enemies, whether predators, parasitoid or pathogens. It means using organisms (useful fauna) that act against pests and help to reduce their population levels*." (Borruel, Punsola, and Garcerán 2016)
Some further information on IPM are available from the Report on Organic Lawn Management of Harvard University (Fleisher 2009), the experiment has been carried out using only non-toxic methods for treating and preventing pests and disease by relying on the following processes and techniques:

- *Monitoring moisture because inadequate moisture levels can weaken plants and make them susceptible to pest problems.*
- *Applying compost teas to suppress powdery mildew.*
- *Introducing and cultivating beneficial insects which prey on destructive insects.*
- *Manually removing infected tree and shrub branches.*
- *Manually removing weeds.*

Important: Before using the above treatments, verify that pests and/or disease are the problem. Performing a comprehensive soil, plant, and field analysis will help identify the underlying issues and determine the best path forward. Time spent in this early phase will allow you to choose solutions that optimize results and minimize the reoccurrence of pest and disease problems. (Fleisher 2009)

2. Watering and irrigation
As stated in the TBG (EU Commission 2011a) water consumption is one of the most significant environmental issues associated with gardening, especially in southern Europe.
The goal of a proper irrigation system is to program the right amount of water in the right location and at the right time.
Over watering could result in the leaching of valuable soil nutrients and in the damage of plants health. However, during periods of drought and transplanting operations additional water may be required.

[125] Information available at: https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides_en
[126] Information available at:
https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides/nap_en

An efficient water application corresponds with an in-ground irrigation system[127].
Even if these systems are used to having automated control, a continuous maintenance and monitoring of the correct state of installation as well as of the rate of water application should ensure an adequate irrigation practice.
According to the indications of the TBG, the strategy for water saving should focus on:

- Using non-potable water for watering
- Calculate accurately the water needs of each green area
- Installing and programming correctly efficient irrigation systems
- Apply mulching as a prevention and water saving techniques
- Arrange plants according to their hydric requirements
- Select regional plants adapted to the weather conditions

(EU Commission 2011a)

Operational management

1. Waste generation

In order to achieve a sustainable management of green areas, composting is the main strategy to achieve a closed loop system where waste from the parks, or from urban compost treatment plants, creates healthy soil that allows the parks' plants to grow.

Once again, from the Harvard Report we can gather practices that include composting as a part of routine management of green areas.

As explained, the organic urban waste (from the neighborhood) together with plant waste from the parks, including all the cuttings, weeds, branches, grass, and leaves, are added to the composting vessel unit in precise arrangements as different plant types need different soil biology for optimal growth. It takes up to six weeks for heat and microorganisms to turn the waste into compost, ready to be used in the parks. Moreover, compost can also be steeped in aerated water to produce liquid biological amendments (compost teas).

A complete description of "receipt" for compost and management practices is available on the web site of the Harvard facilities service above mentioned.

Moreover, concerning the management of garden waste, some improved practices are also described in the publication from GPP in Practice of the city of Barcelona. The indications regard:

- *Foliage: A gathering point for plant clippings is to be predefined and organic waste must be composted.*
- *Lawn mowing: All cut grass shall be immediately removed and composted. No plastic bags are to be used as part of this process.*
- *Pruning: when waste plant materials are generated during tree and hedge pruning, the contractor must have a system in place that allows all branches that are less than 5cm thick to be crushed, and this waste to be composted. No plastic bags are to be used as part of the process.*
- *Any soil and rubble which needs to be disposed of can be reused by the contractor.*

Sludge: The contractor will be responsible for the removal, transport and management of sludge from lakes and streams. The contractor can reuse these materials as fertilizer, as an alternative to taking these to the landfill site. (EU Commission 2014)

[127]Information available at: http://www.energyandfacilities.harvard.edu/facilities-services/landscape-maintenance/organic-maintenance-program

10.6 Cost considerations

The improvements for gardening activities proposed in this study can result in cost savings for administrations.
As shown in the experiment carried out at Harvard University with an organic landscaping maintenance program[128], the sustainable management of green areas can result in overall advantages, both economic and environmental.
In the first year of implementation (2008) this program was able to save 30% of water and reduce the use of products including fertilizer and products for disease control.
With this in mind, we can consider that performing gardening activities in accordance with environmental criteria may enhance savings for public administrations.
Nevertheless, we have to consider that additional costs can be accrued with organic and environmentally friendly products, which have a higher market prices (e.g. ornamental plants, Eco-labeled certified products, reusable packaging etc.).
Still, experience shows that boosting biodiversity and sustainable maintenance of green areas can result in a reduction of irrigation needs and plant protection.

Market availability of environmental friendly products

The garden industry is a large market and sustainability measures can be taken on by local public authorities, as well as among private consumer. In this frame sustainability is boosted in many fields.
A primary foundation for sustainability in the garden industry is ensured by the Eco-label, which, through its requirements and standards, gives a guarantee for the production chain of the different products on the market.
One of the main tools for standardization in the field of garden products is the ENA[129], which establishes European quality standard for plant nursery stock. This tool provides harmonized definitions for plants and activities, and quality standards for the related production chain. This tool is not specifically addressed to the sustainability of the practice. On the other hand, the *Milieu Project Sierteelt*[130] (MPS) is specifically set up as an environmental project by the Dutch country. MPS is responsible for the certification process in the areas of quality assurance and environmental and social aspects, not only for growers, but also for traders and procurers of products.
MPS provides a list of producers for a range of products such as plant, flower and growing media indicating the level of sustainability of operations management with 3,673 participants in 2010 (Rikken 2010).
Another organization committed to the certification of sustainable products is the GLOBAL G.A.P.[131] Even though this organization is mainly focused on horticultural activities, it provides a general framework for crops and livestock.
The GLOBALGAP protocol defines the elements of Good Agricultural Practices (GAP). It includes topics such as Integrated Crop Management (ICM), Integrated Pest Control (IPC), Quality Management System (QMS), Hazard Analysis and Critical Control Points (HACCP), workers' health, safety, welfare and environmental pollution and conservation management.
Among the wide range of product scopes that GLOBALGAP offers for certification, horticultural products are the leading category; flowers and ornamental standard in particular has been increasing strongly lately. The number of certified growers is about 400 companies in 24 countries (Rikken 2010). As of July 2017, flowers and ornamental plants that come from GLOBALGAP certified farms can be labelled with the GGN[132] consumer logo.
Today, a vast majority of European flower and plant growers participate in one or more certification schemes. Some growers have chosen to participate as a form of self-

[128] Information available at: https://green.harvard.edu/topics/nature-ecosystems
[129] Information available at: https://docs.wixstatic.com/ugd/71c698_8a33d7b877964b9dba4904dba2df8328.pdf
[130] Information available at: https://www.my-mps.com/en/certificates-producer/mps-abc
[131] Information available at: http://www.globalgap.org/uk_en/ /
[132] Information available at: http://www.globalgap.org/uk_en/for-consumers/

regulation; others use certification schemes as a management tool to professionalise their business.

The EU Eco-label as well, cover some gardening products as growing media, soil improver and mulch[133]. The EU Eco-label addresses control of the sustainability of the production chain and of the product formulation. As an important supplier to gardening activities, the industry of soil improvers and growing media is an important contributor to the sustainability of the green gardening market.

For further analysis on the current state of the market of growing medium, the Growing Media Europree AISBL[134] is a reliablesource, representing the producers of growing media and soil improvers in the European sector. It gives a broad measure of the market, since it represents an industry with a €1.3 billion turnover accounting for 11,000 jobs across Europe. The Growing Media AISBL is essential to the horticulture industry, which is estimated to have a turnover of approx. €60 billion and to provide over 750,000 jobs.

[133] Information available at: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/revision-eu-ecolabel-criteria-soil-improvers-and-growing-media-technical-report-and-draft

[134] Information available at: http://www.growing-media.eu/

11 Equipment items for Public Space maintenance: Vehicles

Regarding the vehicles employed for the maintenance of public spaces, in the Part I section 5.1 of this preliminary Report the following groups have been identified:

- Human-controlled vehicles:
  - Sweepers and street cleaning vehicles
  - High Pressure cleaner vehicles (water/sand)
  - Snow removal vehicles (with plough blades and salt spreader)
  - Maintenance utility vehicles for public green spaces (such as truck and tractors)
  - Maintenance utility vehicles for watering green spaces
  - Maintenance utility vehicles for goods and material transportation (such as vans)
- Remote controlled, autonomous or robotic vehicles

11.1 Characterization of Vehicles for Public Space maintenance

Directive 2007/46[135] regulates the EC type approval of vehicles. The main objective of the legislation is to ensure that new vehicles, components and separate technical units put on the market provide a high level of safety and environmental protection.

Annex II provides more detailed definitions of vehicle categories and vehicle types that are relevant for the characterization of vehicles used for public space maintenance, as shown in **Error! Reference source not found.**.

Table 11: Table 12: Definitions for vehicles used for public space maintenance of Annex II of Directive 2007/46/EC

N	Motor vehicles with at least four wheels designed and constructed for the carriage of goods
O	Trailers (including semi-trailers)
Special vehicles	
Mobile cranes	
Other special purposes vehicles	

Among N vehicles, N1 vehicles are part of the scope of the EU GPP criteria for road transport and therefore are not included in this study, which will focus only on N2, N3 vehicles, special vehicles for street cleaning and maintenance. Trailers (O vehicles) are used mainly in long haul transportation; hence they are not relevant for this study.

Vehicles

For a technical characterization of vehicles for Public Space Maintenance, the main groups that could be identified are:

Common vehicles used in the logistics chain that enabling the delivery of goods[136];
They could be defined as:
- Heavy duty vehicles (N2 and N3 vehicles)

Special vehicles and other special purposes vehicles are:

[135] Full text available at: http://eur-lex.europa.eu/legal-content/ES/ALL/?uri=CELEX%3A32007L0046
[136] Information available at: http://www.acea.be/publications/article/fact-sheet-vans

- Street Cleaning vehicles
- Vehicles for winter maintenance
- Vehicles for agricultural and landscaping activities.

Heavy duty vehicles

The heavy-duty vehicle category could encompass trucks of different types and sizes.
Tractor trucks are used to move trailers; the configuration of the trailer varies widely based on the freight being hauled or the purpose of activities for which the vehicle is needed.
Tractor trucks for Public Space Maintenance can be loaded with special trailers for the transport of green waste, watering tanks, spreading systems etc..

Figure 37: example of tractor trucks.

Sourced by: https://www.gardenbagsbrisbane.com.au/garden-services/walk-in-garden-skip-bins/; https://is.alicdn.com/img/pb/221/913/112/112913221_269.jpg

Cleaning vehicles
Studies focusing on street cleaning (Idaea-CSIC 2016; F. Amato et al. 2010; CIWM 2008; Kuehl, Marti, and Schilling 2008) gives broad information about this sub group of specialist vehicles.
As stated in (Idaea-CSIC 2016) there are three main types of road sweepers used in Europe.

- Mechanical sweepers: this kind of sweepers use a gutter broom to lift debris from the street surface into the path of the main broom which then works with a conveyor belt to move debris from the ground into a hopper contained within the unit.
In general, these kinds of vehicles are effective in the collection of medium size debris such as branches, leaves, litter, and large quantities of dirt; however, they don't work well in areas with great amounts of debris (Idaea-CSIC 2016). Their use can result in the production of dust clouds, because of that a flush truck sometimes is used to mitigate dust.

Figure 38: Figure 39: Mechanical sweeper.

Source: http://broddson.se/en/product/broddson/broddson-ms1/

- Vacuum sweepers use a gutter broom to loosen dirt and debris into the path of a vacuum nozzle. A center mounted transfer broom windrows debris from the street surface to the vacuum. Pure vacuum sweepers create a strong vacuum within the pick-up head which draws air from outside the head, through a duct, and into the hopper (Idaea-CSIC 2016). Vacuum sweepers utilize a fan that exhausts its air directly to the atmosphere. These sweepers must use water for dust suppression or the fan would blow large amounts of dust into the atmosphere causing environmental issues as well as increased fan wear.

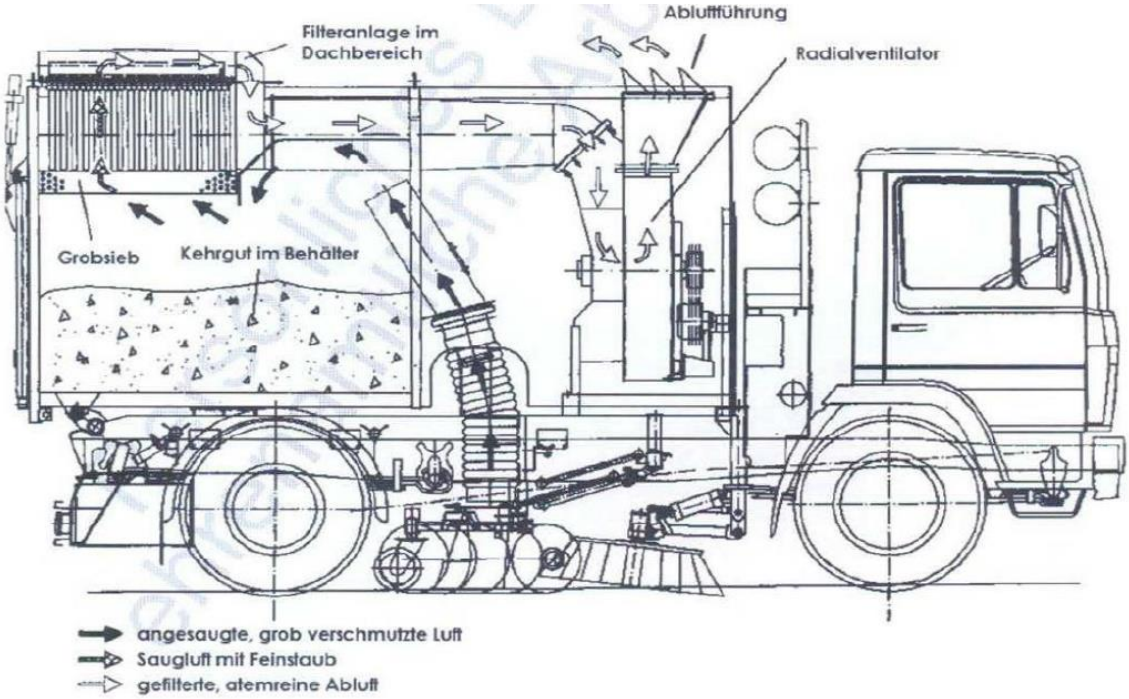

Figure 40: Vaccum sweeper.

Source: (VDI 2014) retrieved in (Idaea-CSIC 2016)

- Regenerative air street sweepers use gutter brooms to move debris from the curb into the path of the sweeper's head. The blast of exhaust air is directed at an angle to the pavement to dislodge dirt.
  The regenerative air process blows air into one end of the sweeper's head and onto the pavement dislodging materials. The non-recirculated portion of the exhaust air is collected into a separate settling chamber before it escapes to ambient air.
  Water sprays can be used with to reduce the release of dust. (Idaea-CSIC 2016)

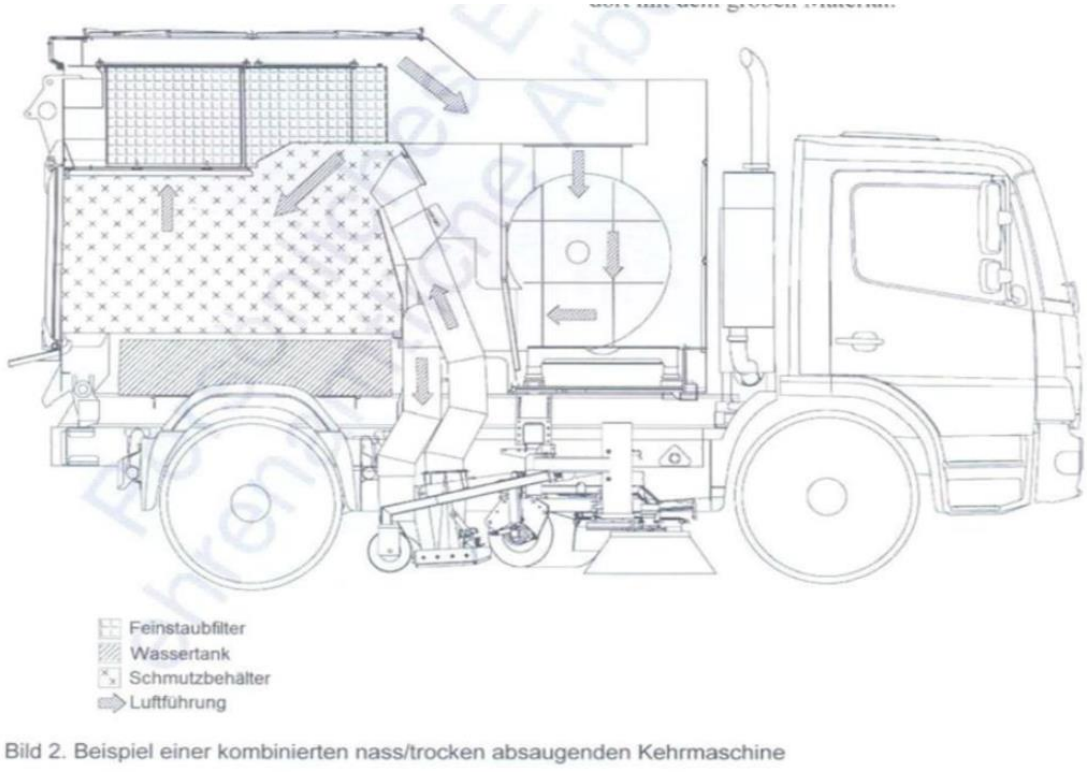

Bild 2. Beispiel einer kombinierten nass/trocken absaugenden Kehrmaschine

Figure 41: Example of a wet and dry sweeper
Source: (VDI 2014) retrieved in (Idaea-CSIC 2016)

The technology of street sweepers has not changed very much over the past few decades with the exception of the use of bag filters to control fugitive PM10 emissions from the dust collected, and diesel particulate filters to control exhaust emissions. (Idaea-CSIC 2016)

Moreover, the same study specifies that in 2004 the public purchasers of new sweepers started to request information on the PM emissions and some European organizations started to develop test procedures to measure the PM concentration around a working road sweeper. One of these organizations is the German Federal Environment Agency (Umweltbundesamt – UBA), which commissioned DMT[137] to develop a reliable method for the determination of particulate emissions from road sweepers under standardized conditions. This standard applies to vacuum-assisted dry and vacuum assisted wet/dry combination Street sweepers as well as to vacuum-assisted wet street sweepers used for municipal street cleaning services.(VDI 2014)

[137]Information available at: http://www.dmt.de/en/press/news-details/article/vacuum-cleaner-test-in-xxl/javascript_a708894199.js.html%26type%3D98.html

Also, the EUnited Association of Municipal Equipment Manufacturers[138] developed the *EUnited PM 10-Test*, a test procedure for measurement of the fine dust swirled up during sweeping. The tested sweepers are identifiable by the EUnited PM10-Test label, now widely adopted across Europe.

Vehicles for winter maintenance

Technical characterization of vehicles for winter maintenance is available in the document Winter Maintenance Equipment and Technologies[139] and also in the study on winter service in Norway (Vignisdottir, Booto, and Bohne 2016).

Vehicles in winter maintenance mainly refer to the winter service vehicles (WSVs) such as trucks and their extra equipment. Extra equipment includes tanks, salt/sand spreaders and the different types of blades and ploughs.
The most common used WSV is a truck or a tractor with mounted a spreader, plough, grader or loader.
Other WSVs are also commonly used during or after weather events to remove ice or snow from the road.
In winter service vehicle, type and size must be selected properly to be able to operate in the required areas as well as carry and operate the mounted equipment and provide a safe and comfortable environment for the operator. Vehicles may also be multi-purpose, and be used for other duties during non-storm event times and during the off-season and summer months.

Figure 42:: example of Snowploughs and Salt spreader.

Source: http://rasco.hr/en/proizvodi/brk/

Concerning winter maintenance vehicles, the manufacturers of spreading machines associated with EUnited Municipal Equipment and the Engineering Center Bygholm in Denmark have developed a test method (EUnited 2014) with the main intention of providing a unique frame for the evaluation of spreading thawing agents.
When these products are applied onto the street surface, is important to control the release of material in order to ensure the safety of road traffic under the current weather conditions, but also to minimize the amount of product in order to limit the environmental impact and to reduce the costs.

The test method of the EUnited (2014) is aimed at testing the performance of a model of vehicle-mounted or (trailer) dragged spreading machines for winter service. In particular, this test is valid for machines which are used to spread the following media:

[138] Information available at: http://www.eu-nited.net/municipal_equipment/sweepers-rcvs-winter-maintenance-equipment-important-topics/list-labelled-machines-eunited-pm10-test-sweeper-list-of-tested-/successful-eunited-pm-test-to-become-official-european-standard-kopie.html
[139] Published from TAC- Transportation Association of Canada in 2007; available at http://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/roadsalt-9.pdf

- Solid thawing media with or without pre-wetted media
- Liquid thawing media

Other standards that are relevant for these vehicles are the following:

EN 13021, Winter service machines - Safety requirement
EN 15144, Winter maintenance equipment - Terminology - Terms used for winter maintenance equipment
EN 15431, Winter and road service area maintenance equipment - Power systems and related controls —
Interchangeability and performance requirements
EN 15597-1 Winter maintenance equipment - Spreading machines (gritting machines) - Part 1: General requirements and definitions for spreading machines

Agricultural vehicles
Agricultural and forestry tractors and their trailers fall in the Vehicle Category T (Wheeled tractors) and C (Track-laying tractors).
They are used for pulling or pushing agricultural machinery or trailers, for plowing, tilling, disking, harrowing, planting, and similar tasks. This kind of vehicle covers steel or rubber tracks, fitted to crawler vehicles.
The Directive 2003/37/EC[140] of the European Parliament and of the Council of 26 May 2003 specify a system of mandatory *European Community Whole Vehicle Type Approval* (ECWVTA). This directive outlined the framework for a European-wide system of approval for agricultural or forestry tractors, their trailers and interchangeable towed machinery together with their systems, components or separate technical units.

A new EU Framework Regulation (EU) 167/2013 (and its amending Regulation (EU) 2016/1788 of 14 July 2016[141]) has been launched. According to this regulation, tractor type approval falling under **Category T** (Wheeled tractors) include:

Category T1: wheeled tractors with a maximum design speed of not more than 40 km/h, with the closest axle to the driver having a minimum track width of not less than 1 150 mm, with an unladen mass, in running order, of more than 600 kg, and with a ground clearance of not more than 1 000 mm.
Category T2: wheeled tractors with a maximum design speed of not more than 40 km/h, with a minimum track width of less than 1 150 mm, with an unladen mass, in running order, of more than 600 kg and with a ground clearance of not more than 600 mm. However, where the height of the center of gravity of the tractor (measured in relation to the ground) divided by the average minimum track for each axle exceeds 0,90, the maximum design speed is restricted to 30 km/h. –
Category T3: wheeled tractors with a maximum design speed of not more than 40 km/h, and with an unladen mass, in running order, of not more than 600 kg. – Category T4: special purpose wheeled tractors with a maximum design speed of not more than 40 km/h.
Category T5: wheeled tractors with a maximum design speed of more than 40 km/h.

[140] Information available at: https://ec.europa.eu/growth/sectors/automotive/legislation/tractors_en
[141] Information available at:
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2016.277.01.0001.01.ENG

Figure 43:: Example of Tractors employed for maintenance of public green areas.

Arm mowers are machines for cutting grass, weeds, bushes and similar vegetation on road edges and drains along the roads, overpass embankments, slopes of drainage networks, and other surfaces requiring landscaping and vegetation maintenance.
Source: http://rasco.hr/en/proizvodi/brk/

Concerning emissions of these vehicles, the recent Commission Delegated Regulation (EU) 2017/686 of 1 February 2017 established Stage IV, outlining more stringent emission limits, which will start being enforced on October 2017 for type approval and October 2018 for the placing on the market.

Tractor types falling under **Category C** (Track-laying tractors) are propelled and steered by endless tracks and include categories C1 to C5 which are defined similarly to categories T1 to T5.
Category C track-laying or 'crawlers' tractors, thanks to the additional track-soil grip and inherent low center of gravity, are usually well-suited to performing operations in steeply-sloping areas, while their slow speed and unsuitability for on-road use make them unsuited for transport applications.
Since these vehicles are mainly used for non-road activities their emissions are covered by the regulation on emissions of NRMM[142].

