SEVENTH FRAMEWORK PROGRAMME

THEME [7]

Theme Title: Transport (including Aeronautics)

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All partners of the project consortium via a return email have approved the final version of this SuperGreen Deliverable.

DISCLAIMER

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0 Executive Summary

This document is the third issue of Deliverable D3.1 of the Task 3.1 "Identify Green Technologies" of SuperGreen project. It presents the results achieved during the whole working session (M1-M36) of Task 3.1. The main objective of Task 3.1 is the identification of Green Technologies to be applied in the selected SuperGreen corridors to solve the bottlenecks and to make corridors greener.

On the basis of different sources (literature review; research projects (both national and at European level); personal know-how) technologies have been identified with reference to the following transport modes:

- waterborne transport (including inland waterways and maritime);
- railway transport;
- road transport;
- multimodal transport.

An extensive collection has been carried out and many innovative technologies have been identified in the following categories:

- engines and propulsion systems;
- fuels and energy sources;
- cargo handling and transfer technologies;
- cargo preparation technologies;
- heating and cooling technologies;
- innovative loading units and their treatment;
- vehicles;
- navigation technologies;
- best practices of technologies integration.

The complete list of technologies identified within Task 3.1 of the project (more than 200 technologies) is reported in Appendix II to this document.

The collected technologies have been further analyzed, as reported in Section 5, in order to identify the most promising in terms of greening potential, which will be applied in the Green Corridors identified in the scope of SuperGreen project. The complete results of the analysis and selection process are reported in Section 5 of this deliverable.

As this task represents the basis for further analysis performed in Task 3.2 and 3.3, the following activities have been performed within Task 3.1: a Technologies vs. Indicators matrix has been defined and filled in (Section 6 of this document) and an analysis on the influence of technologies on KPI (Section of this document).

1 Introduction

The purpose of this document is to describe the work done in SuperGreen Work Package 3 under Task 3.1 "Identify Green Technologies". This task is dedicated to the identification of Green Technologies suitable to a set of applications (i.e. selected Green Corridors as defined by the cargo owners, operators and other stakeholders involved in the project). Technologies have been grouped into different categories, as detailed in Section 4.1 of the document.

Green technologies have been surveyed and analysed on the basis of the experience of the project partners and on past and current research projects. Data and information have been gathered in terms of the main indicators that will be used in Task 3.3 for benchmarking purposes, such as energy consumption, green-house gases emissions, life-cycle costs, external costs, social and spatial planning aspects, etc.

The main activities of Task 3.1 can be summarised as follows:

1. definition of the template to collect information on technologies;
2. collection of the information on technologies;
3. analysis of technologies collected;
4. definition of the matrix "Technologies vs. Indicators";
5. population of the matrix "Technologies vs. Indicators";
6. evaluation of the influence of the technologies on KPI.

The template to collect information on technologies is organized around nine categories (engines and propulsion systems; fuels and energy sources; cargo handling and transfer technologies; cargo preparation technologies; heating and cooling technologies; innovative loading units and their treatment; vehicles; navigation technologies; best practices of technologies integration) with reference to different transport modes. All the modes of transport have been considered a part from air (waterborne transport; railway transport; road transport; multimodal transport).

The first round of data collection has been performed from month M3 to month M9. The result of this activity consists of 197 technologies identified in respect to waterborne transport (inland waterway and maritime), railway, road and multimodal transport. The second round of collections has been performed from month M15 to month M20. The result of this activity consists of 53 technologies identified in respect to the same categories and modes of transport as for the first round collection. The third round of collections has been performed from month M26 to month M31. The result of this activity consists of 13 technologies identified in respect to the same categories and modes of transport used for the first two rounds of data collection. Moreover, the last working session had the purpose of guaranteeing refinement on previous data collection. In particular a special effort has been spent to identify technologies concerning the categories Cargo Preparation and Heating and Cooling category that included only few technologies..

The identification of the technologies and the data collection of parameters have been performed through literature review, past and current research projects (both national and at European level) and personal know-how of partners. However, it is necessary to report that most of the identified technologies are still under design or development phase and for this reason specific data related to onsite applications are not available yet.

At month M9 the analysis of the technologies identified during the first collection phase has been started, in order to select the most relevant technologies for the scope and objectives of the project. The same activity has been then performed at month M21 and M32 with reference to the technologies identified respectively during the second and third collection phases. In fact, the technologies have been divided in six categories in base of their importance (from "Very Important" to "Not Relevant").

At the end of the project more than 200 technologies have been identified and about 30% have been considered as most promising and then used for further analysis in the scope of the project (Task 3.2 and Task 3.3).

The applicability of the selected technologies on the corridors identified in the scope of the project, as well as the evaluation of their green potential is assessed in Task 3.2 and Task 3.3.

Section 2 of this report describes the objectives of the Work Package 3 and of Task 3.1. In Section 3, the methodology applied for Task 3.1 is described. The Technologies Collection activity is described in Section 4 of this report and the Analysis of Technologies is reported in Section 5. In Section 6 it is reported the definition of the Technologies vs. Indicators matrix and the collection of the data. Section 7 is dedicated to the analysis of the influence of the applicability of the technologies on the selected KPI; finally Section 8 presents the conclusions achieved during the whole stage of Task 3.1.

2 Objectives

2.1 Work Package 3 - Sustainable Green Technologies & Innovations

The work package 3 aims at identifying, selecting and benchmarking Green Technologies, to be applied into specific Green Corridors while solving bottlenecks and improving sustainability. Technologies