Figure 44: Example of Track-laying tractors
Source:
https://i2.wp.com/www.mysmith.co.za/pr/wp-content/uploads/2014/12/IMAG2046.jpg?fit=1024%2C579&resize=350%2C200
https://i.ebayimg.com/00/s/OTYwWDEyODA=/z/ViUAAOSw4DJYhsCa/$_35.JPG

11.2 Overview of Life Cycle Assessment studies on vehicles for Public Space maintenance

In the current literature, a wide range of studies are available on the comparison across the life cycle of vehicles with different powertrains, attempting to evaluate the improvement potential of new technologies with respect to conventional vehicles.
In this field, the study *Revision of the EU Green Public Procurement Criteria for Transport- Preliminary Report* (Quintero et al. 2016) presents a broad literature review.
For our study, we make reference at this *Preliminary Report* for the concerns about LDVs.
Furthermore, with the aim of covering the different range of products included in the scope of our study, we provide a review of studies that focus on HDVs with a particular emphasis on Trucks and Tractors, which were not covered in the above-mentioned study of reference (Quintero et al. 2016).
Furthermore, since no LCA studies were found on specialist vehicles, we reported a general overview on street sweeping vehicles and a technical report on winter maintenance and dust control practices.

The reviewed studies are:

About the comparison on conventional and alternative powertrains for trucks:
- *Does a battery-electric truck make a difference? Life cycle emissions, costs, and externality analysis of alternative fuel-powered Class 8 heavy-duty trucks in the United States* (Sen, Ercan, and Tatari 2017)
- *Comparison of Life Cycle Greenhouse Gases from Natural Gas Pathways for Medium and Heavy-Duty Vehicles* (Tong, Jaramillo, and Azevedo 2015)
-

About the estimation of alternative powertrain performances in fleets management.
- *Life cycle based multi-criteria optimization for optimal allocation of commercial delivery truck fleet in the United States* (Zhao, Ercan, and Tatari 2016)
- *Comparative LCA of Electrified Heavy Vehicles in Urban Use* (Inzunza Soriano and Petter Laudon 2012)

About vehicle for agriculture activities:
- *Environmental hot spot analysis in agricultural life-cycle assessments three case studies* (Piringer et al. 2016)

As explained no specific LCA or EPD report was found on the topic of Vehicles for Public Space Maintenance such sweepers, or winter maintenance vehicles. Hence, we present a collection of other technical reports focused on the topic of dust and winter maintenance.

- *Review of impact of street cleaning on PM10 and PM2.5 Concentrations in Northern and Central Europe*. (Idaea-CSIC 2016)
- *Deliverable product of the REDUST LIFE09 ENV/FI/000579 Action 3. A report on PM10 dust emission estimates for current measures and estimation of emission reductions due to additional measures based on first and second year demonstrations.* (Redust 2012)

The table below provide a short description of the mentioned relevant studies.

Table 13: Overview of the selected studies related to vehicles for Public Space Maintenance

Study type	Sub- category	Source	Title	Impact assessment	External critical review	Impact hotspot summary
EIO-LCA	Heavy Duty Truck	Sen, Ercan and Tatari 2017	*Does a battery-electric truck make a difference? – Life cycle emissions, costs, and externality analysis of alternative fuel-powered Class 8 heavy-duty trucks in the United States*	EPA's Motor Vehicle Emissions Simulator (MOVES).	Not specified	The results of this study show that BE trucks significantly outperformed all other truck types in spite of the U.S. electricity generation sector's high dependency on fossil fuels. Overall, it can be concluded that BE trucks are a very promising truck alternative. These results are expected to be even more positive thanks to future technological advancements from renewable energy sources. The results show that CNG trucks did not significantly improve either life-cycle emissions or costs compared to their conventional counterparts. (Sen, Ercan, and Tatari 2017)
LCA	Medium and Heavy-Duty Vehicles	Tong, Jaramillo, and Azevedo 2015	*Comparison of Life Cycle Greenhouse Gases from Natural Gas Pathways for Medium and Heavy-Duty Vehicles*	EPA's Motor Vehicle Emissions Simulator (MOVES).	Not specified	While using natural gas to fuel electric vehicles could achieve large emission reductions for medium-duty trucks, the results suggest that there are no great opportunities to achieve large emission reductions for Class 8 trucks through natural gas pathways with current technologies. (Tong, Jaramillo, and Azevedo 2015)
EIO-LCA	Delivery truck fleet	Zhao, Ercan, and Tatari 2016	*Life cycle based multi-criteria optimization for optimal allocation of commercial delivery truck fleet in the United States*	Multi Objective Linear Programming (MOLP)	Not specified	The results indicate that when fuel economy is high and annual mileage is low, current diesel trucks are able to fulfill the requirement in both cases with reasonably low costs. Conversely, in scenarios with low fuel economy and high utilization levels, hybrid vehicles are preferred. (Zhao, Ercan, and Tatari 2016)
LCA	Heavy vehicles in urban use	Inzunza Soriano and Petter Laudon 2012	*Comparative LCA of Electrified Heavy Vehicles in Urban Use*	Priority Strategies (EPS) and Eco-indicator 99 are described.	Maria Wallenius Henriksson and Niklas Thulin at Volvo Group Trucks Technology; Anders Nordelöf and Ann-Marie Tillman at Chalmers University of Technology.	The conclusions from the study are that the plug-in configuration is preferable to the hybrid version for the waste collection vehicle. In the case of the distribution truck, it is hard to justify a shift from hybrid to plug-in hybrid configuration, due to the small additional environmental gain.

LCA	Tractors	Piringer et al. 2016	*Environmental hot spot analysis in agricultural life-cycle assessments three case studies*	ReCiPe's climate change characterization factors were adjusted to reflect the most current IPCC estimates for global warming potentials	Not specified	*Results over the tractor's life-cycle shows that all environmental impact categories are dominated by the use phase, as indicated by the main processes that contribute to each impact category, with 84.4% to 99.6% of the impact score. (*Piringer et al. 2016)
Technical report	Sweeper vehicles	Karanasiou 2016	*Review of impact of street cleaning on pm10 and pm2.5 concentrations in northern and central Europe*	Not specified	Not specified	*The evidence on the effect of road washing, either alone or in combination with sweeping, is more positive with most studies showing a reduction in ambient PM10 concentrations. This may be due to the water reducing the release of PM10 into the air rather than removing dust from the road surface. Most of the evidence of a benefit of street cleaning (sweeping and/or washing) comes from areas where road dust loadings are particularly high due to the use of winter tyres/tracking sanding or near industrial sources (e.g. in Bootle, and major construction sites. (*Karanasiou 2016)
Technical report	Road salt vehicles	*Redust 2012*	*Deliverable product of the REDUST LIFE09 ENV/FI/000579*	Not specified	Not specified	*PIMU (scrubber with captive hydrology) cleaning is more efficient than traditional cleaning. However, the efficiency of PIMU cleaning is dependent on the initial street dust level, and tends to be most efficient when the dust load is high. For this reason, also the timing of the PIMU cleaning needs to be carefully chosen. (Redust 2012)*
Literature review	Transport	*Quintero et al. 2016*	*Revision of the EU Green Public Procurement Criteria for Transport- Preliminary Report*	-	-	According with the LCA literature review, overall total life cycle GHG emissions are dominated by GHG emissions from the use phase as result of the high GHG exhaust emissions. The main GHG emissions are associated with production of CO2 during vehicle operation

11.3 Analysis of the selected studies

In this section, we present a summary of the mentioned relevant studies.
Concerning the LCA studies, a table is provided to report the main factors for the quality assessment of the method used for the identification of the environmental impacts.
The following base parameters were considered:

- Characterization
- Goal and scope
- Functional units and system boundaries
- Cut off criteria
- Allocation
- Geographical and technological representativeness
- Data sources

Concerning the other relevant studies identified above, in the next section, we will only present a summary since the quality assessment through the mentioned categories is not appropriate for this kind of studies.

11.3.1 Quality assessment of the LCA studies

Table 13. 1: Quality assessment of LCA studies on vehicles for Public Space Maintenance

Source	Characterization	Goal	Scope	Functional Unit	System boundary	Cut-off criteria	*Allocation*	Geograph.representa-tiveness	Technological representa-tiveness	Data source
(Sen, Ercan, and Tatari 2017)	Heavy Duty Truck	To support the sustainability of alternative power train, and evaluate the different emission of HDT operating with different Regional electric sources.	Comparison of LCC of HDT powered by biodiesel (B20); CNG, Hybryd powertrain and BE.	Not specified	Manufacturing and use phase.	End-of life stage is not estimated.	Not specified	North US	Power train technologies for HDT; electric batteries for HDT.	EIO-LCA tool GREET tool's Vehicle-Cycle Model Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) database U.S. EPA's Motor Vehicle database
(Tong, Jaramillo, and Azevedo 2015)	Medium and Heavy-Duty Vehicles	Evaluate the performances of different types of MHDVs operating with a comprehensive set of natural gas derived fuels, engine technologies.	7 Kind of MHDVs operating with 5 different powertrain technologies.	Vehicle distance travelled (gCO2-equiv/km) freight-distance moved (gCO2-equiv/km-metric-ton)	Well to wheel	Emissions from building the infrastructure needed to deploy different fuels and vehicle end-of-life are outside of the scope of this study.	Not specified	USA	MHDVs operating on natural gas derived Fuels and engine technologies.	American Chemical Society (ACS Publications)
(Zhao, Ercan, and Tatari 2016)	Delivery truck fleet	Optimization of GHG emissions, life cycle costs and externality for a fleet of 30 vehicles.	Conventional diesel trucks, grid independent hybrid electric trucks, CNG trucks, and plug-in battery electric trucks	Transportation of parcels from a 30-truck fleet	Well to wheel	The end-of-life phase has not been taken into consideration.	Not specified	USA	Different power train of HDT	EIA NREL Literature review
(Inzunza Soriano and Petter Laudon 2012)	Heavy vehicles in urban use	To evaluate the environmental impacts of two different truck with different drivetrain configurations: hybrid and plug-in hybrid.	-Hybrid electric distribution truck (Volvo FE Hybrid), -plug-in hybrid electric distribution truck (modified Volvo FE Hybrid), -hybrid electric waste collection vehicle (Volvo	One truck over its lifetime. Lifetime of Waste collection vehicle was estimated to 300 000 km.	Cradle-to-grave	LCA of some components and of the waste collection unit and distribution load unit, part of the body, were excluded from the study.	Attributional partitioning has been used for allocation, based on physical properties such as time for the assembly of the drivetrain, energy and weight, for the production of components and end of life treatment.	Manufacturing of components all around the world. Assembling in Belgium; operation and end of life	Hybrid vehicles and Plug in Electric vehicles	GaBi version 4.4.139.1

			FE Hybrid), - plug-in hybrid electric waste collection vehicle (modified Volvo FE Hybrid).	Life time of distribution vehicle was estimated 1million km				Sweden.		
(Piringer et al. 2016)	Mid-sized tractor	To show environmental impacts of agricultural activities	LCA of a common model of tractor	Mid-sized tractor providing agricultural services over its 24-year lifespan	Cradle to grave	Recycle after disposal is not considered	Not specified	Central Europe	Fuel-diesel Tractors	Literature review Ecoinvent 2.2

Table 13. 2: Impact categories of the selected LCA studies related to vehicles

Source	Sen, Ercan and Tatari 2017	Tong, Jaramillo, and Azevedo 2015	Zhao, Ercan, and Tatari 2016	Inzunza Soriano and Petter Laudon 2012	Piringer et al. 2016
Impact assessment	EPA's Motor Vehicle Emissions Simulator (MOVES).	EPA's Motor Vehicle Emissions Simulator (MOVES).	Multi Objective Linear Programming (MOLP)	Priority Strategies (EPS) and Eco-indicator 99 are described.	ReCiPe's climate change characterization factors were adjusted to reflect the most current IPCC estimates for global warming potentials
Impact assessment	Heavy Duty Truck	Medium and Heavy-Duty Vehicles	Delivery truck fleet	Heavy vehicles in urban use	Tractors
Climate Change	√	√	√	√	√
Ozone Depletion	-	-	-	-	-
Ecotoxicity for aquatic fresh water	-	-	-	-	√
Human Toxicity cancer effects	-	-	-	√	√
Human Toxicity non-cancer effects	-	-	-	-	√
Particulate Matter / Respiratory Inorganics	-	-	√	-	√
Ionising radiation– human health effects	-	-	-	-	-
Photochemical Ozone Formation	-	-	-	-	-
Acidification	-	-	-	√	√
Eutrophication terrestrial	-	-	-	-	-
Eutrophication aquatic	-	-	-	-	-
Resource Depletion – water	-	-	-	-	√
Resource Depletion – mineral, fossil	-	-	-	√	√
Land Transformation	-	-	-	-	-
Other categories					

Summary of the LCA studies

- ***Does a battery-electric truck make a difference? Life cycle emissions, costs, and externality analysis of alternative fuel-powered Class 8 heavy-duty trucks in the United States*** **(Sen, Ercan, and Tatari 2017)**

In the US, diesel-powered HDT technology has been the dominant fuel of choice for HDTs for decades; it is estimated that more than 92% of trucks currently run on fossil fuels (Torrey and Murray 2015).
At the same time, the total global market share of hybrid-electric, plug-in-hybrid-electric, and battery-electric (BE) trucks is predicted to be 10 times larger by 2020 compared to 2013 and that technological implementation of renewable sources will increase the production of clean electric energy. Even though, in the US market, the growth of the economy will bring a forecast increase in diesel consumption with an annual average rate of 0.8% until 2040, with trucking responsible for a large share of this increase. (Sen, Ercan, and Tatari 2017)

This study looks at alternative fuel-powered Class 8 HDTs from a life-cycle perspective in order to support the sustainability of alternative choices.
The HDTs considered in this analysis (biodiesel (B20), compressed natural gas (CNG), hybrid, and BE HDTs) are compared to the diesel HDT (conventional HDT).
The study also separates hybrid and BE trucks more specifically into mild hybrid and full hybrid trucks, and 270 kWh motors- and 400 kWh motors-sizes, respectively.
The comparison between conventional and alternative-fuel HDTs is carried out considering their lifecycle GHGs, costs, air pollutants emissions, and air pollution externalities (APE). The emissions considered in this study are CO2, CO, NOX, PM10, PM2.5, SO2, and VOC emissions.
Furthermore, for the analysis of environmental impacts of BE HDTs in the use phase, the study includes a comparison of different electric regional sources as defined by North American Electric Reliability Corporation (NERC).
The method of this LCA study is a hybridized Economic Input-Output-based LCA (EIO-LCA) method. Almost all of the upstream environmental impacts are obtained using the Carnegie Mellon University Green Design Institute's publicly available online EIO-LCA tool[143].
For the estimation of environmental impacts, besides of the EIO model, a variety of process-based models and databases have been used, such as the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET), Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET), and the U.S. EPA's Motor Vehicle Emissions Simulator (MOVES).
Assumptions concerning the battery manufacturing and replacement forecast a life time of the battery of 4 years, meaning that a hybrid truck replaces its battery 2 or 3 times during its entire lifespan, depending on its average lifetime, which is randomized between 6.6 and 10 years.

Results

The study finds that the use phase represents the main contribution to LCCs of HDTs. As shown in the figure below BE and mild-hybrid trucks have the best overall performances.
The dominant contributor to the LCCs of all types of HDTs is the cost of fuel consumption followed by maintenance and repair costs. The fuel consumption cost of a B20 truck is slightly higher than that of a CNG truck; however, a B20 truck performs better overall in terms of economic impacts.

[143] Information available at: http://www.eiolca.net/cgi-bin/dft/use.pl

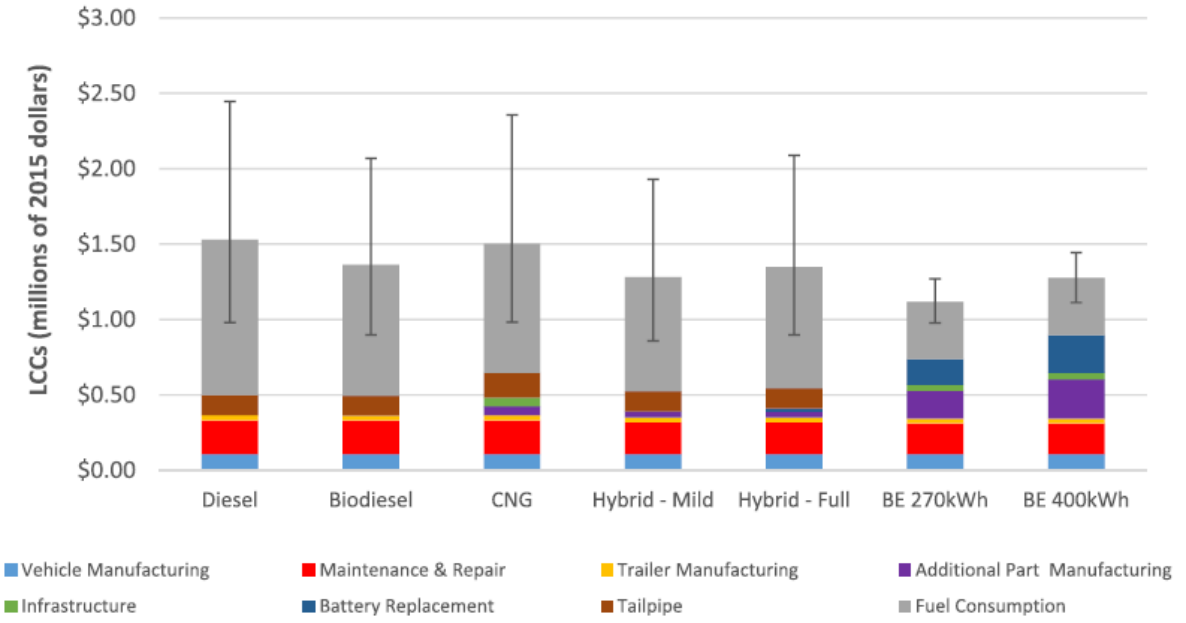

Figure 45: Life cycle costs of heavy-duty trucks.

Concerning environmental emissions, fuel consumption again plays a major role in the total amount of GHGs emissions from each truck type.
Overall, the study found that CNG trucks produced the largest amount of lifetime GHGs emissions compared to other trucks, with BE trucks emitting the least amount of GHGs emissions at 53% less than the GHGs emissions of CNG trucks.

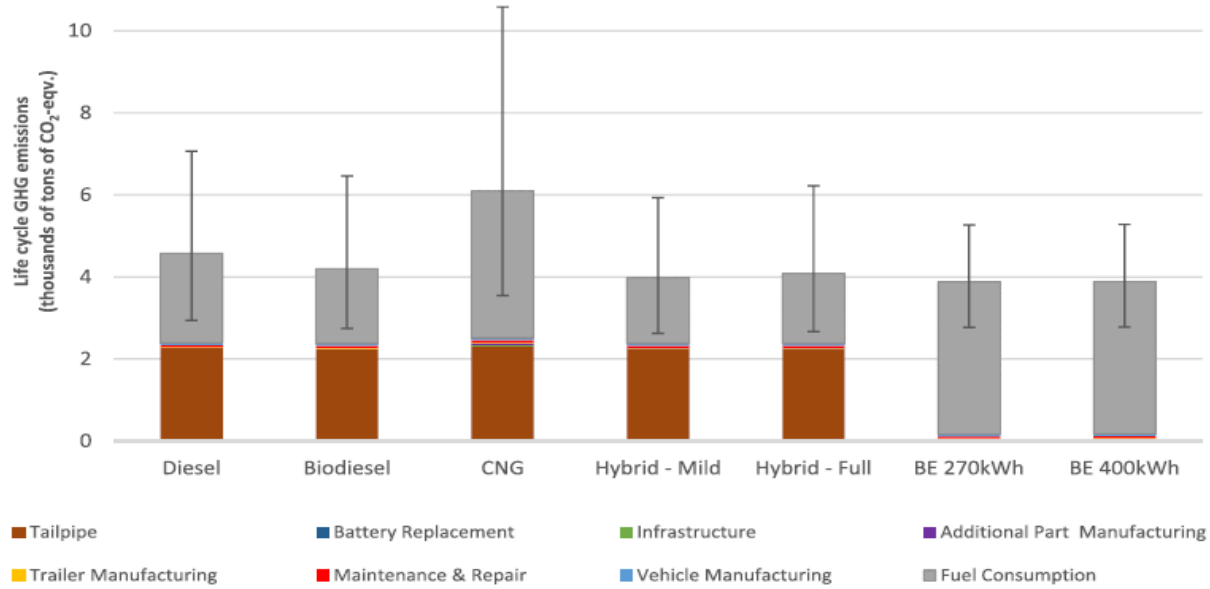

Figure 46: Life-cycle greenhouse gas emissions of heavy-duty trucks.

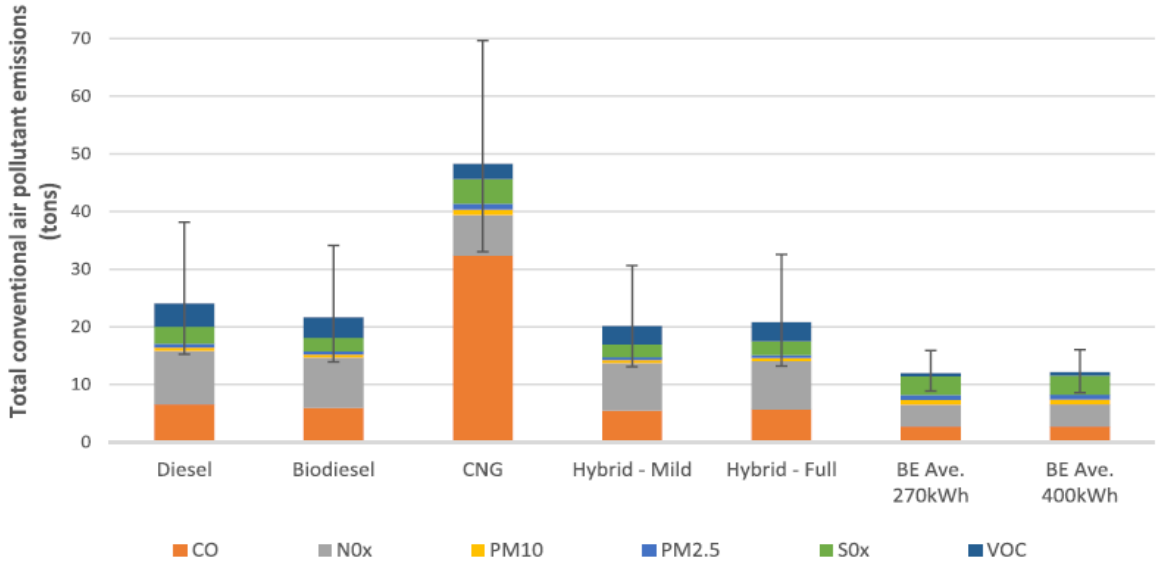

Figure 47: Life-cycle air pollutants emissions of heavy-duty trucks.

From the results, we can gather that BE HDTs outperform all other types of trucks despite their incremental costs and electricity generation-related emissions. Furthermore, from different scenarios according to different regional electricity sources, is found that fuel-consumption related GHGs emissions from BE HDTs could decrease up to 63 percent (in NERC[144] region). Therefore, providing that electricity is generated from renewable energy sources, the use of BE trucks would significantly improve the life-cycle performance of a truck as well as ambient air quality.
Finally, the study concludes that CNG trucks yield no improvements in either HDT's life-cycle environmental impacts or LCCs compared to conventional diesel HDT.

- ***Comparison of Life Cycle Greenhouse Gases from Natural Gas Pathways for Medium and Heavy-Duty Vehicles*** **(Tong, Jaramillo, and Azevedo 2015)**

This study takes in account the abundant and convenient supply of shale gas in the United States, to evaluate the performances of Medium and Heavy-Duty Vehicles (MHDVs) in a scenario of natural gas as main energy source. Thus, the goal of the study is to evaluate the performances of different types of MHDVs operating with a comprehensive set of natural gas derived fuels and engine technologies.

[144] The North American Electric Reliability Corporation (NERC) is a not-for-profit international regulatory authority whose mission is to assure the reliability and security of the bulk power system in North America. Information available at: http://www.nerc.com/Pages/default.aspx

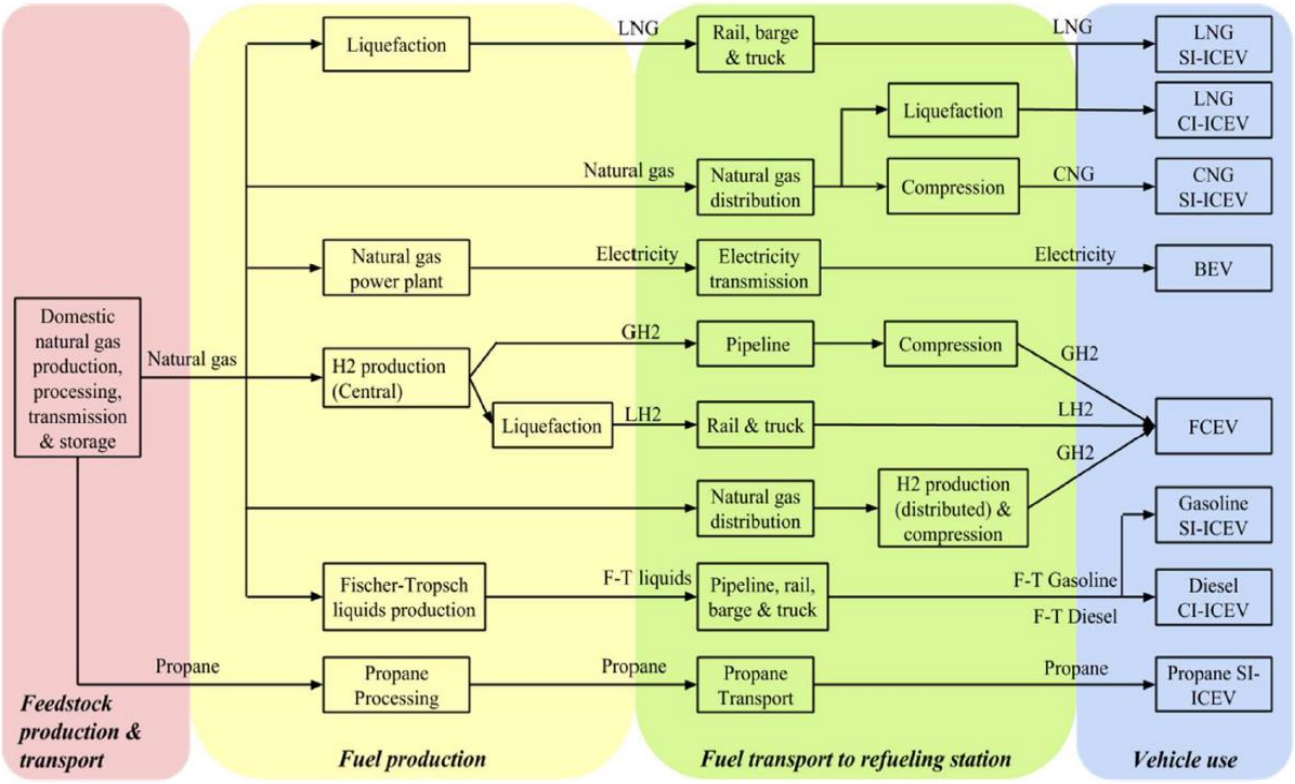

Figure 48: Study system boundary of natural gas pathways. Different colored areas correspond to different life cycle stages: natural gas upstream (pink), fuel production (yellow), fuel transport (green), and vehicle operation (blue) (indicated by engine technologies). Both feedstock and energy carriers are marked along each pathway. LNG = liquefied natural gas; CNG = compressed natural gas; H2 = hydrogen; GH2 = gaseous hydrogen; LH2 = liquid hydrogen; F-T = Fischer–Tropsch; LPG = liquefied petroleum gas, or propane; ICEV = internal combustion engine vehicle; SI = sparking ignition; CI = compression ignition; BEV = battery electric vehicle; FCEV = fuel cell electric vehicle.

Source: (Tong, Jaramillo, and Azevedo 2015)

The study considers seven types of MHDVs: 67,76 Class 2b pick-up truck, Class 4 parcel delivery truck, Class 6 box truck (such as beverage delivery truck), Class 8 transit bus, Class 8 local-haul tractor-trailer, Class 8 long-haul tractor-trailer, and Class 8 refuse truck.
The study also includes five vehicle engine technologies: sparking ignition internal combustion engine vehicle (SI-ICEV), compression ignition internal combustion engine vehicle (CIICEV), hybrid electric vehicle (HEV), battery electric vehicle (BEV), and fuel cell electric vehicle (FCEV).

The study compares the life cycle greenhouse gas (GHG) emissions from different natural gas pathways for the different MHDVs, in particular, it focuses on estimating emissions of three GHGs: CO_2, methane (CH_4), and N_2O.

The system boundary includes the natural gas extraction and ends with the use of the natural-gas-derived fuel during vehicle operation.

Emissions related to manufacturing of batteries and fuel cells for electric vehicles are included, while emissions with manufacturing of other vehicle components are assumed to be similar.
Emissions from building the infrastructure needed to deploy different fuels and vehicle end-of-life are outside of the scope of this study.

For the LCA, the study considers two functional units: vehicle distance traveled (gCO2-equiv/km) and freight-distance moved (gCO2-equiv/ km-metric-ton).
The first functional unit is simple but fails to reflect the function of vehicles and its operational characteristics. Moreover, heavier trucks are more efficient in moving the same weight of load even with a lower fuel economy. For that reason, the study introduced a second functional unit considering for HDV a load-normalized fuel economy (gallons per cargo-ton-mile) than lighter vehicles.

Results

Medium duty vehicles (MDT) (Class 2b, Class 4, and Class 6) powered by batteries with natural gas-based electricity achieve the largest (31−40%) emission reductions compared to the baseline petroleum fuels (gasoline for Class 2b, and diesel for Class 4 and 6). Similarly, Battery electric vehicles (BEVs) powered with natural gas-produced electricity are the only fuel-technology combination that achieves emission reductions for Class 8 transit buses (31% reduction compared to the petroleum-fuelled vehicles).

CNG and propane achieve relatively smaller emission reductions for MDT and HDT (0−6% and 19%, respectively, compared to the petroleum-based fuels), while other natural gas pathways increase emissions for non-Class 8 MHDVs.
When compared to the petroleum-based fuels currently used in these vehicles, CNG and centrally produced LNG increase emissions by 0−3% and 2−13%, respectively, for Class 8 trucks.
For Class 8 tractor-trailers and refuse trucks, none of the natural gas pathways provide emissions reductions per unit of freight-distance moved compared to diesel trucks.
In conclusion, while using natural gas to fuel electric vehicles could achieve large emission reductions for medium-duty trucks, the results suggest there are no great opportunities to achieve large emission reductions for Class 8 trucks through natural gas pathways with current technologies.

As seen in many articles (Hawkins et al. 2013; Quintero et al. 2017; Inzunza Soriano and Petter Laudon 2012; Taefi et al. 2016) the source of electric energy is an important issue when estimating the overall emission in life cycle of vehicles, for that reason the results of these study could be profitable for those scenarios where electric energy is produced with high environmental impacts.
As stated in the paper, strategies may enhance the reduction of the carbon footprint of using natural gas for MHDVs, ranging from increasing vehicle fuel efficiency and reducing life cycle methane leakage rate.

- ***Life cycle based multi-criteria optimization for optimal allocation of commercial delivery truck fleet in the United States*** **(Zhao, Ercan, and Tatari 2016)**

Urban delivery trucks are characterized by intensive stop-and-go operational patterns, which may result in lower fuel efficiency and higher environmental impacts to urban areas. The adoption of alternative fuel trucks may mitigate the environmental impacts; however, the higher cost of purchase could be a limitation.
The study is aimed at providing a scientific support for improvement solutions for a fleet consisting of 30 commercial delivery trucks.
The research focuses on optimization of GHG emissions, life cycle costs and externality.

An economic input–output based hybrid life cycle with respect to conventional diesel trucks, grid independent hybrid electric trucks, CNG trucks, and plug-in battery electric trucks, is performed in this study.

Furthermore, six scenarios were proposed to represent variations in real life driving conditions and fuel economy. In particular the scenarios simulate the sensitivity to fuel economy and lifetime vehicle miles of travel levels (VMT) with respect to diesel, hybrid and CNG trucks, while the fuel economy of BE trucks is assumed to remain stable for any scenario.

Scenarios	Annual utilization (mile)	Life time mileage (mile)	Diesel truck fuel economy (mpg)	Hybrid truck fuel economy (mpg)	CNG truck fuel economy (diesel mpg)
Scenario 1	12,000	120,000	11.70	13.90	8.26
Scenario 2	16,000	160,000	11.70	13.90	8.26
Scenario 3	20,000	200,000	11.70	13.90	8.26
Scenario 4	12,000	120,000	8.50	12.50	6.69
Scenario 5	16,000	160,000	8.50	12.50	6.69
Scenario 6	20,000	200,000	8.50	12.50	6.69

Figure 49:: Scenarios. Source (Zhao, Ercan, and Tatari 2016)

The system boundary of the LCA includes vehicle manufacturing (including raw material extraction and other related processes), battery manufacturing, fuel production and vehicle operations (tailpipe impacts), while end-of-life of vehicles is excluded.

Both direct and indirect impacts are evaluated based on the vehicle miles of travel (VMT), and so the functional unit of this analysis is the transportation of parcels from a 30-truck fleet.
Concerning the costs for infrastructure, the study assumes that existing fuel stations are adequate for refueling diesel and hybrid trucks, but that the application of new CNG and battery electric trucks will require the construction of new fuelling and/or charging infrastructures. From the literature review, the study gathers that to fulfill a 30-truck fleet's average daily fuel consumption, the infrastructure cost ranges from $400,000 to $600,000.

For electric trucks, the cost of Electric Vehicle Supply Equipment (EVSE), which is commercially available for fleet owners, is calculated with reference to the Clipper Creek Model CS-60, whose cost is $5000 (two sets are needed for the whole lifespan of a vehicle for a total of $10,000 per BE truck).

Finally, the results are input to a MOLP optimization model to determine an optimal fleet mix for achieving the best possible environmental, social and economic performance.
Furthermore, the results are considered from two perspectives, the first being a case in which no constraints are taken into account, and the second case being considered under tailpipe emission constraints.

Results

As mentioned the research evaluates the vehicle's performances by means of three objectives: LCC, GHG emissions and air pollution health cost (externality). The results are presented with their respective weights, providing a basis for comparison and evaluation of more efficient optimization.
Consequently, in order to show a comparison between scenarios and weight cases, four different weight cases (one weight case predicts the same priority for the three objectives) are integrated into the same figure.
For the representation, the incompatible numeric scales of the three indicators are normalized: the GHG emission results are divided by 10^3; the air pollution externalities (in US dollars) results are divided by 10^5; and the life cycle cost results are presented in million dollars. After these adjustments, all impacts and cost data are within a scale of zero to eight as indicated by the right-hand-side axis.

Fleet truck combinations, on the other hand, are represented by their percentages of the total fleet instead of the specific numbers of each type of truck within the fleet; these percentages are indicated by the left-side axis.

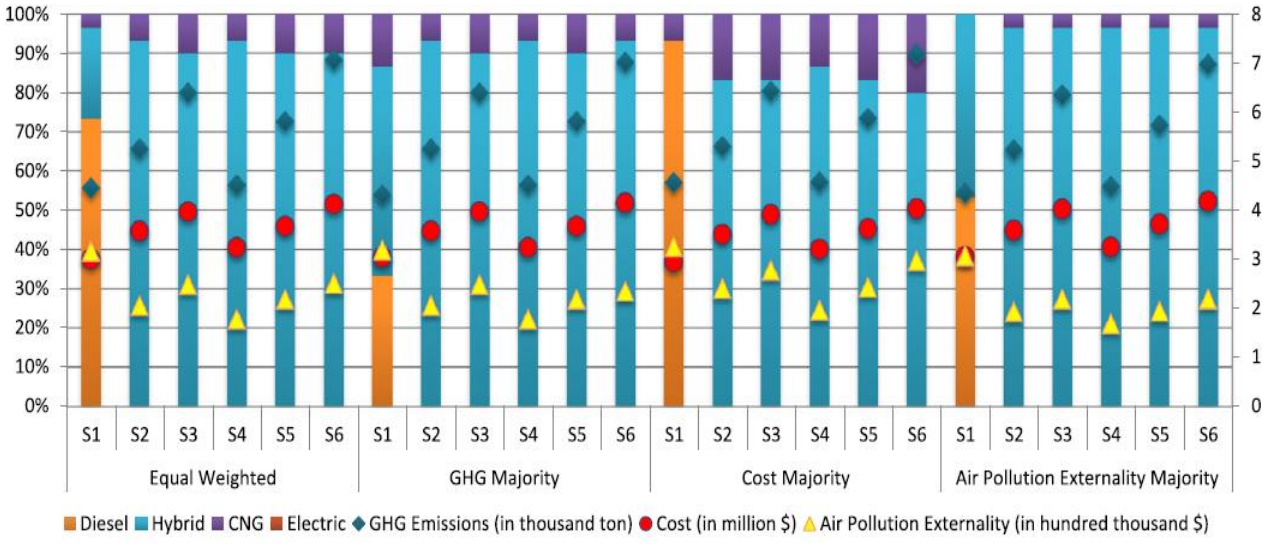

Figure 50:MOLP results without constraint. Source (Zhao, Ercan, and Tatari 2016)

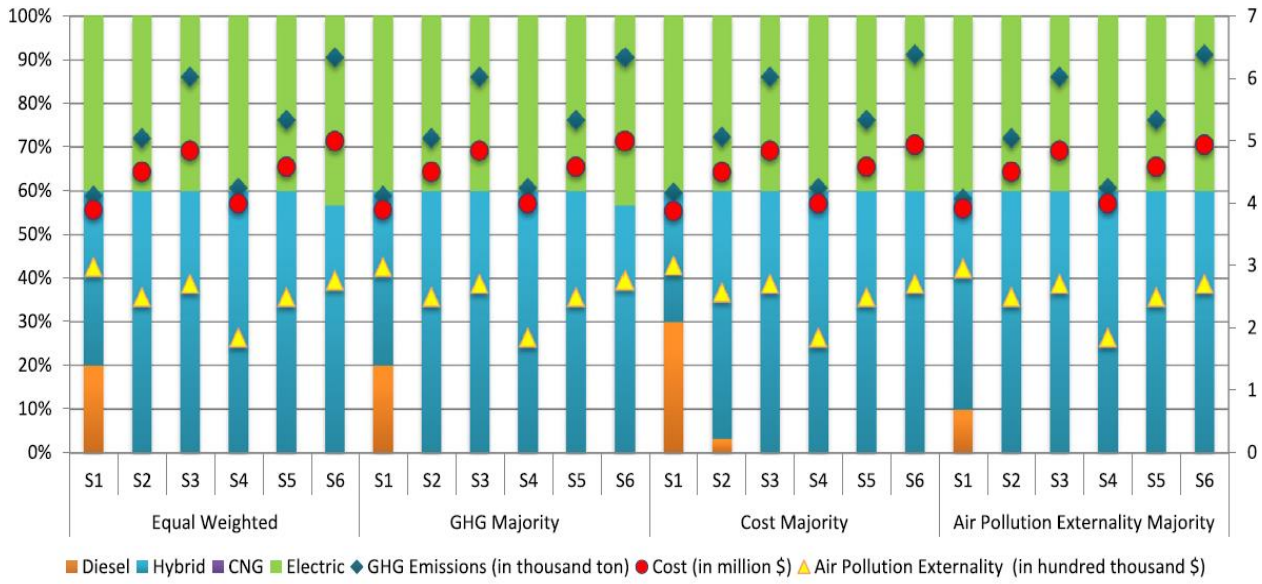

Figure 51:MOLP results with constraint. Source (Zhao, Ercan, and Tatari 2016)

Overall, the study finds that GHG emissions increase with the decrease of LCC value, which means that there is a negative correlation between them.

In the case of no tailpipe emission constraints, hybrid trucks have the dominant fleet share with more than 80% of the fleet in almost every scenario and weight case.
This is because they have a significant advantage in terms of fuel economy, and their braking power regeneration mechanism is suitable for trucks with frequent stop and- go driving cycles.
Diesel trucks were selected for the optimal fleet only under ideal driving conditions, i.e. less traffic congestion and low utilization intensity in Scenario 1.

In this case, conventional diesel trucks account for a rather large percentage of the fleet for each weight case, especially when cost is prioritized above all other considerations, in which case the optimized fleet consists almost entirely of diesel powered trucks.
On the other hand, when GHG emissions are prioritized under Scenario 1, hybrid trucks still outnumber diesel trucks in the optimal fleet.
Thus, the priority of GHG emissions is the main driver in reducing the number of diesel trucks in the result.
CNG trucks and electric trucks were a less profitable option for the optimal fleet because a CNG truck fleet would need a great deal of investment in additional infrastructure and would not have an outstanding emission reduction performance.
EV trucks are not given any significant fleet share for any scenario.

Conversely, electric trucks comprise a significant portion of the fleet when emission constraints were added to the model despite their high purchase cost.
Within each weight case, the emission reduction potential of electric trucks becomes more obvious when utilization levels are high and fuel economy is low, indicating that electric trucks are suitable for heavily congested areas and long operating hours.

- ***Comparative LCA of Electrified Heavy Vehicles in Urban Use*** **(Inzunza Soriano and Petter Laudon 2012)**

This study has been developed in collaboration with Volvo to estimate the environmental potential of alternative powertrains against their conventional counterparts represented by a diesel fueled Volvo FE truck.
Two electric powertrains have been analysed, hybrid and plug-in hybrid.
The Volvo FE Hybrid has been already launched as a fuel-efficient alternative to the conventional, while the design of the plug-in hybrid configuration is currently in an advanced engineering phase, with no industrialization decided.
However, the aim for Volvo is to learn which are environmental potentials that these two configurations of electrification can enhance in a future state.

The study carries out a comparative LCA, where all life cycle stages for the electric part of the drivetrain were included. The analysis has been made for both a distribution truck and a waste collection vehicle.
The study includes in the cradle-to-grave estimation the life cycle of a dozen components, including lithium-ion battery and electric motor.

These components were studied throughout their life cycle: raw material extraction, material processing, manufacturing processes, transportation, use phase, maintenance and disposal. For the assessment of environmental impacts two weighting methods, EPS and Eco-indicator 99, have been used on four different environmental indicators: global warming potential, acidification potential, human toxicity potential and resource depletion potential. In addition, energy use and recycling of metallic parts have been included in the estimation.

Results
Taking into account the total lifecycle, the well-to-wheel phase is dominating for all impacts except HTP where the production of components almost reaches the same level of impact as the well-to-wheel phase. Chinese electricity use in the battery production and toxic substances in the electronics like arsenic and cadmium are the reason for the high impact of the production of the drivetrain. For that reason, among the components, the battery has by far the largest impact for all characterization indicators.

Concerning the impacts related with GWP, the savings in the well-to-wheel phase for HHDVs are much bigger (10 to 40 times larger) than the emissions from the other stages (a similar pattern is shown also for the others impacts), since so much diesel combustion is avoided during the life time of the trucks.

The battery is responsible for more than half of the emissions for all components in the hybrid and plug-in hybrid drivetrain. While the impacts associated with assembly and transport stages of components are very small compared to the other stages, which means that most of the environmental burden of the production comes from the material extraction and transformation.

Most of the GWP emissions for the conventional vehicle come from the combustion of diesel, about 85%. The rest is shared between the production of diesel (10%)and the production of urea (5%).

The results for the distribution vehicle show that the step to hybridization gives the largest environmental gain. Modification to a plug-in hybrid configuration of the same vehicle showed only a little additional environmental benefit, while for waste collection vehicle a shift from hybrid to plug-in hybrid configuration gives a relatively large environmental benefit compared to hybridization only.
The relative environmental benefit is higher for the waste collection vehicle than for the distribution vehicle because the environmental benefit when going from hybrid- to plug-in hybrid- configuration increases with decreasing driving distance. This is because the plug-in function of battery charging is used to a higher degree when driving distance decreases (linear function).

Finally concerning the estimation of gains from metal recycling, the results show that the increase of the recycling rate of metals to 100% may lead a decrease of global warming potential in end-of-life stage by approximately 50% for both hybrid and plug-in hybrid configurations.
While comparing the whole lifecycle of the drivetrain for the two configurations, the 100% percent metal recycling rates show a GWP100 decreasing between 10.5% and 6.6% for the distribution and waste collection vehicle respectively.
The worse result of plug-in hybrid configuration depends on GWP100 emissions released during production and from additional raw material needed for the modified energy storage system (ESS).

End of Life (GWP100)	Hybrid (CO_2-equivalents)	Plug-in hybrid (CO_2-equivalents)
EoL lifecycle stage (Original recycling rates)	-1067	-1482
EoL lifecycle stage (100% recycling of all metals)	-1653	-2200
Relative change EoL-stage	**-54.9%**	**-48.4%**
Cradle-to-grave, excluding use phase (original recycling rates)	5604	10798
Cradle-to-grave, excluding use phase (100% recycling of all metals)	5018	10081
Relative change cradle-to-grave, excluding use phase	**-10.5%**	**-6.6%**

Figure 52: Effect of changing end of life treatment of all metals to 100% recycling. (Inzunza Soriano and Petter Laudon 2012)

- ***Environmental hotspot analysis in agricultural life-cycle assessments three case studies*** **(Piringer et al. 2016)**

This study is aimed at investigating environmental impacts in agricultural activities. Nevertheless, we selected it because of the first section of the study, dedicated to middle size tractor, provides a framework for the estimation of environmental impacts of this kind of vehicle across its entire life cycle. The study analyzes a common Austrian tractor model (Steyr Profi 4110, 81 Kw rated power) using primary data from a manufacturer and measured load profiles for field work. The declared functional unit is one mid-sized tractor providing agricultural services over its 24-year lifespan. The system boundary includes manufacturing, use, and disposal of the tractor.

The manufacturing phase was modeled using primary data that include an aggregate bill of materials for the tractor components, as well as the tractor assembly plant's energy consumption. For the use phase, the tractor was assumed to be operated at an organic 140-ha farm in eastern Austria with five farming processes (plowing, cultivation, harrowing, baling and bale transportation)
Data related to fuel consumption and emissions during the operation were collected from a literature review on similar models of tractor.
The estimation yielded specific results for the hourly fuel consumption and air emission factors for each of the five chosen processes.
The study also assumes the increasing of emission due to engine aging over tractor's life. Moreover, the estimation also considers the maintenance and replacement of components. In particular, engine oil, filters and filter pump are replaced every 600 hours, and other oils and transmission belts every 1200 hours.

For the end-of-life scenario, the disposal was modeled according to specific disposal processes of the main groups of materials.
In particular: metal components are shredded and recycled; the polymer components, as well as used motor oil, are combusted in a waste incineration plant; used tyres were assumed to be incinerated in cement kilns (60%) or shredded for reuse.
The impact assessment method covers the six selected categories from the ReCiPe (H) midpoint impact assessment method.

Results

Concerning all but one of the impact categories studied, potential impacts were dominated by the operation phase of the tractor's life-cycle (mainly due to diesel fuel consumption), with 84.4-99.6% of total impacts.
The up-stream module (raw materials and final assembly) accounted for 0.4% and 12.1% of impacts, while disposal of the tractor was below 1.9% in all impact categories.
During the use phase, the combustion of fuel causes most impacts, while maintenance is of secondary importance.
Within the operational phases, the intensive fuel consumption of tillage processes (plowing, harrowing, cultivating) generate the strong impacts on climate change with 55%, 13%, and 10% of the category total

	Tractor lifetime impacts (24 years)		
Impact category	Unit	Quantity	Main contributing Process
Climate change (GWP 100)	kg CO_2-eq	287,822	Diesel combustion during cultivation
Freshwater ecotoxicity	kg 1,4-DCB-eq	329	Diesel extraction and refining
Human toxicity	kg 1,4-DCB-eq	12,609	Diesel extraction and refining
Particulate matter formation	kg PM10-eq	555	PM emissions during diesel comb.
Terrestrial acidification	kg SO_2-eq	1,335	NOx emissions during diesel comb.
Non-renewable energy resources	MJ-eq	4,182,198	Diesel use for cultivation processes

Figure 53:Potential environmental impacts of 24-year tractor life-cycle at 281 operating hours per year. (Piringer et al. 2016)

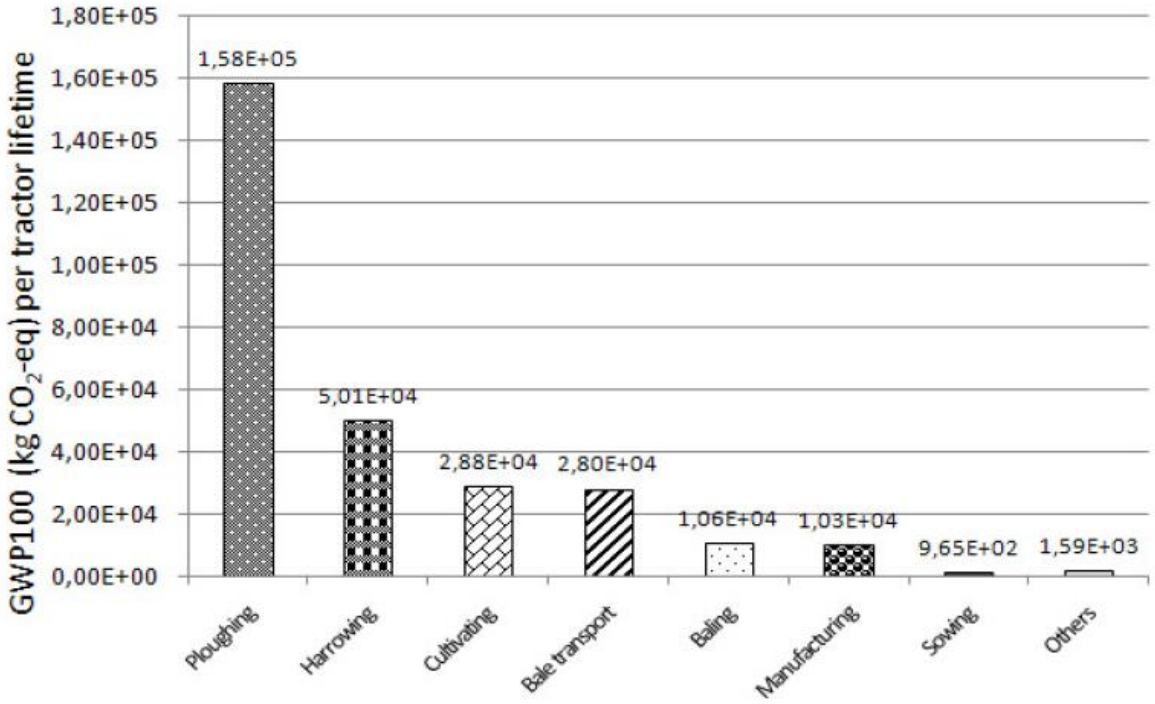

Figure 54:Contribution of individual processes to total climate change impact of tractor life-cycle (Piringer et al. 2016).

11.3.2 Summary of other relevant studies

- ***Review of impact of street cleaning on PM10 and PM2.5 Concentrations in Northern and Central Europe*.** (Idaea-CSIC 2016)

This report focuses on the potential to reduce ambient PM10 concentrations by street cleaning, i.e. the sweeping and washing of street surfaces. It provides a huge literature review on the topic of street cleaning vehicles and of the experiment and text carry out not only in the European context but also in USA and Canada. It analyses the kinds of road sweepers and the current directives for certification of road sweepers. Finally, it analyses the impact of street sweeping on PM10 concentration and the literature review on this issue, with many insights about the street cleaning practice in the European context.

Results

Of particular interest are the results from the German certification on street sweepers.
As described in the study:
"The German Federal Environment Agency (Umweltbundesamt – UBA) commissioned DMT to develop a reliable method for the determination of particulate emissions from road sweepers under standardised conditions. This has been published as German technical guidance by VDI (2014). This document applies to dry, wet and combined wet and dry vacuum assisted sweepers produced specifically for municipal purposes. It describes the state of art sweepers with low-emission characteristics, but which are also effective at collecting dirt and litter.

The best sweeper of those tested on the VDI procedure was the Dulevo sweeper (Dulevo 5000 Evolution). This sweeper is not a conventional vacuum sweeper and is described as a mechanical suction machine. It uses a patented 24 m2 moisture resistant Gore-Tex fabric filter to remove particulate matter from the air stream exiting the dust/dirt

container. The filter includes a driver operated shaking device to release the particles trapped into the waste container, prolonging its use but avoiding the buildup of excessive pressure.
The road dust/dirt is picked up using side brushes which convey the debris towards the centre of the machine, where a central cylindrical brush throws it at high speed onto a vertical conveyor system. This loads the waste container from above. The dust raised by the central cylindrical brush is sucked into the waste container by the vacuum created by two fans. Water can be sprinkled on the side brushes to control dust. The sweeper has a unique four wheel steering system that makes it a very mobile." (Idaea-CSIC 2016)

Moreover, the study presents some evidence on the effect of road washing, either alone or in combination with sweeping.
It seems that the effect of road washing in combination with sweeping is more positive with most studies showing a reduction in ambient PM10 concentrations. This may be due to the water reducing the release of PM10 into the air rather than removing dust from the road surface. (Idaea-CSIC 2016)

- ***Deliverable product of the REDUST LIFE09 ENV/FI/000579 Action 3 A report on PM10 dust emission estimates for current measures and estimation of emission reductions due to additional measures based on first and second year demonstrations.*** **(Redust 2012)**

As already mentioned in the chapter dedicated to cleaning services, the REDUST project aims to find the best practices in the fields of traction control, dust suppressing and street cleaning, and accelerate their implementation to reduce levels of breathable street dust (PM10) in urban areas.
While in the chapter dedicated to cleaning services and products we focused on the description of the findings concerning best practices of the services, in this section we will focus on the main founding related with the effectiveness of sweeper vehicles in the control of fine dust.

The vehicles equipment used for the REDUST tests falls into two main categories: modern street scrubbers (PIMU: scrubber with captive hydrology technology[145]) and traditional vacuum sweepers.

Figure 55:PIMU street scrubber with captive hydrology (left) and traditional Vacuum sweeper.

[145] *Captive Hydrology technique was developed to clean airport pavement surfaces. The pick-up heads may include a high-pressure washer system followed by intensive vacuum pressure. Relatively small amounts of water are entrained leaving a nearly dry pavement surface. Water is recycled within the machine. Mobility is a big advantage, as cleaning can be done where and when needed.* (Idaea- CSIC 2013)

Source: (Redust 2012)

For the tests on the effectiveness of sweepers, the spring-time street cleaning and dust binding practices in the studied routes were:
– In Helsinki, dust binding was frequently used and street cleaning was performed with traditional vacuum sweepers.
– In Vantaa, dust binding was less frequent and modern street scrubbers were used on several streets.
– In Espoo, dust binding was not used in most streets and street cleaning was performed with traditional vacuum sweepers.

Results
PIMU cleaning is found to be more effective than traditional cleaning. However, the efficiency of PIMU cleaning is dependent on the initial street dust level and tends to be most effective when the dust load is high.
The effect of the street cleaning on dust reduction was estimated to end gradually during one week after the cleaning. Moreover, if the amount of dust on a street surface is very low it is possible that the cleaning becomes ineffective in removing the dust from the street. For that reason, the time schedule of operations has to be planned carefully.

Street dust level before cleaning (Sniffer, µg/m^3)	Day 1*	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
over 6500	-40 %	-30 %	-20 %	-16 %	-12 %	-8 %	-4 %	0 %
5500-6500	-35 %	-26 %	-18 %	-14 %	-11 %	-7 %	-4 %	0 %
4500-5500	-30 %	-23 %	-15 %	-12 %	-9 %	-6 %	-3 %	0 %
3500-4500	-25 %	-19 %	-13 %	-10 %	-8 %	-5 %	-3 %	0 %
2500-3500	-20 %	-15 %	-10 %	-8 %	-6 %	-4 %	-2 %	0 %
1500-2500	-15 %	-11 %	-8 %	-6 %	-5 %	-3 %	-2 %	0 %
below 1500	-10 %	-8 %	-5 %	-4 %	-3 %	-2 %	-1 %	0 %

Reduction by traditional vacuum sweeper:

	Day 1*	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Same for all dust levels	-10 %	-8 %	-5 %	-4 %	-3 %	-2 %	-1 %	0 %

Figure 56: Reduction of fine dust by street sweeping. (Redust 2012) * The dust level is described as *PM10 dust emission level behind the left rear tyre of the Sniffer mobile laboratory van –see REDUST Deliverable 2012 Action1&2)*

11.4 Overview of environmental impact hotspots of vehicles for Public Space Maintenance

Literature identification, review, and selection have allowed an understanding of the environmental impacts of different types of vehicles for Public Space Maintenance giving a framework to identify the main hotspots of their Life Cycle.
A summary of the quality and availability of environmental impact assessment literature maintenance is provided below:

Literature availability – The number of studies on the environmental impact assessment for vehicles is wide and gives a broad framework. The studies analyze a

different group of vehicles, different technologies, and kinds of fuels, particular attention is paid to the comparison between ICEV and EVs vehicles.
Impact category coverage – The studies on the environmental impacts of vehicles are mainly focused on the GWP impacts in the use phase.
Representative study of vehicles for Public Space Maintenance – The literature analyzed was mainly focused on the evaluation of HDV and tractors performances since the existing GPP for transport already provides background information for other kinds of vehicles included in the scope of our study such as LDV.
Regarding special vehicles, such as street sweepers and winter maintenance vehicles, no specific LCA study was found, even though the Technical Reports analyzed (REDUST – AIRUSE) gave a broad range of information.

In the following paragraph, a synthesis of the environmental hotspots from the literature review is presented.

UP stream phase

Vehicle manufacture

A wide range of impacts is related to the production chain for vehicles.
The materials used in vehicle manufacturing comprise metals such as steel, aluminium, plastics, rubber and glass.
The chain involved in the production of vehicles has on average a 20% influence on the total life cycle of vehicles (Quintero et al. 2016).
From the comparison of EVs and ICEVs in the literature review, we found that the supply chain involved in the production of electric power train and batteries add significant impacts at the production of vehicles. Those impacts are related to the need of particular raw materials and metals for the composition of elements e.g. lithium batteries (Egede et al. 2015). As underlined in the study about electric trucks (Inzunza Soriano and Petter Laudon 2012), the production phase of the drivetrain of HHDV shows high impacts on HTP because of the Chinese electricity use in the battery production and toxic substances in the electronics like arsenic and cadmium.
However, for EV lower emissions during the use phase compensate the additional burden caused during the production phase, although these findings are very sensible with respect to electrical energy source and its emissions (Hawkins et al. 2013; Sen, Ercan, and Tatari 2017).
Large-scale transportation associated with the distribution of vehicles in the upstream module also has a significant environmental impact on GHG emissions.

Use phase

Emissions

The emissions from vehicle operative phase could have a significant impact on climate change, Photochemical Oxidant Formation, Acidification, Depletion of abiotic resource, depletion of no- renewable resources, PM formation. (Egede et al. 2015; Hawkins et al. 2013; Quintero et al. 2016; Piringer et al. 2016)

The TBT (EU Commission 2011c) and its revision (Quintero et al. 2016) give a broad framework on the many hotspots of Life Cycle use phase on vehicles. In particular, it highlights the main issues related with:

- Vehicles emissions
- Vehicle power technologies
- Vehicle fuels
- Vehicle noise
- Vehicle size/ class
- Vehicle tyres

- Fuel consumption
- Tyre noise
- Motor lubricant
- Mobile air condition

The literature review showed that for all categories the main environmental impacts are related to the use phase of the vehicles. The main impacts during this phase are dominated by GHG emissions (in particular CO_2 emissions), air pollutant, particulate matter released, and noise.
The study on alternative powered HDT (Sen, Ercan, and Tatari 2017) shows that CNG trucks produce the largest amount of lifetime GHGs emissions compared to other trucks, with BE trucks emitting the least amount of GHGs emissions at 53% less than the GHGs emissions of CNG trucks.
Besides GHG emitted in the use phase, acidification, photochemical oxidant formation, and energy depletion also result in relevant impacts.
- Concerning Photochemical Oxidant Formation all types of vehicles score similar levels, but CNG vehicles and BEVs score best, while conventional vehicles and hybrids have the major contributions.
- Air acidification, depletion of abiotic resources and cumulated energy demand, non-renewable are mainly related with the energy supply chain for electrical vehicles.
- Acidification (ATP) and PM formation (PMF) for electric vehicles are mainly linked to the electricity mix. Regarding these impacts, CNG vehicles have a better performance than ICEV vehicles and HEV due to the shift of fuel (Quintero et al. 2016).

Related to technological and fuel environmental impacts, it seems that petrol hybrids provide significant reductions in overall environmental impact (by around 26%). The analysis also shows that diesel hybrids provide a significant reduction in overall environmental impact. (Lane 2006; Inzunza Soriano and Petter Laudon 2012)
For plug-in electric vehicles, the impact on use stage depends on the electricity source when charging. *"When this source has a strong GHG intensity PHEVs reduce gasoline consumption considerably, but only marginally reduce life Cycle GHGs, when compared to gasoline-electric hybrids or other fuel efficient engine technologies."* (Samaras and Meisterling 2008)

Moreover, as gathered from many studies (Quintero et al. 2016; Egede et al. 2015; Piringer et al. 2016; Redust 2012), the emissions in the use phase also strongly depend on the size and weight of the vehicle and on the driving style. In the case of EVs it depends on charging behavior and for plug-in vehicles also on the share of kilometres driven electrically.

Maintenance and end of life

The impact of maintenance and end-of-life management of vehicles represent less than 10% (Quintero et al. 2016) of the overall environmental impact and therefore do not receive much attention in the literature of LCA studies.
As found in many studies the end-of-life stage, it is often characterized by the discomposing of vehicles and recycling of main groups of materials (EVONIK 2016; Piringer et al. 2016)
The disposal of batteries for EVs has a stronger impact within the life cycle of this kind of vehicles. (Quintero et al. 2016)
As gathered in the proper studies on the comparison of 5 Electric Vehicle Battery technologies (Matheys et al. 2017) it appears that *"the lead-acid battery has got the highest impact, followed by nickel-cadmium, lithium-ion, nickel-metal hydride and sodium-nickel chloride. Additionally, the recycling phase allows compensation of a*

significant part of the environmental impacts of the production phase." (Matheys et al. 2017)

11.5 Environmental improvement areas

The PRT (Quintero et al. 2016) provides a broad framework for improvement areas on GHG emissions, air pollutant emissions, and noise
The following paragraphs synthesize the key information of the study (further information can be found in the full document).
Some insight from the literature review is also available on the topic of street cleaning and winter maintenance.

Vehicles

1. Vehicles involved in street cleaning
Street sweepers contribute to air quality issues in urban areas by the reduction of particulate matter (PM) coming from vehicles emissions and resuspension of dust deposited on the road surface (Idaea- CSIC 2016)

The performance of the sweeper is usually defined by two parameters: the removal efficiency and the PM10 and PM2.5 emissions.
Two different standardized test methods are available in the European context, one of them is a European standard, EN 15429-3:2015, developed by EUnited[146] and it is used for the certification scheme owned by this association.
The other one is a German standard, VDI 2096:2014, which also includes requirements that qualify a sweeper as low-emission. As stated in the study of AIRUSE project (Idaea-CSIC 2016) the German test procedure appears to be better at differentiating between sweepers.

The parameters that affect the potential reduction of PM10 emissions are the removal efficiency of the sweeper and its ability to retain the particles.
From the literature review, we could found data on the performances of different kind of street sweepers.

- Mechanical broom sweepers seem to be the best option for the collection of larger particles like debris and litter (REDUST 2015; F. Amato et al. 2010).
- Vacuum sweepers with captive hydrology technology (PIMU) are found to be more effective compared with the traditional mechanical and vacuum sweepers (REDUST 2015).
- Regenerative-air sweepers are more effective for removing finer sediments

Regenerative air technology has also enabled an important improvement on PM emissions of sweepers, allowing in some cases 90% lower emissions than conventional mechanical sweepers (City Council of Toronto 2015).

Since the operation of street cleaning using water can result in a very large rate of water depletion, in the case of Vacuum sweepers with captive hydrology technology, some options are available on the market that could represent a good technological improvement, since they are provided with a system aimed at the recycling of water[147].

[146] Information available at: http://www.eu-nited.net/municipal_equipment/sweeper/index.html
[147] Information available at:
http://sweeper.buchermunicipal.com/en/products/compact_sweepers/citycat2020/?c=austria

2. Vehicles emissions:

To reduce GHG emissions

For rigid trucks, a literature review has been carried out to identify the technologies that are able to reduce GHG emissions compared to a conventional diesel vehicle. Alternative fuel types, including hybrid electric vehicles (HEVs), Compressed Natural Gas (CNG) vehicles, and battery electric vehicles (BEVs) have been considered, as also different scenarios concerning the mix of energy.

From the literature review we see that the fuel consumption of heavy duty vehicles is highly dependent on the operational pattern and duty cycles, therefore, a distinction has to be made between urban and regional cycles.

Vehicles meant for urban operations are characterized by long idling times and frequent stop-and-go driving cycles.

Under these conditions, we found that grid-independent HEVs are a potentially good option due to their power-regeneration capabilities while braking(Zhao, Ercan, and Tatari 2016). Moreover, from another study, we can find that for vehicles in urban use such as Waste collector, characterized by very short driving distances, the Plug in Hybrid option seems to be better (Inzunza Soriano and Petter Laudon 2012). This is because the plug-in- battery charging is used to a higher degree when driving for short distances.

CNG trucks, in the past decades, were adopted on a large scale as alternative powertrain, however, the improvement potential of dedicated natural gas vehicles is not so clear.

While some studies found a saving of emissions for vehicles running on biomethane-blend up to 15% (Atkins-Cenex 2016), in general, no significant advantages are identified from the comparison of CNG vehicles with the conventional diesel counterpart (Sen, Ercan, and Tatari 2017; Tong, Jaramillo, and Azevedo 2015)

Finally, as we can gather from the GPP for transport, some technical improvement are currently available on the market that may be considered in order to control GHG emissions:

- Tyre-pressure monitoring system (TPMS): this system is a monitoring tool that informs the driver on the air pressure in the tyres. It aims to prevent unnecessary fuel consumption, by informing the driver when there is low pressure in the tyres, creating rolling resistance. Because "*Tyres account for around 20-30% of the fuel consumption of vehicles as result of their rolling resistance"* (Quintero et al. 2016)*,* reducing this resistance would contribute greatly to the energy efficiency of road transport and thus to the reduction of emissions *(Viegand Maagøe A/S, 2015).*
-
- Low-resistance tyres: this type of tyre has the potential of reducing fuel consumption and rolling resistance, which lowers the costs for consumers. Its energy efficiency label has different classes: A the most efficient, G the least. Even if these tyres are available on the market since the 90's - "a*bout 50% of passenger car tyres sold in EU on the replacement market are low-resistance tyres"* (Quintero et al. 2016) - most of them are C to G class.
- Start-stop system: this system, installed in 50% of the newly registered vehicles, has become a standard technology in the last years. It allows the saving of fuel by automatically shutting the engine off when a vehicle is at a stop. When the driver accelerates again, the engine instantly restarts.
- Gear-shift indicators (GSI): "*A GSI helps a car driver by visually indicating the optimal gear in case this is different to the selected gear, and propose the action required (shift up* or down) to reduce fuel consumption." Already mandatory for passenger cars, they are not yet mandatory for LCVs, trucks, and buses.
- Fuel consumption meter (FCM): this display device indicates its consumption data, in order to monitor if the eco-driving measures that he has taken result in fuel

consumption. This feedback is important to confirm if the eco-driving measures actually reduce fuel consumption.
- Lubricants/low viscosity lubricants (LVL): used for lubrication of various combustion engines, there are two types of lubricants: mineral and synthetic. Synthetic oils have far better product characteristics than the mineral and have the potential of reducing fuel consumption and improving engine performance.
- Mobile Air Conditioning (MAC): there is a strong regulatory driver in place that favours the use of low GWP or even non-HFC (e.g. CO2) technologies in this sector. The use of MAC in trucks increases the CO2 emissions and fuel consumption. HDVs are excluded from the MAC Directive (2006/40/EC) which provides a gradual phase-out of refrigerant HFC-134a from mobile air conditioners.

To reduce air pollutant emissions

The introduction of Euro VI standards significantly reduced the PM emission limits by 67% compared to Euro IV and V, and includes a PN (particle number) limit. It also decreases the NOx emission limit by 77% compared to Euro V.
Other changes are a new limit for ammonia emissions due to the selective catalytic reduction systems using urea and stricter limits for methane on CNG and LNG vehicles (ICCT, 2015).
As stated in the publication *NOX emissions from heavy-duty and light-duty diesel vehicles* (ICCT 2016c)*,* Cooled exhaust-gas recirculation (EGR) is one of the most important technologies for reducing the NOX emissions and is used in both light-duty and heavy-duty diesel engines.
EGR reduces NOX by recirculating a portion of the engine exhaust back to the combustion chamber, where it is combined with "fresh" air.
Using this combustion-air mixture for in-cylinder combustion has the effect of reducing the peak combustion temperature, thereby reducing the amount of thermal NO production during combustion.

3. Vehicle noise

In the urban environments, the control of noise is an important improvement area for vehicles. Within the analysed studies on vehicles involved in public services, the electric powered vehicle seems to have a higher performance in respect to the noise emissions (EU Commission 2017b) (Idaea-CSIC 2016).
Regarding noise, a proper focus on tyres is of strong importance as well. From the PRT study on vehicles, the following options have been identified as relevant for noise reduction*:*
- Noise level: regulation 540/2014 has introduced new limits for vehicle noise (engine noise).
- Low noise tyres: as indicator, the classification of the EU Tyre Label Directive (EC regulation No 1222/2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters) can be used.

Further information can be gathered in the same study and in the TBT (EU Commission 2011c) particularly about the contention of tyres noise.

4. Vehicle size/class

As gathered in many studies (Bob Hodgins and Ecoplans 2013; Vignisdottir, Booto, and Bohne 2016; Lane 2006) the size and weight of the vehicle has a strong relationship with the environmental impact. For this reason, as recommended in the TBT and in the PRT (EU Commission 2011c; Quintero et al. 2016) the proper size of the vehicles should be adapted to the services, with a preference to small and light vehicles.

Particularly, as indicated in the TBT: *"The general guideline when purchasing cars or contracting transport services should be to identify the real need, in terms of size and power, and define clearly the use requirements of the vehicles and to choose the smallest, lightest and least powerful vehicle that meets these needs."* (EU Commission 2011c)

Alternative powertrains

Within the study on vehicles (Quintero et al. 2016), technical options for alternative powertrains and fuels are analysed. This information provides a broad framework for:

Electric vehicles

Electric vehicles, whether they are fully electric vehicles powered by electric motors, plug-in hybrid vehicles (PHEV) or range extender vehicles (REEV), represent only 1% of the car sales in most European countries. Nevertheless, they could significantly improve air quality, especially in urban area, as "they don't produce tailpipe emissions, include NOx emissions or particles (PM) while running in electric drive mode".

According to the literature review on the comparison of different vehicles types, hybrid technology seems to be the most advantageous, particularly given the current technology available for production of batteries, that make the production of Plug-in vehicles less profictable from an environmental point of view (Zhao, Ercan, and Tatari 2016; Inzunza Soriano and Petter Laudon 2012)

The improvement potential also depends on the source of the electricity. As experimented in Norway in a case study (EU Commission 2017b), since hydroelectricity is considered a renewable source of energy, approximately 300 tonnes of CO_2 emissions can be saved per year only by switching public waste vehicles to electric waste vehicles and reducing transportation routes. Moreover, *"with Norwegian hydropower and low electricity costs, the total cost of ownership for these cars will prove far lower than the conventional ones. Electric powered trucks are significantly quieter, reducing noise pollution in urban areas. Furthermore, other trucks, which currently run on diesel, will be converted to biogas. Thus, the entire fleet will operate completely free of fossil fuels in the short-term future."* (EU Commission 2017b)

FCEV (fuel cell electric vehicle)

These vehicles use an electric motor powered by fuel cells in combination with a battery. Oxygen and compressed hydrogen are used to generate electricity; therefore, they only emit water and heat, which means there are no GHG emission or air polluting emissions. The source used to produce the hydrogen influences greatly their improvement potential. *"Fossil fuel sources, like natural gas and coal gasification result in substantially higher WTT emissions and in case of natural gas these higher emissions therefore also result in an increase in WTW emissions compared to a conventional diesel. All options of using hydrogen produced through electrolysis result in overall WTW savings."*(Quintero et al. 2016)

Biofuels

Compared to other alternative fuels, biofuels are commonly used due to the fact that they can be bought on the market in low blends without any vehicle modifications.

The feedstock used to produce the biofuels and the proportion of biofuel in the fuel blend strongly influence the GHG emission reduction potential, because of the direct and

indirect land use change impacts. *"It is recommended to shift away from food/land based biofuels towards biofuels from waste and residues, like used cooking oil, and advanced biofuels, like cellulosic ethanol and biofuels derived from algae" (Quintero et al. 2016).*

Compressed Natural Gas (CNG)

CNG is a compressed natural gas mainly composed of methane that takes up 1% of its original volume once compressed, and that is stored and distributed under pressure. It is used in dedicated vehicles (that only run on CNG), or in the dual-fuel or bi-fuel system, which represent systems running on two fuels. The improvement potential of CNG resides in the use of renewable gas like biogas: *"Biogas can result in negative WTT emissions because biogas production also avoids methane emissions in case of biogas from manure" (Quintero et al. 2016).*

11.6 Cost considerations

In the public purchase of vehicles, the Directive 2009/33/EC[148] establishes that to estimate the total life cycle cost of a vehicle (LCC), operating and disposal costs have to be considered in addition to the purchase price. Moreover, some other costs have to be considered in the operating phase such as: annual motor vehicle taxes and insurance, fuel or energy consumption, maintenance of the vehicle and substitution of engine oil, tyres and spare parts.

This kind of estimation ensures the choice of a more environmentally friendly and energy efficient vehicle.

In the *Preliminary Report* (Quintero et al. 2016) regarding the revision of GPP for transport, the total cost of ownership for LCVs is calculated. The vehicles are subdivided into two size classes (small and large); furthermore, various scenarios are used for the annual mileage of the vehicle, as the total cost of ownership of a vehicle is also strongly dependent on this.

Four types of costs are taken into account: acquisition costs, fuel costs, maintenance costs and insurance costs. These costs are calculated with and without taxes; in the figure below is a reported summary of the total cost of ownership without considering taxes, since in many cases in the public sector vehicles are exempt from taxation.

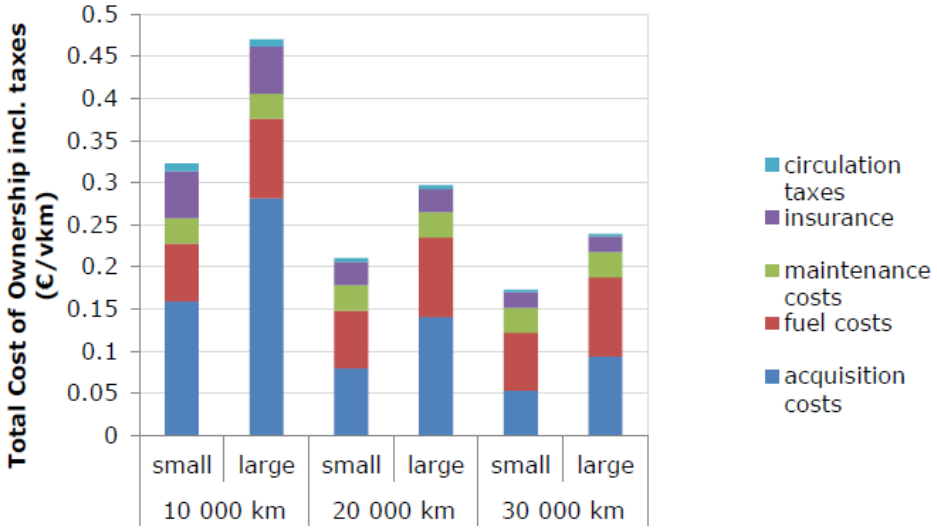

Figure 57: Total Cost of Ownership without taxes per km for LCVs (Quintero et al. 2016)

[148] Information available at: https://ec.europa.eu/transport/sites/transport/files/facts-fundings/evaluations/doc/2015-09-21-ex-post-evaluation-directive-2009-33-ec.pdf

Concerning HDV, the study *Natural Gas in Transport* (CE Delft, TNO and ECN, 2013) provides insights about the cost per km of various options for rigid trucks and tractor-trailers. The study finds that: *"The cost of natural gas routes is comparable (LNG pilot, GTL) to, somewhat higher (CNG and LNG dual fuel) or significantly higher (H2) than that of diesel hybrid trucks."* (CE Delft, TNO and ECN, 2013)
The lower taxes on CNG, LNG and H2 do not compensate the higher vehicle cost in large distances usually covered from HDV. In fact, moving services are to be executed by small to medium sized trucks due to more freight. For this reason, a shift to alternative powertrains is more likely than a shift to non-motorized or electric small vehicles.

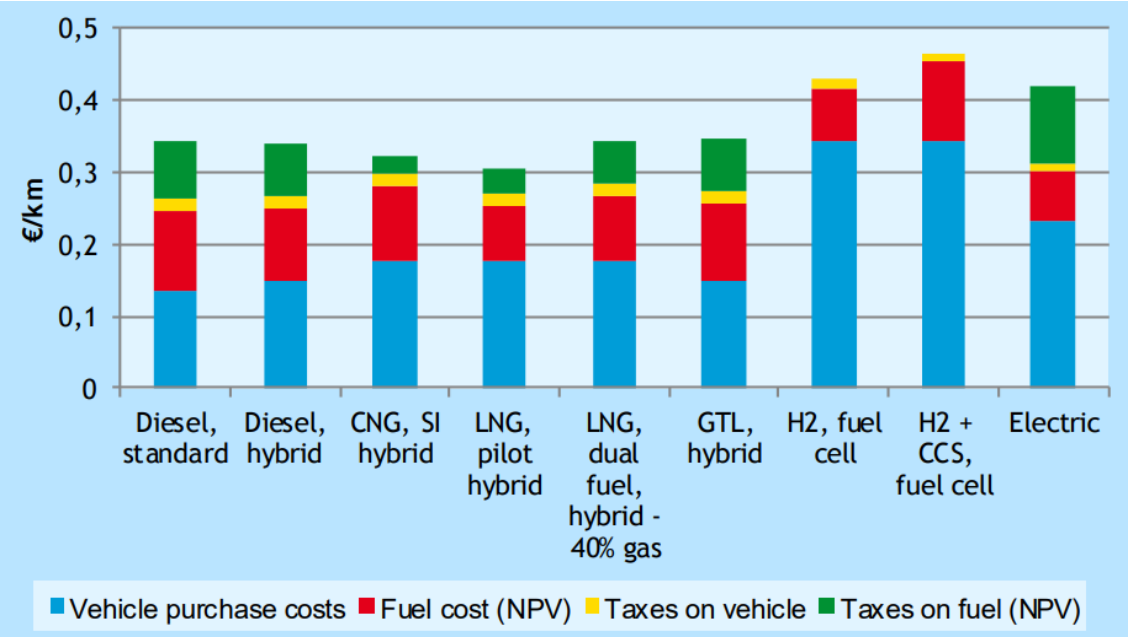

Figure 58:Costs per km for rigid trucks with different fuel types (Verbeek et al. 2013)

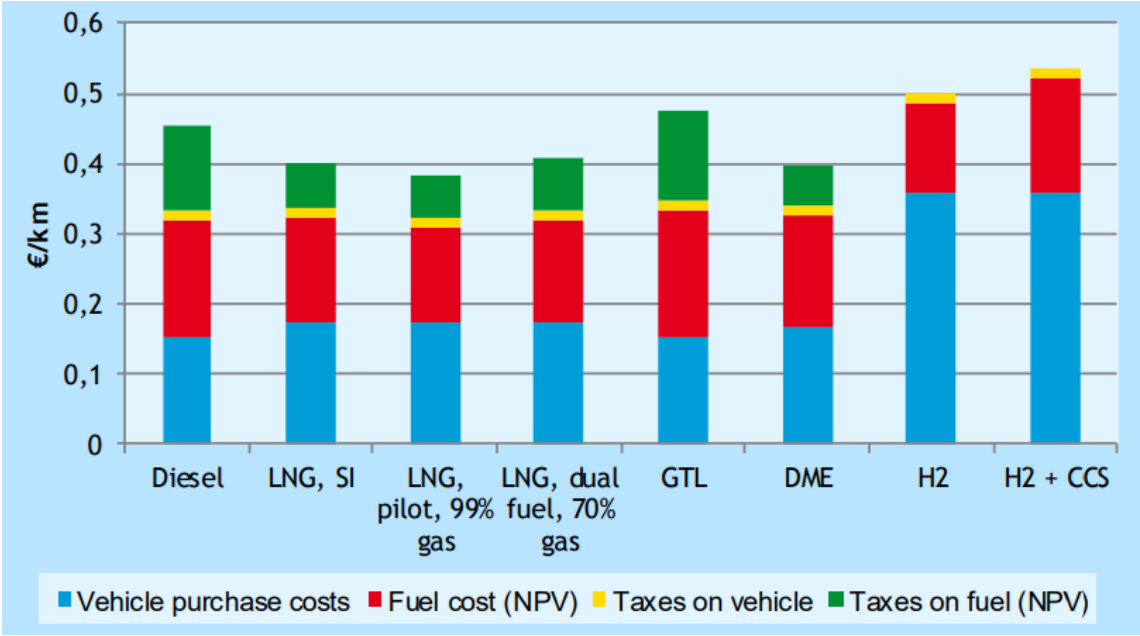

Figure 59:Costs per km for tractor-trailer with different fuel types (high NG price)

As concluded in the *Preliminary Report*: *For short distance transport, the battery electric technology is a feasible option for delivery trucks, because of the generally lower daily*

driving distances, and recharging can occur at scheduled downtimes, like overnight. Nowadays, around 1 000 battery electric distribution trucks are operated worldwide. Significant improvements are expected within the next five years, especially when it comes down to the costs and durability of battery technologies that would increase the potential of electric distribution trucks. (Quintero et al. 2016)

Market availability of environmental friendly products

Vehicles:

Concerning the procurement of public vehicles, it was stated in the recently published *Preliminary Report* for Transport, that according to the estimation for 2016, the public sector is responsible for procuring 575 000 vehicles a year and relevant services that might have a value in the order of billions of Euros. The vehicle market is still dominated by vehicles using diesel and petrol, moreover, the study (Quintero et al. 2016) stresses that the fleets are dominated by vehicles that meet Euro emissions standards of Euro 4/IV or earlier. The European Union currently has a fleet of 23 million light commercial vehicles (LCVs). Almost the entire fleet of light commercial vehicles runs on diesel fuel (96.8%) and only a small fraction uses petrol/gasoline (2.0%) or alternative fuels (1.2%). The percentage of LCVs running on diesel fuel increased slightly between 2009 and 2014 (Quintero et al. 2016).

The European Automobile Manufacturers Association (ACEA)[149] in *The Automobile Industry Pocket Guide 2017 / 2018* provides an estimation of the vehicle market, in particular giving insight into the trends and size of the market for alternative vehicles. As seen in the figure below, commercial vehicles show a slower rate of increases in clean vehicles.

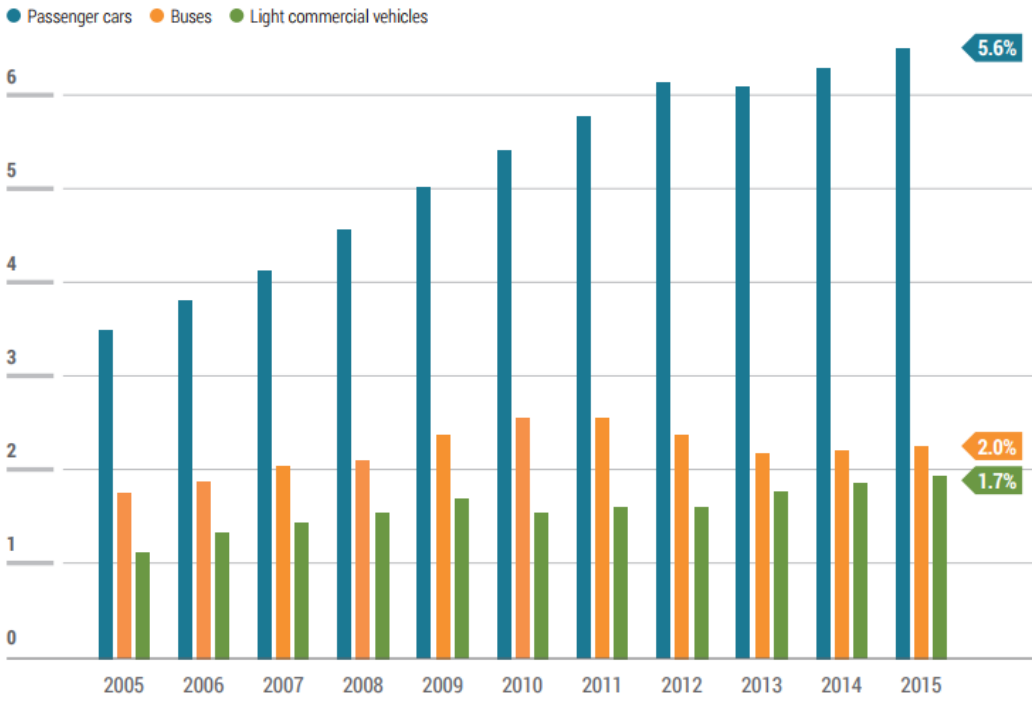

Figure 60: Share of alternative fuel vehicles per vehicle segment, including LPG, natural gas and electric vehicles. (ACEA 2017a)

However, the same study (ACEA 2017b) also reports an increasing trend of improvement in the field of manufacturers. As explained in the study, even if the increasing complexity of products causes a higher demand for energy, the manufacturers of vehicles have reached a diminution of energy consumption of 12,1 % (ACEA 2017b). The same trend of improved technologies in the upstream production of vehicles enabled the reduction of

[149] Information available at: http://www.acea.be/publications/article/acea-pocket-guide

CO2 emissions (25.8% between 2007 and 2016) thanks to the increased sourcing of energy from renewable and/or low-carbon sources.
Moreover, the manufacturers also achieved good results in reducing water depletion (31.9% between 2007 and 2016) and Volatile Organic Compounds (VOC) (30.7% over the last 10 years), the latter thanks to the replacement of solvent-based paints with solvent-free, water-based equivalents.
Concerning other kinds of vehicles specialized in moving services, such as rigid trucks, pickup/vans or other HDV-vehicles the *European Vehicle Market Statistics Pocketbook 2016/17* (ICCT 2016a) gives an estimation of the market. As found in this study, *heavy-duty vehicles (HDVs) represent only 4% of the on-road fleet in the EU but are responsible for about 30% of on-road CO_2 emissions. CO_2 emissions from LDV show a decreasing trend as result of the existing standards. Due to the lack of standards for HDVs emissions are still increasing for this market segment* (ICCT 2016b). Moreover, the *Eurostat statistics*[150] show that the use of electrical energy in trucks is still very limited and the biggest growth is caused by the application of natural gas in vehicles with a load capacity of <1500 kg. Natural gas in vehicles >1500 kg is also limited.

'Special vehicles':
Concerning what we defined as special vehicles, the *EUnited Municipal Equipment (European Association of Municipal Equipment Manufacturers*[151]*)* provide a study from 2014[152] that describes the entity of the market of mobile machines for municipalities including street sweepers and winter maintenance vehicles.
The study estimated that the industry had a market size of around 2 billion Euros in 2014. Aside from the product segment of waste collector vehicles, the market of street sweepers in 2014 was the second largest product segment in Europe with a turnover of around 650 million Euros (in 2013 around 5.000 - 6.000 sweepers were sold by the European manufacturers). *Compact sweepers accounted for around 70% of the sales, while large truck-chassis mounted sweepers accounted for the other 30%.*
The market of vehicles for winter maintenance has found to be strongly influenced by cold or warm winter seasons. As reported in the study in 2013 around 5.000 salt spreaders and 4.500 snow ploughs were sold by the manufacturers.
In the last years, due to the increasing interest of public procurers with respect to environmental aspects, the industry via *EUnited Municipal Equipment* has reacted, developing several test procedures and certificates on key environmental aspects.
The Eunited PM10-Test[153] provides a list of tested and labelled sweeper types according to the EUnited PM10-Test procedure.
A test has also been developed for the quality of winter maintenance vehicles. Following the well-established EUnited PM10-Test for sweepers, a EUnited test procedure and certificate on the accuracy of salt spreading have been launched.
Concerning agricultural vehicles, we found little information on the market size of vehicles used in public procurement, however, it appears that the market for sustainable products is increasing fast. Major brand names like Komatsu, John Deere, Caterpillar and others, manufacture big vehicles (mainly hybrid), while other manufacturers offer smaller, pure-electric versions (Gonzales and Harrop 2017).

[150] Information available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics
[151] Information available at: http://www.eu-nited.net/municipal_equipment/home/index.html
[152] Information available at: http://www.eu-nited.net/municipal_equipment/upload/press_release/Press_Release_IFAT_2014_en.pdf
[153] Information available at: http://www.eu-nited.net/municipal_equipment/upload/Sweeper_list_tested_machines/EUnited_PM10-Test_-_List_of_tested_sweepers_2017-07-11i.pdf

Fuels:
The EU Commission has changed policy to enhance the use of alternative fuels for sustainable mobility. As explained in the web page of *EU Commission on clean transport*[154]transport still relies on oil for 94% of its energy needs. Europe imports around 87% of its crude oil and oil products from abroad, with a crude oil import bill estimated at around €187 billion in 2015, and additional costs to the environment.
Nowadays, the *Clean Power for Transport* package by the EU Commission[155] aims to facilitate the development of a single market for alternative fuels in Europe.
Concerning diesel, the European Biodiesel Board (EBB) provides a background for the diffusion of green diesel within the European Union. This association includes a market of 65 executive and associate members that account for around 80% of EU biodiesel production and two-thirds of biofuels produced in Europe.
Biodiesel is a renewable fuel produced from plant oils such as rapeseed, as well as recycled waste oils or tallow. EBB members produce EN14214 standard level biodiesel, which can be marketed in blends with conventional diesel up to 7%-10% in volume. It is also used in transport fleets in a 30% blend. EU Biodiesel production in 2013 was 10,4 million tonnes, meaning an increase of 16,1% compared to 2012[156].

Lubricants:
Concerning lubricants, the market is classified on the basis of type, namely, mineral oil lubricants, synthetic lubricants, bio-based lubricants, and greases.
The lubricant market is dominated by mineral oil lubricants because of its low cost and easy availability. However, owing to increasing government regulations and consumer awareness, synthetic lubricants, and bio-based lubricants are projected to register a high growth. Nonetheless, currently, the penetration of bio-lubricant in the market is limited due to the high price and lack of high-performing formulations.
Europe has a specific Eco-label set of criteria addressing the control and standardization of lubricant qualities. Products covered by the Eco-label include hydraulic fluids, tractor fluids, grease, chainsaw oils, wire rope oils, two-stroke engine oils and gear oils (Aslanian 2015).
The last mentioned publication about the growth of the bio-lubricant market (Aslanian 2015) gives a broad framework regarding the current situation in Europe.
In this study, it is found that Germany is actually the leading consumer among the market of bio-lubricants in Europe and that this market is being supported by two German Eco-labels (Blu Angel and FNR).
The same study found that the Benelux market is expected to exceed in the next years all other European countries in the consumption of bio-lubricants.
Indeed, through the boosting and subvention of green products, a strong incentive to the growth of customers' interest towards these products is expected.

Tyres
The European Tyres Market 2012-2020[157] provides an executive-level overview and delivers deep quantitative and qualitative insight into the European tyres market, analysing key trends in the market. The study found that the volume of tyres sold in Europe rose 1.7% between 2015 and 2016 and that the market value is forecast to grow by 11.2% by 2020. Moreover, as previously explained the market growth is being driven by manufacturers continuing to chase fuel efficiency gains through the use of different compounds and lightweight construction methods.

[154] Information available at: https://ec.europa.eu/transport/themes/urban/cpt_en
[155] Ibidem
[156] Information available at: http://www.ebb-eu.org/dl/EBB_Brochure2015.pdf
[157] Information available at: https://www.reportlinker.com/ci02307/Tire.html/coverage/Europe/mode/public/since/2012/typologies/I

12 Equipment items for Public Space Maintenance: machinery

The scope of this sub-group of equipment has been identify in the Part I- section 5.1 of this Preliminary Report As indicated in this report, machinery for Public Space Maintenance includes:

- Lawn-mowers (including lawn tractors) and scarifiers
- Chainsaws
- Brush saws
- Strimmers
- Hedge trimmers
- Pruners and similar hand-operated machines
- Leaf collectors and leaf blowers
- Auto-scythes
- Auto-hoes
- Rotary cultivators
- Compost shredders

12.1 Characterization of machinery for Public Space Maintenance

An extensive study on machinery and in particular on non-road machinery is shown in the study *Impact Assessment Study – Reviewing Directive 97/68/EC emissions from non-road mobile machinery Specific Contract n° SI2.ACPROCE018014400 ENTR/04/093 Lot 5 Final Report EC DG enterprise and industry* (Arcadis 2009).
It offers a technical characterization on the category of spark-ignition (SI) engines, which are typically gasoline-fueled engines found in lawn and garden machines (hedge trimmers, brush cutters, lawnmowers, garden tractors, snow blowers, etc.), in light-duty industrial machines (generator sets, welders, pressure washers, etc.) and in light logging machines (chainsaws, log splitters, shredders, etc.).
A first distinction can be made between hand held engines (SH) and non-hand-held engines (SN). A second distinction concerns the size of the engines.
Emissions from these engines are regulated by a new regulation which was enacted on January 1, 2017 ("NRMM Regulation")[158].
Regulation for Pesticide application machinery is covered by the EU concerning the placing of plant protection products on the market (Article 2(1) of Regulation (EC) No 1107/2009). The design and maintenance of this kind of machinery has particular regulation aims to prevent *unintended exposure of the environment to pesticides.* (EU Commission 2006)

Besides of machinery, in this chapter we will also consider some related products such as fuel and lubricants since important environmental concerns are related to their use.

Fuel
NRMM operate in different sectors such as agriculture, forestry, construction, and gardening etc. From a study on the relevance of NRMM emissions (Helms and Lambrecht 2008) we can gather that a large number of this equipment has combustion engines that mainly use diesel. As an example, the same study underline that in Germany, the diesel particle emissions from the considered non-road sectors are about as high as road

[158] REGULATION (EU) 2016/1628 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 September 2016 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery, amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC . Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1628&from=EN

transport emissions and nitrogen oxide emissions have a level of over 20% of road transport emissions.
Currently, the emission limits of these substances are regulated according to EU directive 97/68/EU[159].

Lubricant
For the technical characterization of lubricants, the study from the EU Ecolabel for lubricants (Vidal-Abarca, Kaps, and Wolf 2016) provides a complete background.
Therefore, for the information contained in the following section, we used this document as a reference.
The categories of lubricants of interest for our study are:

Engine oils: are used to power cars, motorcycles, lawnmowers, engine generators and other machinery. In two-stroke engines (commonly found in small portable machines, lawnmowers, chainsaws, weed-wackers) lubricants are mixed with fuel. Two stroke engine oils are emitted in form of burned and unburned emissions to the air and water, often in sensitive spaces like green areas, or natural ecosystems, depending on the specific operations of machines

Gears oils: are used in transmissions, transfer cases, and differentials in automobiles, trucks, and other machinery.

Hydraulic fluids: are used in machines and equipment to transfer pressure from one point to another. They are used in many ways including all fluids for car automatic transmissions, brakes, and power steering. Hydraulic fluids are also used in many machines like tractors and other farm equipment.

Greases: are used when it is not practical or convenient to use oil lubricant. Semisolid lubricants are applied to mechanisms where lubricating oil would not stay in position. Grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive contaminants and foreign materials.

Temporary protection against corrosion: they are protective lubricants that can be easily removed from the metal surface after treatment.
Some application includes:
- Machined parts and components either as finished items or for later assembly
- Tools and machine tools in manufacture, storage and supply
- Fasteners such as screws, rivets, bolts, etc.
- Electrical parts and assemblies
- Metal tanks, valves, and lines
- Agricultural parts and machinery

Lubricants are composed of base oils and additives. The main categories of lubricants are listed below according to the specific kind of base oil.

Oil based lubricants: these lubricants are based on vegetable oils mainly derived from rapeseed, sunflower, palm and coconut. In Europe, rapeseed and sunflower oils are the major vegetable oils used for industrial purposes, including lubricant production.
Besides of their easy availability, the main advantages are thermal oxidation stability, and superior flowing properties compared to other vegetable oils.
Compared with other lubricants, the main advantages of vegetable oils are that they are readily available, have a lower price than synthetic ones, are 100 % renewable, and are readily biodegradable. The technological limits are their sensitivity to high temperatures and poorer low-temperature performances and oxidative stability.

[159]Information available at: http://www.umweltbundesamt.de/publikationen/erarbeitung-eines-konzepts-zur-minderung-der

Mineral oils: are produced from crude oil through several processes of distillation and refinery. According to (Vidal-Abarca, Kaps, and Wolf 2016) 112 kg of base oil are produced from 1 t of crude oil.

Synthetic oils: include among others polyalphaolefins (PAO), synthetic esters and polyalkylene glycols (PAGs).
The environmental impact of synthetic oils can be higher in the production phase because of the important rate of GHG emissions due to a more energy consuming production process. However, a longer lifespan allows fewer oil changes, decreasing impacts per distance covered.

Regenerated oils: used lubricants undergo an extensive re-refining process to remove contaminants to produce fresh base oil. *In cases where primarily the composition and source of used oil is known and reliable the resulting oil can be blended with additives and returned to the original application.* (Vidal-Abarca, Kaps, and Wolf 2016)
As stated by GEIR[160] (Groupement Européen de l'Industrie de la Régénération), it seems that regenerated used oils can be re-refined over and over with no quality loss of its derivative product.

12.2 Overview of studies on machinery for Public Space Maintenance

For the literature review on machinery for Public Space Maintenance, we analyzed five studies including three LCA studies focused on lawn mowers machinery. These are:
- *Life Cycle Assessment of Lawnmowers* (Lan and Liu 2010)
- *A Comparative Life Cycle Analysis of Gasoline-, Battery-, and Electricity-Powered Lawn Mowers (Sivaraman and Lindner 2004)*
- *Review of Life Cycle GHG emissions from LPG riding mowers (Unnasch and Waterland 2011)*
- *Life cycle assessment of chainsaws. A case study of two Husqvarna products with different power systems (Kristinsdóttir, Fernando, and Corredor 2011)*
- *Life-Cycle Assessment of Chainsaw Lubricants made from Rapeseed Oil or Mineral Oil (Wightman et al. 1999)*

Another relevant study represents an LCA literature review focused on the identification of environmental impacts and improvements areas for machinery. This document represents the background research for the Nordic Ecolabelling Criteria for machines for parks and gardens. – Version 5.3[161]
- *Machines for parks and gardens - Background to ecolabeling (Nordic Ecolabelling 2013)*

A study on environmental impacts of small engines for garden outdoor activities:
- *Comparative Assessment of the Environmental Performance of Small Engines - Outdoor Garden Equipment (Environment-Link 2007)*

The already mentioned study (section 4.2) on lubricants also provides useful information concerning lubricant for machinery.
- *Revision of European Ecolabel Criteria for Lubricants- Preliminary Report (Vidal-Abarca, Kaps, and Wolf 2016)*

The table below provides a short description of the mentioned relevant studies.

[160] Information available at: http://www.geir-rerefining.org/
[161] Full text available at: file:///C:/Users/User/Downloads/Criteria_document_040_English.%20(1).pdf

In a further section, a deeper analysis provides an overview of the quality assessment of the studies focusing on impact categories and highlighting the main hotspots in the products/services life cycle.

Table 14:Overview of selected studies related to machinery for Public Space Maintenance

Study type	Sub-category	Source	Title	Impact assessment	External critical review	Impact hotspot summary
LCA	Lawn mowers	Lan and Liu 2010	*Life Cycle Assessment of Lawnmowers*	SETAC-WTA2 list (SETAC-Europe, 1996)	Not specified	The production phase, which also covers raw material extraction and the use phase together dominant environmental impacts. Increasing the share of recycled metals could make better environmental performances.
LCA	Lawn mowers	Sivaraman and Lidner 2004	*A Comparative Life Cycle Analysis of Gasoline-, Battery-, and Electricity-Powered Lawn Mowers*	Eco-Indicator 99 and CML methods	Not specified	The gasoline-powered models emitted the highest amounts of all contaminants. Moreover, gasoline and battery powered lawn mowers pose specific threats to environmental and human health, whereas the corded models are the most benign in all impact categories and scenarios considered.
LCA	Riding mowers	Unnasch and Waterland 2011	*Review of Life Cycle GHG emissions from LPG riding mowers*	CA- GREET	Not specified	LPG-fueled engines used in ridden mower applications have 27% lower GHG emissions than gasoline fueled mowers in comparable applications.
LCA	Chainsaw	Kristinsdóttir, Fernando, and Corredor 2011	*Life cycle assessment of chainsaws. A case study of two Husqvarna products with different power systems*	EDIP	Not specified	The comparison between a fuel engine chainsaw and a battery chainsaw show that battery powered models had lower environmental impact single score for all cases.
LCA	Chainsaw lubricants	*Wightman et al. 1999*	*Life-Cycle Assessment of Chainsaw Lubricants made from Rapeseed Oil or Mineral Oil*	Not specified	Not specified	The environmental impacts of replacing mineral oil with rapeseed oil in chainsaw lubricants are described using comparative life-cycle assessment (LCA). Impacts were lower for rapeseed chainsaw oil, in all scenarios, than for the mineral oil product.
Technical report	Small engines	Environmental link 2007	*Comparative Assessment of the Environmental Performance of Small Engines - Outdoor Garden Equipment*	-	-	*Small engines for outdoor garden Equipment are not as advanced in environmental terms as motor vehicle engines. As a result, even the better-performing small engine emit far greater quantities of pollutants per hour than typical modern car engines.*
Literature review	Lubricants	*Vidal-Abarca, Kalp and Wolf 2016*	*Revision of European Ecolabel Criteria for Lubricants- Preliminary Report*	-	-	The raw materials extraction phase can have strong impacts. The highest impacts for vegetable oils are due to agriculture operations. Regarding synthetic oils, the refining phase is the main contributor of impacts. For mineral base oil, the highest contribution is due to the extraction phase. With modern refining technologies, CO2 emissions can be reduced by more than 50% The environmental impact of water base fluid could occur mainly during the disposal of waste fluids. Proper collection and posterior re-refining is the best option from an environmental point of view.

12.3 Analysis of the selected studies

In the following section, we present a summary of the LCA studies. The following parameters were considered:

-Characterization
- Goal and scope
- Functional units and system boundaries
- Cut off criteria
- Allocation
- Geographical and technological representativeness
- Data sources

Concerning the other relevant studies identified above, in the following section we will only present summaries for each, since the quality assessment through the mentioned categories is not appropriate for this kind of study.

12.3.1 Quality assessment of the LCA studies

Table 14. 1: Quality assessment of LCA studies on machineries for Public Space Maintenance

Source	Characterization	Goal	Scope	Functional Unit	System boundary	Cut-off criteria	*Allocation*	Geog. Repr.	Tech. Repr.	Data source
(Lan and Liu 2010)	Lawn mower	Investigation of the environmental impacts of these two products; Suggestions of improvement in internal LCA implementation and application.	- Lawnmower LC 48VE with petrol engine which is assembled in Höör, Sweden - Automower 220 AC which is assembled in Newton Aycliffe, UK.	mowing 1000 m2 lawn in south Sweden for 10 years	Cradle to grave	Transports from the central warehouses to retailers, from retailers to consumers and from consumers to waste treatment plants were not included	Average energy source from Sweden for the first products, and from Sweden and UK for the second product.	Sweden	Current technology for Lawn mowers	Primary data from Husqvarna AB. Secondary data from Simapro 7.1
(Sivaraman and Lindner 2004)	U.S. EPA's Phase 2 compliant land mowers U.S. EPA's Phase 1 compliant land mowers	Encourage the choose of alternative electric landmowers powered by battery or electricity.	Compare emissions and relevant environmental impacts of the three different kinds of lawn mowers	the total number of mowing required of a 0.5-acre lawn for 8 years	Crudle to grave	Stages involving the extraction of raw materials present in the lawn mower body materials, manufacture of body materials, manufacture, packaging, and distribution of the mower, and its disposal after use were not included in this study because they were all assumed to yield the same emissions and thus impacts	Average mix of energy sources of the United States	Global	Current technology of land mowers	Primary data: literature, personal communication, reports, and databases of U.S. EPA, the U.S. Department of Energy (DOE) Secondary data: SimaPro 5.1; ETH-ESU; IDEMAT; BUWAL 250.
(Unnasch and Waterland 2011)	Riding mower with fuel engines	To provide basis for the reduction of emission from lawn activities	Estimation of greenhouse gas (GHG) emissions from liquefied petroleum gas (LPG) and conventional fuel riding mowers. Emissions	Emissions per MJ of fuel	WTW	Not specified	Different allocation of impacts from different energy sources	USA	Energy sources and small fuel engines	EPA
(Kristinsdóttir, Fernando, and Corredor 2011)	Chainsaw	To identify the main hotspots in the chain saw life cycle.	LCA comparison of traditional gasoline two stroke motors and Lithium-ion battery driven motors.	1000 m2 of cutting through Swedish soft wood.	Cradle to grave	Only transportation of raw materials in the up-stream phase has be considered	Allocation of the site-specific data from the Husqvarna facilities towards one chainsaw. The impacts of production and consumption of fuel and lubricant are allocated in the use phase of the chainsaw.	Global	Current market of chain saw	Husqvarna manufacture and supply. SimaPro database

(Wightman et al. 1999)	Chainsaw lubricants	To analyze improvement potentials of rapeseed oil in replacing mineral oil-based products	Comparative LCA on chainsaw lubricants made from either mineral oil or from rapeseed oil, in the UK.	Volume used in cutting 1000 m3 of wood	Cradle to grave	Not specified	An allocation based on 70:30/ oil:meal in land use was defined on a mass x economic value basis.	UK	Lubricant for open systems	Literature review

Table 14.2: Impact categories of the selected LCA studies related to machineries

Source	**Lan and Liu 2010**	**Sivaraman and Lidner 2004**	**Unnasch and Waterland 2011**	**Kristinsdótti r, Fernando, and Corredor 2011**	***Wightma n et al. 1999***
Impact assessment	SETAC-WTA2 list (SETAC-	Eco-Indicator 99 and CML methods	CA- GREET	EDIP	Not specified
Product Sub group	Lawn mowers	Lawn mowers	Riding mowers	Chainsaw	Chainsaw lubricants
Climate Change	√	√	√	√	√
Ozone Depletion	√	√	-	√	-
Ecotoxicity for aquatic fresh water	√	√	-	√	-
Human Toxicity cancer effects	√	√	-	√	-
Human Toxicity non-cancer effects	√	√	-	√	-
Particulate Matter / Respiratory Inorganics	-	√	-	-	-
Ionising Radiation – human health effects	-	-	-	-	-
Photochemical Ozone Formation	√	-	-	-	-
Acidification	√	√	-	√	-
Eutrophication – terrestrial	√	√	-	√	√
Eutrophication – aquatic	√	√	-	√	√
Resource Depletion – water	-	√	-	√	-
Resource Depletion – mineral, fossil	-	√	-	√	-
Land Transformation	-	-	-	-	-
Other impact categories				Slags/ashes Bulk waste Radioactive waste	

Impact categories are not comparable within the different studies due to the difference of scope and impact methods.

-

Summary of the LCA studies

-*Life Cycle Assessment of Lawnmowers (Lan and Liu 2010)*

This report presents LCA studies of two lawn mowers produced by the Husqvarna AB company.
The goal of the LCA is to analyze environmental impacts of the two selected products to highlight environmental impacts and give recommendations to the company for improvement potentials in the design and production chain of the lawn mowers.
The study analyzes two models, one is the traditional walk-behind lawnmower LC48VE and the other one is named Automower 220AC. The main difference between them is that the former one is petrol-driven while the latter is electricity-driven. Due to the highly different working patterns and market consideration, the results of the LCA study for both cases are not comparable.
The study uses a cradle to grave system boundary.
Concerning the production stage, the study estimates the impacts from the extraction of different materials and assembling of different components. The lawnmower chassis module consists of several materials, mainly steel and plastic. The major parts of a power module are the engine, gearbox and starter battery. For the traditional machine, the Automower power module consists of an engine, *NiMH battery*, printed circuit boards (PCBs) and other small electronic parts.
Concerning the different transport stages, only first tier suppliers were taken into consideration. While transports from the company to consumers and from consumers to waste treatment, plants were not included; a basic assumption for procurement is that transport in Europe was with trucks while outside of Europe was by ship.
The end-of-life stage data was collected from literature reviews and local waste treatment. With the assumptions that all the plastics are incinerated and metallic parts are recycled. Recycling of lead-acid batteries is done by the blast-furnace process.

Results

Lawnmower LC 48VE with petrol engine:

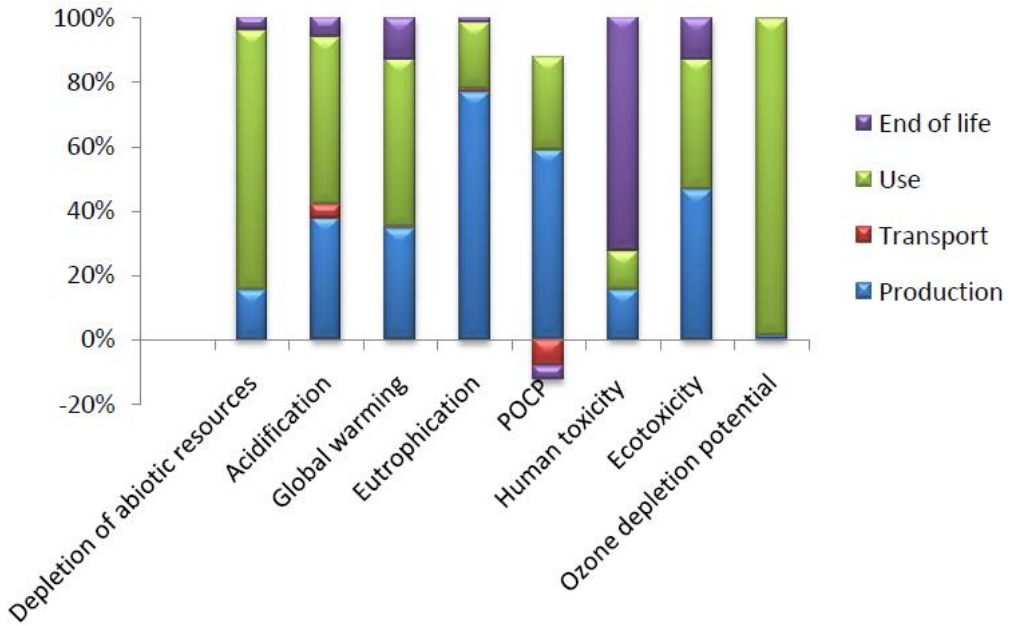

Figure 61: Characterisation results from the whole life cycle of Lawnmower LC48VE. (Lan and Liu 2010)

For the model running with a petrol engine, as we can see in the figure, the production and use phases show a strong environmental impact. In particular, in the first phase of the production chain, the emission for transport contributes with negative value in POCP column due to NOx (Nitrogen Oxides) emissions from fuel consumption.
As shown in the figure the production phase accounts for more than 60% of the total impact, while the use phase takes 80% of the total impact in resource depletion category due to crude oil consumption.

In conclusion for this model of lawnmower, the main impacts can be summarized as follow:

- *Production phase and use phase together contribute dominant impacts after characterization impacts of each environment categories, especially major impacts in Human toxicity.*
- *Weighting methods as EPS2000 and Eco-indicator 99 being applied show difference in final result which is because different emphasis of each method, while in EPS2000, production contributed the major impact 47% and use phase for 49% of final and for Eco-indicator 99 use phase took 75% in total.*
- *In production phase, the major impacts contribution was from chassis module and power module due to the large metal demand in these two modules. In use phase, no matter which weighting method used, oil consumption contributes dominant impacts, both more than 60% of total.*
- *The assembly in Höör only contributes a very small part of the environmental impact.*

Automower 220 AC:

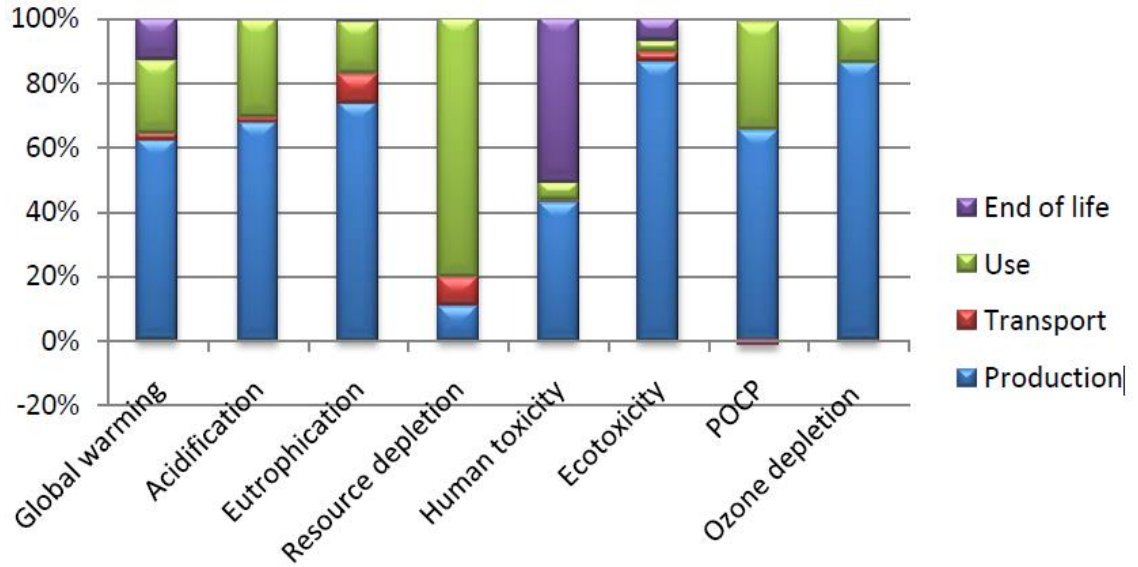

Figure 62: Contribution to the characterisation results from the entire life cycle of Automower. . (Lan and Liu 2010)

The results (in the figure below) show that electronic module accounts for approximately half of all the impact categories due to the toxic and chemical substances which have large consumption in PCB and battery production. Moreover, plastic component modules share approximately 40% of the impact in resource

depletion and ozone depletion due to the crude oil consumption in plastic production. Cable module gives 40% acidification and POCP impacts because of the sulfur dioxide emissions in copper ore extraction.
In conclusion, this model of lawnmower contributes 60% of the impacts in the production phase including raw material extraction.
The main impacts can be summarized as follow:

- The extraction of Copper ore and production of cable from same occupied more than half EPS indices.
- The electronic module production has dominants environmental impacts according to Eco-indicator 99.
- Using Automower in Sweden has better environmental performance than using it in the UK due to different sources of electricity production.
- Assembly in Husqvarna's factory only takes a minor part of total impacts.

For both models of land mowers, the production phase and use phase represent the main hotspots, and the extraction of raw material being one of strongest factors. Because of that, for both cases a better environmental performance can be achieved if more recycled metals are used in the product system.

- ***A Comparative Life Cycle Analysis of Gasoline-, Battery-, and Electricity-Powered Lawn Mowers (Sivaraman and Lindner 2004)***

Due to the recent awareness of the impacts of gasoline-powered no handheld equipment on atmospheric pollution, such as lawn mowers, policy and studies are boosting the use of alternative electric models for lawn management.
With this in mind, this study compares impacts of 12 gasoline-powered lawn mowers and one battery- and one electricity-powered lawn mower using life cycle analysis methods.

The first group of engine lawn-mowers is divided into two broad groups:

- Engines compliant with the U.S. EPA's Phase 2 standards, based on performance at the end of the mower's useful life of 125, 250, or 500 h.
- Engines compliant with the U.S. EPA's Phase 1 standards.

All mowers in this category are manufactured by the American Honda Motor Company. These mowers represent the next generation of gasoline-powered engines.

The second case is the battery-powered lawn mower.
The model that has been considered is the Black & Decker CMM 1000 (Towson, MD), is a 19-inch cordless mulching mower, powered by a 24-V sealed lead acid battery providing 5.0 BHP of power.

The third case is an electricity-powered lawn mower. The model considered is manufactured by MTD Yard Machines (Cleveland, OH). This model has an engine power of 2.0 BHP, a 12-amp electric motor, and mulching capabilities.

Manufacturer[a]	*Valve type*	*Power (BHP)*	*Durability (hours)*[b]
Gasoline (4-stroke)			
Phase 2-compliant			
Honda Motor (H1)	Overhead	3.9	500
Honda Motor (H2)	Overhead	5.3	500
Honda Motor (H3)	Overhead	3.9	250
Honda Motor (H4)	Overhead	5.3	250
Briggs & Stratton (B1)	Side	3.6	125
Briggs & Stratton (B2)	Overhead	3.8	125
Tecumseh (T1)	Side	6.8	125
Tecumseh (T2)	Overhead	7.0	125
Phase 1-compliant			
Briggs & Stratton (B3)	Side	2.4	N.A.
Briggs & Stratton (B4)	Side	3.4	N.A.
Kawasaki Motor (K1)	Overhead	4.5	N.A.
Fuji Heavy (F1)	Overhead	4.9	N.A.
Electric			
Battery			Battery
Black & Decker (E1)	N.A.	5.0	Lifetime: 4.5 years
Power cord			
Yard Machines (E2)	N.A.	2.0	N.D.

[a]Abbreviations in parentheses represent the reference notation used for each model in the remainder of the study; [b]N.A. = not applicable; N.D. = not determined.

Figure 63: Lawn mower models considered in this study. (Sivaraman and Lindner 2004)

Since the primary objective of this study was to compare environmental impacts of the three different lawn mowers, the system boundary was modeled to include only those stages that *differ* in each of the model types considered. Therefore, stages involving the extraction of raw materials present in the lawn mower body materials, manufacture of body materials, manufacture, packaging, distribution of the mower, and disposal were not included in this study because they were all assumed to yield the same emissions and impacts.

The modeled scenario for the first group considered the primary inputs related to the extraction and refining of raw materials necessary for energy production.
The energy produced, comparable with the average US mixture of energy sources, is applied to petroleum extraction and refining related to the production of gasoline, which, in this model, is used in the transportation and mower use stages.

For the second scenario, both the raw material and energy required for primary lead production have been considered, also the production of polypropylene and sulfuric acid and the transportation of both of these intermediate materials for battery manufacture. Transport in the production phase was considered to be a distance of 260-300km round trip.

For the last model, we only considered raw material extraction and refinement for production of electricity required for use of this model of mower over an 8-year period.

Results

From the study we found that with the exception of lead emissions released in greatest quantity from the life cycle of the battery-powered mower, *the gasoline-powered models emitted 1,500 times more carbon monoxide, 31 times more hydrocarbons and nitrogen dioxides, and 18 times more carbon dioxide, released quantity from the life cycle of all three mower types. (Sivaraman and Lindner 2004)*
Moreover, the gasoline mower resulted in the highest percentage of contributions to global warming potential, acidification, and eutrophication, respiratory effects, and fossil fuel resource depletion. While the battery-powered mower shows the highest percentage of contributions to carcinogenicity and human toxicity, ozone depletion potential, and ecotoxicity. In particular, concerning the terrestrial toxicity, the higher value is due to emissions of lead and, in part, to arsenic and mercury, all involved in lead mining and lead acid battery recycling.
Finally, the corded electric mower contributed the lowest percentage in all categories calculated by both methods.

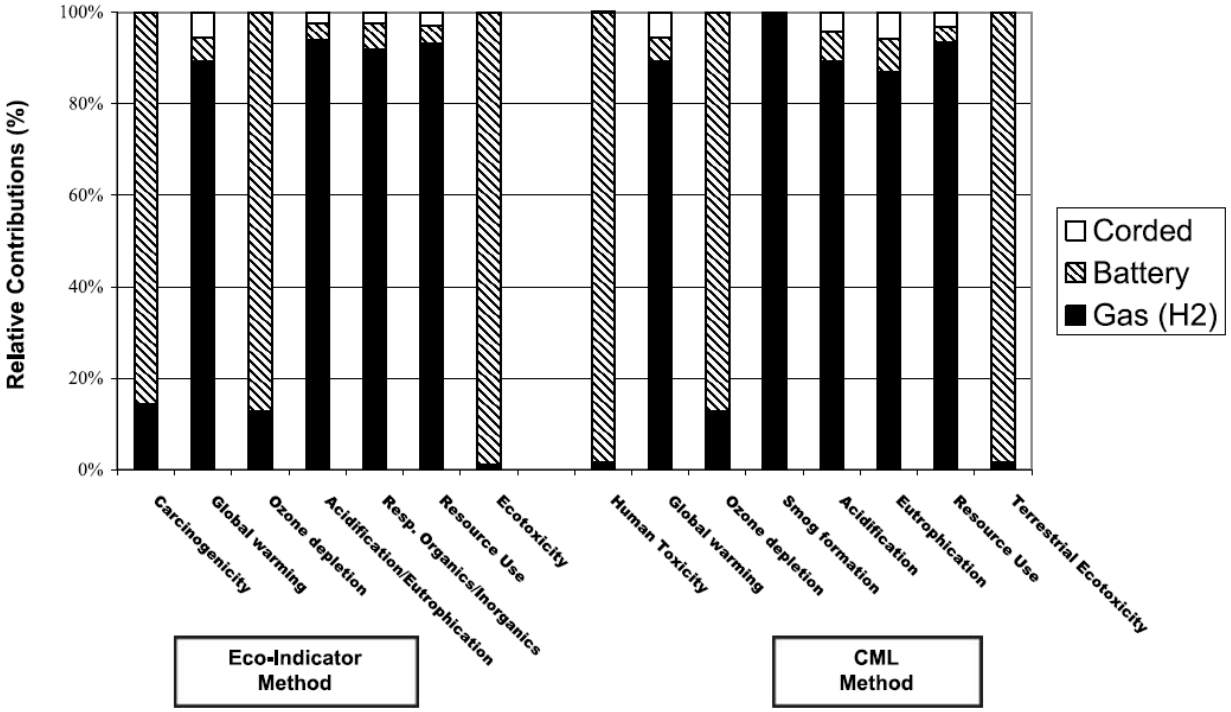

Figure 64:Comparison of impacts calculated using the Eco-Indicator 99 and CML Baseline methods on the base-case scenario. Percentages represent the degree of contribution of each model to their combined impact. (Resp. = Respiratory). (Sivaraman and Lindner 2004)

- ***Review of Life Cycle GHG emissions from LPG riding mowers (Unnasch and Waterland 2011)***

This study carries out an estimation of the greenhouse gas (GHG) emissions from liquefied petroleum gas (LPG) and conventionally fueled riding mowers, through a well-to-wheel (WTW) system boundary which includes the production of feedstock, transport to refining, refining, distribution, and end use in the mower.
The sources of emissions for each step in the fuel cycle are given in the figure below for natural gas and petroleum derived LPG.

Step	Petroleum LPG	Natural Gas LPG
Feedstock Production	Crude Oil Extraction, Associated gas venting and flaring. Same emissions applied to gasoline	Natural gas extraction, fugitive losses. Natural gas recovery. Same emissions applied to natural gas pathways
Feedstock Transport	Transport of crude oil to oil refinery. Same emission applied to gasoline. Transport of LPG to distribution centers	Transport of LPG to distribution centers
Refining	Oil refinery emissions with efficiency input for LPG	LPG refining
Product Transport	Transport to local fuel station	Transport to local fuel station
Fuel Combustion	Carbon in fuel converted to CO_2 plus Vehicle CH_4 and N_2O emissions	

Figure 65:Pathway Steps for LPG Fuels in GREET Analysis

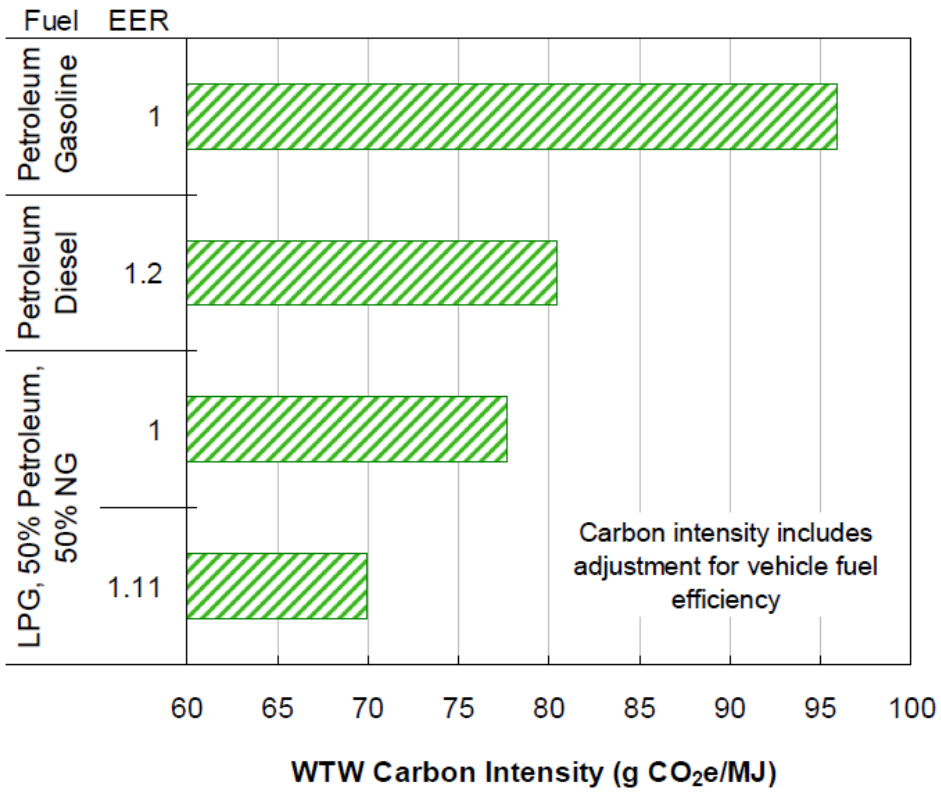

Figure 66:Comparison of WTW Emissions from LPG, Gasoline, and Diesel Mowers (adjusted for engine efficiency, EER from EPA

Upstream emissions for fuel production chain correspond to the energy inputs and emissions associated with feedstock production, transport, refining, and fuel delivery.
The figure above shows the differences between petroleum and LPC chain emissions.

Results

According to with the study, LPG-fueled (on a mix of 50% petroleum-derived LPG and 50% natural gas-derived LPG) mowers have 27% lower GHG emissions than comparable gasoline-fueled mowers.

This result depends on three factors:

- the lower carbon content of LPG compared with gasoline and diesel
- the easy upstream refining of LPG
- the increased engine efficiency of LPG fueled mowers.

Moreover, the overall conclusion of the study highlights that:

- Even if no efficiency improvement of LPG engine is considered, the emissions remain 20% lower than gasoline fueled mower, and 14% lower than diesel.

- The production chain of LPG from natural gas has fewer impacts than producing LPG via processing fuels in an oil refinery.

- If LPG is generated as a co-product from oil refineries, the GHG emissions are even lower because the upstream energy requirements are zero for co-product LPG. These upstream emissions are allocated entirely to the gasoline and diesel fuel products.

- ***Life cycle assessment of chainsaws. A case study of two Husqvarna products with different power systems (Kristinsdóttir, Fernando, and Corredor 2011)***

The Husqvarna company was interested in carrying out this study with the main purpose of find the stages, processes or materials in the product life cycle with the highest contribution to the total environmental impacts of two professional top handle chainsaw models.

The two machines have similar function but different power systems; a gasoline driven two-stroke internal combustion engine and an electric motor with a Lithium-ion battery.

The T540XP is a new improved model of petrol powered chainsaw that has the potential of reducing fuel consumption by up to 20% and harmful exhaust emissions up to 60% compared with previous models. This model is produced in Sweden for the European and USA market.

The battery-powered chainsaw is a new model, that enables to reduce health risk for the user by greatly limiting exposure to emissions as well as reduced noise and overall better environmental performance

Both products are obliged to *compliance with the existing environmental regulations, with regard to chemical content and emissions, REACH directive (EC 1907/2006) and general exhaust regulations (Kristinsdóttir, Fernando, and Corredor 2011).*

For the setting of the stages of this cradle to grave LCA, special focus was given to processes that are different between the product type production and those who are within the range of influence of Husqvarna.

The base scenario used for the analysis of the two products is modeled with a use phase and end-of-life in Sweden. Moreover, additional use scenarios were modeled for sensitivity analysis. The additional scenarios estimated are:

- Sweden: The Nordic electricity system and Swedish fuel standard and waste scenario

- Average European electricity, fuel standard and waste scenario
- Average North- American electricity, fuel standard and waste scenario

Results

From the study concerning the fuel engine, the use phase emerges as the main hotspot, with lubricating oil production and fuel production and consumption as the processes that contribute the most to the total environmental impacts (the impacts of production and consumption of fuel and lubricant are allocated in the use phase of the chainsaw).

For the Battery saw, the use phase impacts come mostly from the production of the lubricating chain oil and the production of the electricity used to charge the battery for the chainsaw operation. In particular; the production of the chain oil is the main hot spot process, dominating most of the categories including global warming and acidification.

Concerning the use phase, the analysis on different geographical scenarios, showed a strong sensibility of the result in relation to background energy system changes, as different data in petrol production leads to different results.

Since the production phase is found to be dominant across many impacts, such as resource use, hazardous waste and some toxicity subcategories, the study underlines potential environmental improvement from the use of recycled material and biomaterial.

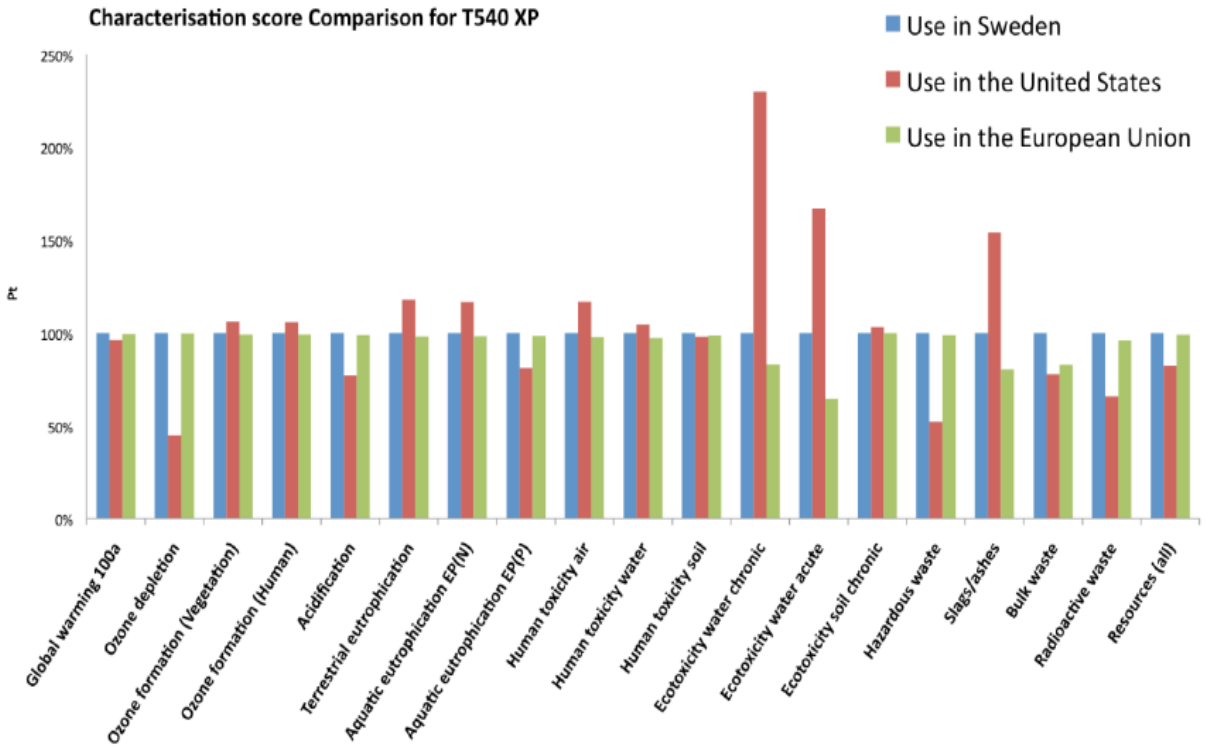

Figure 67: Comparison of different energy systems (facilities, raw materials) for the use phase of the T540XP. (Kristinsdóttir, Fernando, and Corredor 2011)

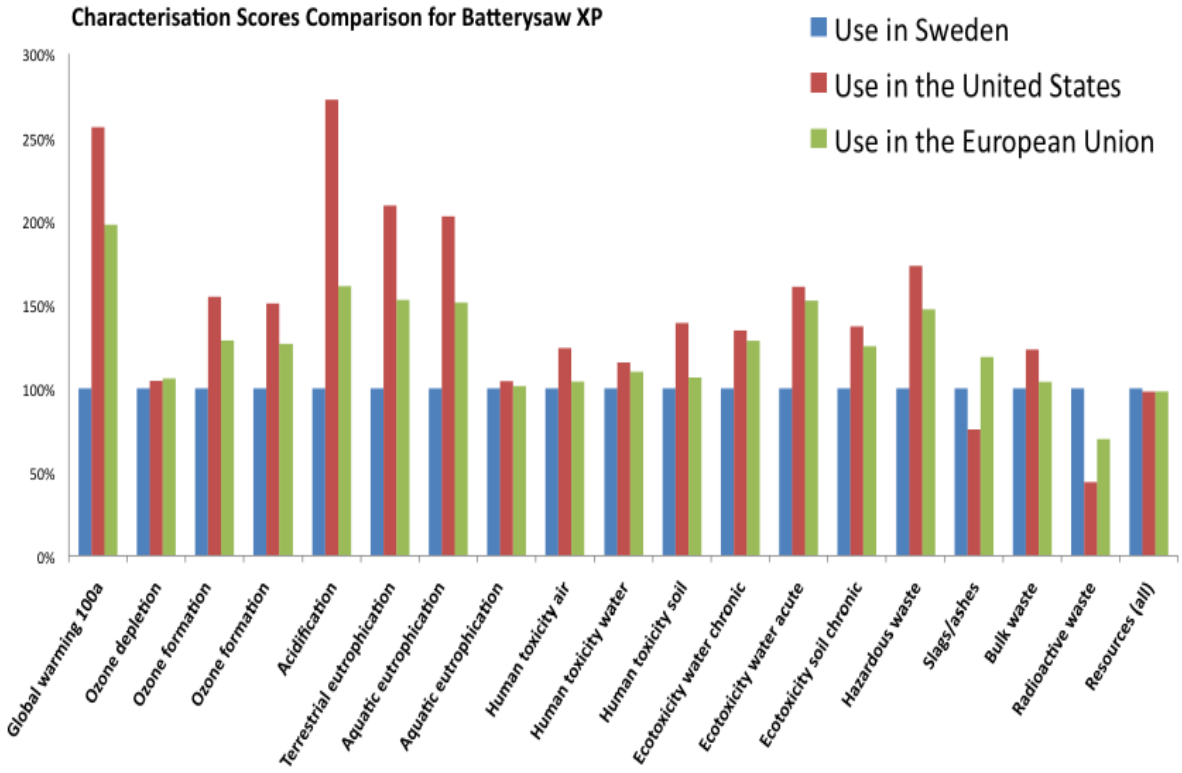

Figure 68:Comparison of different energy systems for the use phase of the battery saw. (Kristinsdóttir, Fernando, and Corredor 2011)

- ***Life-Cycle Assessment of Chainsaw Lubricants made from Rapeseed Oil or Mineral Oil (Wightman et al. 1999)***

The general goal of this study is to analyse improvement potentials of rapeseed oil in replacing mineral oil-based products. The use of lubricant in chainsaws results in a spillage or loss of material in the environment. Thus, the substitution of mineral oil with a biodegradable product nowadays is of strong interests.
Chainsaw lubricants are used to reduce friction between the chain and the cutting bar of the chainsaw, they are based of oil (either mineral or vegetable), plus a package of performance-enhancing additives.
This study carries out a comparative LCA on chainsaw lubricants made from either mineral oil or from rapeseed oil, in the UK.
Concerning the up-stream stage of rapeseed oil, the environmental impact of crop management was considered, thus the study takes into account emissions such as nitrous oxide which are released from the soil whether a crop is grown or not.
Consequently, two different scenarios (winter wheat and set-aside) were considered for crop emissions.
The system boundary for the rapeseed oil assumes that the product lifecycle starts with ploughing of the land in preparation for crop production in the autumn, and end after the lubricant has completely degraded in the environment.

Concerning mineral oil production, the product lifecycle is assumed to start with the mineral oil exploration and production activities, and end after the lubricant has degraded in the environment.

Results

The study shows significant advantages from the use of rapeseed chainsaw bar oil in terms of Global Warming Potential (GWP). However alternative allocations and

land use assumptions have a large influence on other impacts such as eutrophication.

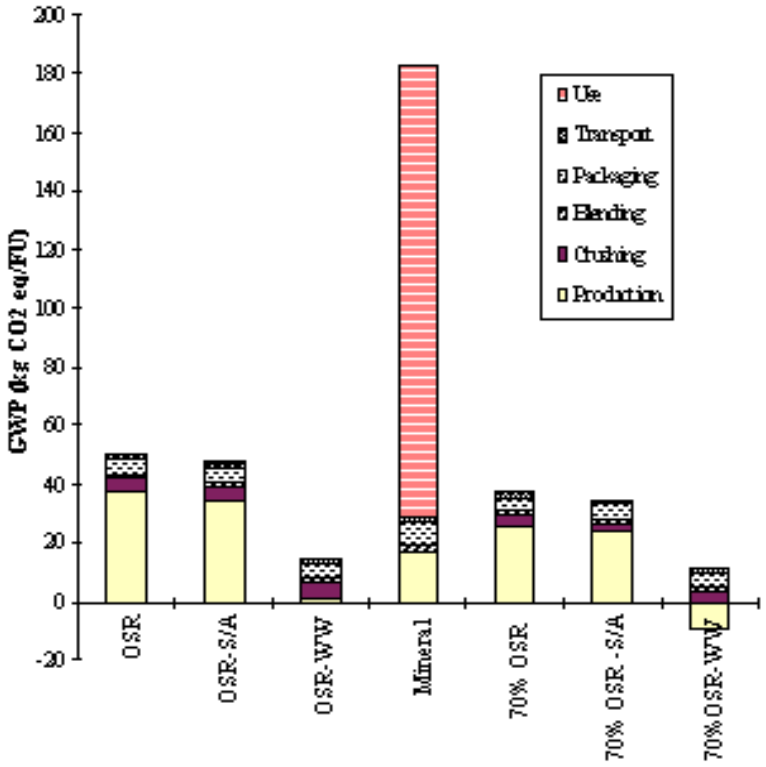

Figure 69: GWP for LCA of chainsaw oil

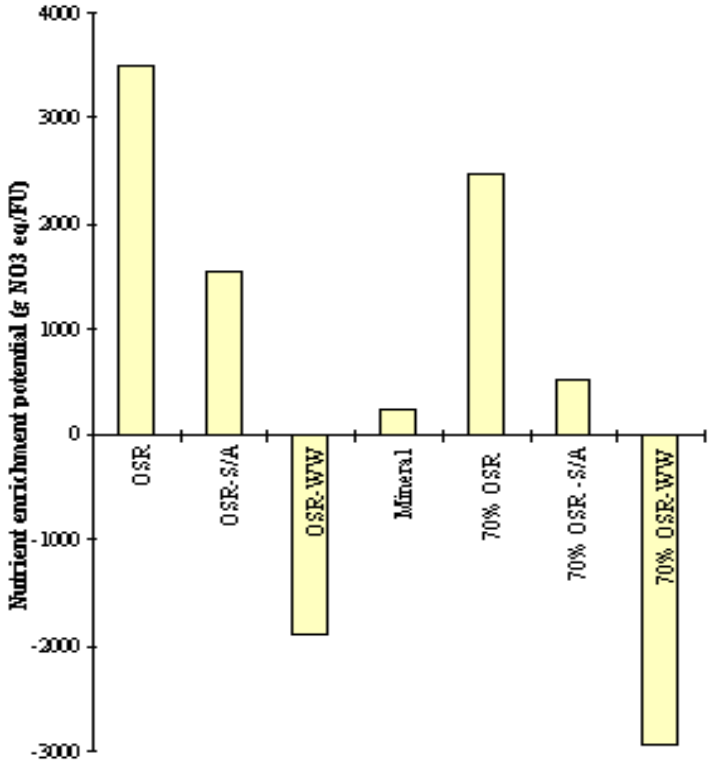

Figure 70:Nutrient enrichment potential for LCA of chainsaw oil

12.3.2 Summary of other relevant studies

- ***Machines for parks and gardens - Background to ecolabeling (Nordic Ecolabelling 2013)***

Based on previous pre-studies, assessments, and revisions, the Nordic Ecolabel imposes requirements within eight different areas:

1. Environmental and quality requirements with regard to manufacturing and the license holder
2. Product design
3. Materials and packaging
4. Emissions (air)
5. Energy efficiency
6. Noise
7. Vibrations
8. Customer information

This section describes these areas based on environmental relevance, the potential for improvement and how Nordic Ecolabelling can steer improvement through its requirements. This study is mainly focused on the use stage of machinery which is why environmental and quality requirements with regard to manufacturing and the license holder are not described.
This study provides an analysis of main environmental hotspots for machinery.

Results

The study highlights that material production and use/operation accounts for, by far, the highest environmental impact.
In the up-stream phase, material production accounts for strong impacts due to the energy consumed in the extraction and production of the metals and metallic materials used to manufacture the end products.
During the operation phase of machinery, the impacts are far greater for machines with combustion engines than for electrical/battery operated machines.
Moreover, impacts for health and environment are linked to the emissions of hydrocarbons from the fuel system.
Finally, noise is also an important issue for the staff and general public.

Thanks to this broad background of environmental impacts, the study from Nordic Ecolabelling is able to provide a set of potential improvements for garden machinery and related criteria, which resultantly is of large interest to our study.
The framework provided by this study has been used in the following sections to carry on the analysis of environmental hot spots and improvement areas for the sub-group of machinery for Public Space Maintenance.

- ***Comparative Assessment of the Environmental Performance of Small Engines - Outdoor Garden Equipment (Environment-Link 2007)***

This report is aimed at identifying improvement potential for the use of small fuel engines that are used to power outdoor garden equipment; engines which were available for sale in Australia during 2006.
At a first glance, the study reports a framework of the main environmental impacts related to GHG emissions and $PM_{10.}$
The scope of the study covers five types of spark-ignition engines that are used in lawnmowers, brush cutters, and hedge trimmers:

- *Two stroke with carburetor (2c)*
- *Two stroke with pre-chamber fuel injection (2i)*
- *Two stroke with direct fuel injection (2di)*

- *Four stroke with carburetor (4c)*
- *Four stroke with fuel injection (4i) (includes direct injection)*

The study shows that these engines are not as advanced in environmental terms as other motor vehicle engines. As a result, even the better-performing small engines emit far greater quantities of pollutants per hour than typical modern car engines. Therefore, the study underlines the need of improved regulation to reduce such impacts.
In the study, an overview of the regulations of emissions from outdoor garden equipment from USA, California, Canada and Europe is provided and new improvement criteria are proposed.

Results
The study provides a framework on the environmental impacts from emissions of small engine machinery used for gardening activities.
As found in the study, carburetor and pre-chamber fuel injection two stroke engines are inherently more polluting than the other three types. This is due to their inability to completely separate the inlet gases from the exhaust gases and the need to add oil to the fuel to lubricate the engine.
These kinds of engines tend to have fewer components and are generally cheaper to purchase and are cheaper to maintain.
In comparison with two stroke engines, four stroke carburetor engines are generally quieter, more fuel efficient and are less polluting.
Direct fuel injection (DFI), is found to have the strongest emissions, however, from the study, we can see that there is not any evidence that DFI engines are being used in outdoor garden equipment available in the market. Although, it seems that most common engines used in outdoor garden equipment are two and four stroke carburetor engines.
Moreover, the study shows that, because of the combustion of oil, these engines also emit high levels of particle emissions. Although it has to be considered that the amount of these emissions is significantly lower than the rate of particle release from other machines like lawnmowers, which can emit over *10 times more particles (in terms of grams per hour) than a petrol motor vehicle (manufactured between 1994 and 2001). (Environment-Link 2007)*

- ***Revision of European Ecolabel Criteria for Lubricants- Preliminary Report* (Vidal-Abarca, Kaps, and Wolf 2016)**

This study provides a broad framework on the market of lubricant, on their technical characterization, on related environmental impacts and on improvement options.
In particular, the section concerning the technical analysis provides a wide literature review of Twelve Life Cycle Assessment studies (LCAs).
This Eu Ecolabel study aims at the boosting of products with reduced impacts, for that reason it highlights the importance of evaluating the most significant impacts including:
- *Impacts on climate change, nature and biodiversity*
- *Energy and resource consumption*
- *Generation of waste*
- *Emissions to all environmental media, pollution through physical effects*
- *The use and release of hazardous substances*

Thus, the Ecolabel study covers all these aspects and other *"non-LCA" aspects related to health and hazards inherent to the products* (Vidal-Abarca, Kaps, and Wolf 2016).

The scope of the study covers manufacturing, use, end of life, and with system boundaries encompassing petroleum, petrochemical, oleochemical and engineering industry activities. The declared functional unit, used for the comparison of the different LCA studies within the literature review, is 1KG of base oil.
Through a prioritization methodology, the study provides a basis to prepare a proposal of improvement options attending to aspects such as environmental impacts or hotspots.

Results

Raw material extraction, transport and processing of components

The extraction and processing phase of raw materials can have strong environmental impacts depending on the specific composition of lubricants:

- Concerning vegetable oils, the main impacts are related to the impacts coming from agricultural operations, such as the use of fertilizer and pesticides or the land use. Even though the literature review of this study shows for vegetable oils lower impacts with respect to the global warming potential than mineral and synthetic oils.

- Synthetic oils seem to be related to strong impacts during the refining phase, at this stage they have higher impacts than mineral oil due to more complex processing and higher energy consumption. However, those impacts are compensated during the use phase by a longer life and lower impact.

- For mineral base oil, the highest contribution is due to the extraction phase.

- The strongest environmental impact of water base fluid could occur mainly during the disposal of waste fluids.

- In the production phase recycled/re-refined oils could bring environmental advantages, in fact, thanks to modern re-refining technologies, CO2 emissions can be reduced by more than 50% as compared to the conventional production of base oil.

For all the products, the environmental impacts related to the transport seem to be of low relevance.

Manufacturing of lubricant, packaging and distribution

Manufacturing mainly consists of the blending of processed substances; therefore, this stage has lower environmental impacts than the previous stage.
The packaging of lubricants covers a wide range of types depending on the purpose of products. As stated in the study, the LCA literature review doesn’t give much information on impacts related to packaging, even though some improvement potential could be indicated that lye in the use of environmentally friendly materials and a proper design for the correct use/application/resistance to spillage and correct disposal.

Use phase

The main impacts occurring in the use phase are related with the loss of product in the environment. This concern is highly important since approximately 50% of all traditional lubricants are released into the environment during use, spills, or disposal.
The release of used oils in the environment may affect soil ecosystem and water ecosystems by endangering drinking water supply and aquatic organisms.

End-of-life

The correct disposal of lubricant is an important issue to pay attention in order to avoid adverse effect on the soils, aquatic life and drinking water. The 50% of used oils will become waste oils potentially recoverable (the rest is lost during use; through leakages, exhaust emissions, etc.).
Waste oils (WO) have to be managed as hazardous waste since they can contain metals from engine wear, unburned fuel, PAH (polyaromatic hydrocarbons) and particulates.
The recycling through the re-refining is the best option from an environmental point of view; it has lower impacts than disposal (burning) and also it has associated environmental savings with respect to using new lubricant as raw material.

12.4 Overview of environmental impact hotspots of Machinery for Public Space Maintenance

A summary of the quality and availability of literature on the environmental impacts of machinery utilized for Public Space Maintenance is provided below:

Literature availability – Due to the large awareness concerning the emissions of NRMM and particularly of small engines used in machinery such as chainsaws and lawn mowers, a wide variety of publications and regulations have been produced, representing a broad background for the identification of main environmental impacts and hotspots across the life cycle of these products.
Less literature has been found on the specific topic of cleaning machinery for outdoor utilization. Nevertheless, we can consider that the general findings on the impacts resulting from the utilization of small engines can be generalized and also applied to these kinds of machines.

Impact category coverage – the most iimportant environmental impacts are related to the use of machineries and include noise generation, fuel consumption, exhaust gas emissions and the consumption of lubricant oils. The studies found in the literature are mainly focused on the emissions (e.g. GHG and PM_{10}) resulting from the production and use phase. Although, many studies have also been found to analyze other categories mostly related with:
- Ecotoxicity mainly related with the production and disposal of batteries for electrical machinery as also related with the releasing of lubricants in the environment.
- Energy depletion in the extraction and manufacturing of materials in the production phase, and in the use phase related with the powering of machinery.
Representative study on machinery for Public Space Maintenance– the studies that have been selected for the literature review are in line with the scope of our study and have been useful for expanding upon the issues related to the use of machinery.

The main hotspots identified from the literature review are listed below:

Production phase

The production phase has been found to be one of the main hotspots across the life cycle of machinery; different concerns of this phase have to be considered:

Transformation of raw materials and components production

In the literature review, the production phase including raw material extraction is found to contribute 60% impacts of each environment category, exclude resource depletion and human toxicity (Lan and Liu 2010). In particular in this phase, the cable (Cu) production and the production of the electronic module dominate

environmental impacts (Lan and Liu 2010). As also underlined in the *Nordic Ecolabell background study on garden machineries*, a more in-depth analysis shows that it is the use of copper and iron ore that has the largest individual impact on the environment from a life cycle perspective. *The same results are essentially achieved regardless of whether the object of analysis is a standard, petrol fueled walk-behind lawnmower or a modern robot machine that does not require any manual handling at the time of mowing. Nor are there any significant differences between different manufacturers.* (Nordic Ecolabelling 2013)
In general, the relevance of the impacts in the production phase is explained by the need for different materials like petrol based material, plastics and rubbers, or the use of metallic materials, which require a large amount of energy during their production (Nordic Ecolabelling 2013; Samaras and Meisterling 2008).
Moreover, as shown in the literature, the extraction and processing of raw materials have strong impacts also in the life cycle of lubricants. The strongest impacts are found to be related to the refining of synthetic and mineral oils.
For that reason, the use of recycled materials, both in the case of machines components that in the case of recycled oils, can lead better performances in the life cycle of machinery thanks to the lower rate of raw materials extraction and processing.

In the LCA study on lawnmower (Lan and Liu 2010) a sensitive analysis with different recycle ranges of metals was carried out since metals show to have a large impact related to the extraction phase.
As found in the study, obviously, increasing the share of recycled metals makes better environmental performances of lawnmower. Photochemical oxidant creation and acidification categories are the most influenced factor by variation of recycling rate.
The weighting results from variations of recycling rate show that ELU (Environmental Load Units) value decreased 35% if all the recycled metals go back to the system compared to the base case, however only 17% impact is decreased according to Eco-indicator 99.

Battery production

The battery production chain is found to be dominant across many impacts, such as resource use, hazardous waste and some toxicity subcategories for battery powered machinery.
Studies on battery-powered mowers have shown that they have a high contribution to carcinogenicity and human toxicity, ozone depletion potential, and ecotoxicity. In particular, the terrestrial toxicity the higher value is due to emissions of lead and, in part, to arsenic and mercury, all of which are involved in lead mining and lead acid battery recycling (Lan and Liu 2010; Samaras and Meisterling 2008).

Fuel and lubricant production

The production phase of lubricants and fuels also results to generate a strong impact for the categories of GHG emissions, energy depletion and acidification (Kristinsdóttir, Fernando, and Corredor 2011).
In the case of the production of bioproducts from crop lands, we see that there could also be environmental impacts associated with agricultural activities as well with land use changing. The latter concerns result very significantly when exploitation of land for these kinds of crops mean a competition factor for biodiversity (Mcmanus, Hammond, and Burrows 2004).

Use phase

Fuel and lubricant emissions

Machineries used for outdoor activities have a great environmental impact during the usage phase, especially due to the air emissions that they produce and related emissions from energy sources. However, not all types will have the same damaging level. Electricity powered machines will, of course, be far less harmful than the fueled powered ones, since fuel combustion results in greenhouse effects from carbon dioxide emissions, and in tropospheric ozone and health effects from nitrogen oxides emissions. Nevertheless, the impact from electricity powered engines will differ greatly depending on how the energy is produced (using coal, natural gas or nuclear power).

However, concerning fuel powered small engines as summarized in the above mentioned study (Environment-Link 2007), carburetor and pre-chamber fuel injection two stroke engines are more polluting than other kinds of similar engines. This is due to their inability to completely separate the inlet gases from the exhaust gases and the need to add oil to the fuel to lubricate the engine. Moreover, the study highlights that the oil combustion of these engines which also emits high levels of particle emissions.

Furthermore, as many types of machines, such lawnmowers, are not equipped with catalysts, unlike cars, some health affecting substances could be released during the shift from petrol to ethanol: "*when ethanol combusts in a car engine, formaldehyde and acetaldehyde can form under certain conditions, especially when the engine is cold. The catalyst handles these unwanted substances once the engine has heated up. Machines for parks and gardens also generate air emissions that are created when fuel evaporates when the engine is turned off, so called evaporative emissions. Organic gas molecules penetrate the walls of the material used in the fuel system and components and evaporate from surfaces such as the fuel tank, fuel hoses, gaskets and seals."*(Nordic Ecolabelling 2013)

As explained in the GPP for gardening products and services : *Greases and lubricants can be used in either open or closed applications. Lubricants used in open applications are called Total loss lubricants (TLLs) (two-stroke oils, chain saw oils, etc.). They are often if not always used in outdoor machinery and are by definition directly emitted into the surroundings, making them more dangerous for the environment than other lubricants (such as engine oils) used in closed systems* (EU Commission 2012).
Traditional mineral lubricants can be harmful to the environment because of their low rate of biodegradability and also because they could contain harmful substances, such as petroleum-derived compounds and additives characterised by their toxicity. (Nordic Ecolabelling 2013; Wightman et al. 1999). Biobased lubricants from vegetable oils, are completely biodegradable in the environment and are best suited for total loss lubricant applications although as mentioned before their major impacts are allocated in the up-stream phase.

Noise and vibrations

Noise pollution is one of the more significant environmental impacts arising from the use of public space maintenance machineries.

The European directive (Directive 2000/14/EC**)**, regulating environmental noise from equipment[162] intended for outdoor use was tightened when step II of the directive came into force in March 2006.
The machinery Directive mandates a determination and declaration of the emission sound pressure level. However, this declaration is only required if the emission sound pressure level exceeds 80 dB(A).
All types of machinery covered by the outdoor equipment directive must be labeled with the guaranteed sound power level before they can be sold in Europe.
To effectively decrease the environmental noise levels from outdoor equipment, low noise outdoor machinery is needed

Vibration requirements for hand-held and ride-on machines currently only apply to the professional use, as there is a major difference in exposure between a professional user and a consumer who mows his/her lawn intermittently during the season.

End-of-life phase

This phase has not been found as a main hotspot across the life cycle of machinery. With respect to the disposal of the machine, the aim is to disassemble it as much as this is possible to maximize the number of components that can be recycled, especially the metals, which are easier to separate than the plastic components since plastics are often composites. They are often sent to incineration, for energy extraction, which at least minimizes the amount of waste sent to landfill. (Lan and Liu 2010)

In the LCA study on land mowers (Lan and Liu 2010) the recycling rate of machinery was estimated at a rate of 97%. However, has to be considered that in this study the disposal and recycling of components were lubricated in Sweden. No further information is available on the recycling practices in other regions.

Some important issues in the disposal of machinery concerns components like batteries and compressor oils that must be handled as hazardous waste.(Lan and Liu 2010)

12.5 Environmental improvements areas

Production phase

1. Design of products and use of recycled materials

The studies mentioned in the literature review show that the extraction and transformation of raw materials for the manufacture of parts/components has a strong environmental impact. Many studies recommend the use of recycled material as a good strategy to achieve low environmental impacts, for example, using recycled plastic in the manufacturing process. As well, the reduction of the overall weight of components and materials can result as better environmental performance (Lan and Liu 2010).

[162] Information available at: http://ec.europa.eu/growth/sectors/mechanical-engineering/noise-emissions_en

Furthermore, the exclusion of lead accumulators would have a good improvement potential, replacing them with either nickel metal hybrid (NiMH) accumulators or lithium ion accumulators (Nordic Ecolabelling 2013). This change would however increase the price of the product, as they are currently only used by manufacturers who claim to favor quality over price.

According to Nord Ecolabelling criteria (Nordic Ecolabelling 2013), also packaging should be recyclable or reusable.

Use phase

1. Exhaust emission levels for machinery

As previously mentioned, pollutant emissions from combustion engines installed in outdoor machineries could significantly contribute to air pollution by emitting carbon oxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter.
Due to a common awareness of the problem, policies are being developed with the main objective of progressively reducing the pollutant emissions and to phase out equipment with the most polluting engines.
As known, since the 1st of January 2017 emissions from these engines are controlled by a new regulation. These recent directives of the NRMM Regulation define emission limits for NRMM engines for different power ranges and applications. The NRMM Regulation also establishes the procedures which engine manufacturers have to follow in order to obtain type-approval for their engines, which is a prerequisite for placing their products on the EU market.[163]
The study from the Nordic Ecolabelling, provides broad criteria for the contention of emissions from garden machinery (Nordic Ecolabelling 2013).
From the literature review concerning traditional small fuel power engines, we can find that within the different types of engines the four stroke carburetor engines are generally quieter, more fuel efficient and are less polluting. (Environment-Link 2007)
More in general, we found that there are differences in efficiency between the various engines available on the market and there is potential for improvement for both electric and battery-operated products, e.g. robot mowers/automatic mowers, but also for fuel efficient products. For example, the literature review showed the potential of LPG fueled engines for the reduction of GHGand PM_{10} emissions *(Unnasch and Waterland 2011)*.
Finally as taken from the Nordic Ecolabelling: *Biofuels may potentially also reduce CO2 emissions, however there is an ongoing debate about their relative environmental impacts regarding CO2 and other exhaust gas emissions as well as their production and processing impacts* (Nordic Ecolabelling 2013).

2. Lubricant oils and greases

Lubricant oils and greases can be sourced from renewable materials or mineral fossils.
The framework of the EU Ecolabel for lubricants, aimed at promoting products with lower environmental impacts, specifies criteria in order to exclude or limit

[163]Information is available at: https://ec.europa.eu/growth/sectors/automotive/environment-protection/non-road-mobile-machinery_en

hazardous substances and mixtures, aquatic toxicity requirements, biodegradability and bioaccumulation potential and renewable materials content.
From the literature review carried out, it has been found that rapeseed oil shows good results concerning emissions and biodegradability (Wightman et al. 1999; Mcmanus, Hammond, and Burrows 2004).
Biobased (from vegetable oils) lubricants are completely biodegradable in the environment and CO2 emissions from their degradation will be assimilated in subsequent crops, thus giving no net contribution to global warming. (Wightman et al. 1999),
Biobased oils are best suited for use in applications where partial, incidental or total loss of lubricants can occur. In particular, in open systems like many outdoor machineries (e.g. chainsaw), potentially harmful substances should be limited as far as possible.
Also, regenerated oils contribute to CO2 emissions reduction associated with extracting and processing crude oil, which is a key process for closing the loop of the lubricant lifecycle.
With modern re-refining technologies, CO2 emissions (kg of CO2 per ton of base oil) can be reduced by more than 50% as compared to the conventional production of base oil.

3. Noise of outdoor machinery

From the background document of Nordic Ecolabelling for gardening machineries, we can gather that it is likely that the best machines overall are currently close to the Noise Directive's limit values (Directive 2000/14/EC**)**, and this is above all true for professional products. In addition, these machines are used by professionals who are usually obligated by working environment legislation (Nordic Ecolabelling 2013) to wear hearing protectors.
Even though, the effort both from Nordic Ecolabelling and from the GPP studies to steer the market of low noises products may counteract further positive effects on the market of low-noise machinery.

End-of life

According to Nordic Ecolabeling criteria (Nordic Ecolabelling 2013) the consumer of machinery should hand the end-of-life product to a waste handling station in order to facilitate recycling or other correct waste handlings in accordance with national and local regulations.
The assemblage of machinery components should allow, as much as possible, the separation of materials for an easy recycle and management of end-of-life.
Particularly for plastic parts: "*Uniform marking of plastic components is a requirement in order to be able to separate parts at disassembly for further treatment and materials recycling. At present, a very large share of plastic material in end-of-life machines for parks and gardens is incinerated. Increased materials recycling would therefore be a positive development. In order to ensure alignment with other product groups within Nordic Ecolabelling, the weight limit for the marking of plastic parts has been lowered to 25 grams/part.*" (Nordic Ecolabelling 2013)
The amount of waste sent to landfills should be minimized. Some components, for instance batteries and compressor oils, must be handled as hazardous waste.

Finally, if gardening machinery is broken and cannot be repaired, it should be possible to return it to the manufacturer for proper disposal or reuse of its parts.

Operational management

Beyond the purchasing of environmentally friendly products, the way in which such products are managed also could result in environmental impacts, or on the contrary, ensure a better operational practice.
For this reason, the staff employed in the use of machinery should be properly trained to guarantee the best performance of the machine and avoid its negative impacts on the environment.
From the case study of good practice in Barcelona (EU Commission 2014)[164] some recommendations can be gathered:
"Engine should only be left running for the amount of time it is strictly necessary to carry out the related task".
"The engine must be turned off if the machinery is not in use for more than 3 minutes."
"All equipment is subject to a periodic inspection to ensure they meet the Technical Inspection of standard in terms of gases and fumes".
"When there is strong wind, operations involving the use of materials that can generate dust must be avoided" (EU Commission 2014)

12.6 Cost considerations and market availability

Little information has been found on life cycle cost of equipment (LCC) with respect to machinery.
In general, as seen in the literature review presented in the *Preliminary Report* (Espinosa, Kofoworola, et al. 2017) and as considered in the case of vehicles to estimate the total LCC, operating and disposal costs must be considered in addition to purchasing price. Moreover, some other costs have to be considered in the operating phase such as fuel or energy consumption, maintenance of the machinery, substitution of engine oil and spare parts.
Concerning the technology of engines from the specific study on garden machinery (Nordic Ecolabelling 2013) we found that four stroke engines are deemed to have better economic and environmental performance within the different kinds of fuel engines.
Generally, we found that there are differences in efficiency between the various engines available on the market and there is potential for improvement in both electric and battery-operated products, e.g. robot mowers/automatic mowers, and fuel-efficient products. For example, the literature review showed the potential of LPG fueled engines for the reduction of GHG and PM_{10} emissions and reduction of costs *(Unnasch and Waterland 2011)*.

Market availability of environmental friendly products
Concerning cleaning machinery, the manufacturers associated with the European Cleaning Machines Association EUnited Cleaning[165] place the following products on the market:

- Floor cleaning machines for indoor and outdoor cleaning for commercial use (e.g. sweepers, vacuum cleaners for industrial use, scrubber-dryers, single-disc machines).
- High pressure cleaning machines and systems for commercial use and car cleaning.

[164]Information available at: http://ec.europa.eu/environment/gpp/pdf/news_alert/Issue43_Case_Study90_Barcelona.pdf
[165] Information available at: http://www.eu-nited.net/cleaning/technical-matters/directives/index.html

EUnited Cleaning is a type of label for these products and provides a set of requirements, both for safety standards[166] and for technical recommendations.
Technical recommendations from EUnited Cleaning are semi-standards for issues that are not adequately covered by European or international standards.
The documents[167] apply to cleaning machines within the scope of international standards as stipulated by IEC SC 61J 'Electrical motor-operated cleaning appliances for commercial use' and by CEN TC 197/SC 1/WG 1 'High-pressure cleaners', for use in residential, commercial, light industrial and industrial environments within the single European market.
In particular the EUnited Cleaning set requirement concerns guideline for the application of the Machinery Directive 2006/42/EC for commercial cleaning machines[168].

Concerning garden machinery, the European Garden Machinery Federation[169] (EMF) is an important stakeholder. It has 16 ordinary members, including Honda and Briggs & Stratton.
According to EMF statistics, their customers sell more than six million lawnmowers, four and a half million chainsaws, three million brush cutters and as many hedge trimmers annually on the European market.
Following the USA market, the second largest is Europe with 35 per cent of the world market, with the UK, Germany, France and Italy representing the largest national markets. (Nordic Ecolabelling 2013)
In the field of garden machinery Nordic Ecolabelling ensures the sustainability of products carrying this specific label, thanks to a set of criteria that take into consideration the full product life cycle (Nordic Ecolabelling 2013).
Moreover, the EU ecolabel also covers lubricant products for chainsaw machines or tractors, ensuring the sustainability of these products.[170]

[166] Information available at: http://www.eu-nited.net/cleaning/technical-matters/standards/index.html
[167] Information available at: http://www.eu-nited.net/cleaning/technical-matters/technical-recommendation/index.html
[168] Information available at: http://www.eu-nited.net/cleaning/upload/Technical_Recommendation/EUC-TR-34002_201003_MD_Guide.pdf
[169] Information available at: https://www.egmf.org/
[170] Information available at: http://ec.europa.eu/ecat/

Conclusion

The literature review on environmental impacts of products/services related with Public Space Maintenance has given a good framework for the current state of related publications and practices.

Regarding Cleaning Services, many of the LCA studies exist about cleaning products and services for indoor activities (Kapur et al. 2012; ÉCOSÍ 2011; Neto et al. 2014), while there is a lack of information on the topic of products and services related with outdoor activities. However, some information have been gathered from the study of Nordic Ecolabelling for I&I cleaning products.(Nordic Ecolabelling 2016b).
Moreover, many studies and technical reports are also available on the topic de-icing products, highlighting the advantages and impacts of the different options, as well as best practices for winter maintenance services (Ritthoff 2011; Layman 2012; Vignisdottir, Booto, and Bohne 2016); also a specific ecolabel for de-icers is available (Nordic Ecolabelling 2016a).
Broad literary publications are available on the topic of street cleaning and dust suppression, highlighting the effectiveness of current practices and the related environmental impacts (F. Amato et al. 2010; Yee 2005; Idaea-CSIC 2016; CIWM 2008; Layman 2012; Redust 2012)
Also on this occasion, it has been noticed that some countries, like The Netherlands, have a wide coverage of Public Procurement for different groups of products/services (e.g. the group of *Public Space Cleaning Services* and *Winter Maintenance*[171]*).*

Regarding the gardening services for Public Space Maintenance, the literature of LCA studies is very broad with respect to the topics related with agricultural activities and products such as fertilizers, soil improvers and pest control. This literature provides a wide framework allowing the comparison of different options (Berthoud et al. 2012; Scam 2012; Lammel and Brentrup 2003; Hasler et al. 2015; EPAGMA 2012). Most of these products are also covered in specific eco label indications (EU Commission 2013; Quintero et al. 2013).
In the case of Gardening activities for public space maintenance the coverage of the literature by the GPP represent a background about environmental key impacts and hotspots (EU Commission 2011a). Many publications about Gardening services are also available from good practice reports and from other national GPPs (e.g. Netherland[172]). Moreover, from the literature review, many studies have been found concerning lawn management activities, due to the strong environmental impacts associated with these practices (Wesström 2015; Caceres, Bigelow, and Richmond 2010).

Regarding vehicles, much literature about LCA is available in the field of transport and other related issues, such as different powertrains technologies, fuel, lubricants and tyres (Boureima, Sergeant, and Wynen 2007; Samaras and Meisterling 2008; Hawkins et al. 2013; EVONIK 2016). However, this literature mostly concerns the investigation of common passenger vehicles or light duty vehicles. Concerning the Puplic Purchase of these kind of vehicles, the current literature on GPP for Transport (EU Commission 2011c) and its review (Quintero et al. 2016) represent a good background, even though the GPP doesn't cover the specific group of vehicles for public maintenance except for the case of the Waste Collection Vehicle, which are not included in the scope of our study.

[171] Available at: https://www.pianoo.nl/public-procurement-in-the-netherlands/sustainable-public-procurement-spp/environmental-criteria-for-sustainable-public
[172] Ibid.

With aim of covering this lack of information, the LCA literature review of our study has been mainly focused on the topic of truck and tractor, which are commonly used by maintenance services.

It was not possible to find any LCA study specific for the topic of vehicles dedicated exclusively to public maintenance, such as sweepers or winter maintenance vehicles.
Although, was possible to cover this lack of information thanks to various studies regarding good practices in topics like winter maintenance, dust control and street cleaning (Idaea-CSIC 2016; Redust 2012; Roosa 2011; Strappa, Amato, and Camporeale 2015).

Regarding machinery, a wide variety of publications is available on lawnmowers, small engines and chain saws. These are mainly related to emissions generated during the use-phase (Lan and Liu 2010; Sivaraman and Lindner 2004; Wightman et al. 1999; Kristinsdóttir, Fernando, and Corredor 2011). Broad information is also provided from the specific Regulations on the topic of noise[173] and emissions[174].
Furthermore, the Nord Ecolabelling with its study (Nordic Ecolabelling 2013) provides many information about environmental hotspots and improving areas for machinery.
The GPP literature doesn't cover this topic with a specific group/service, however some information is available in other groups. For example in the group of Gardening services (EU Commission 2011a) a good amount of information is provided about the key impacts of machinery noise, emissions, etc.

In conclusion, for the products/services groups of Public Space Maintenance, a harmonized framework containing information about the different impacts of all the products and services sub-groups has been provided with the *Part III* of this *Preliminary R*eport by analyzing the existing literature about the topic.

[173]Information available at: http://ec.europa.eu/growth/sectors/mechanical-engineering/noise-emissions_en

[174]REGULATION (EU) 2016/1628 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 September 2016 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery, amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1628&from=EN

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GENERAL CONCLUSION

In the first part of the study, with the overview of existing legislation, standards and criteria, and together with the analysis of statistical and technical categories, it enabled us to create a first draft for the proposition of categories of the services and products involved in the maintenance of public space.
After a review, in accordance with a survey of relevant stakeholders, four groups were described for the scope of our study: cleaning services and products, gardening services and products, vehicles used for Public Space Maintenance, and machinery used for Public Space Maintenance. For these groups, a set of sub categories has been determined according to the CPV proposed from the GPP directives.
The market analysis enables us to understand the size of the market for these products and the potential of the GPP to enhance better practices in the field of public procurements.
In the last section, thanks to the technical and environmental analysis, we have reached a broad understanding of a wide range of services and products.
The analysis developed in a LCA perspective enable us to describe the overall impacts of the activities included in the scope of the public space maintenance. Moreover, identification of improvement potentials provides a useful background for the proposal of criteria, which is the main goal in these studies, aimed at the redaction of GPP for Public Space Maintenance.

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KJ-NA-29953-EN-N

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doi:10.2760/648744
ISBN 978-92-76-12784-0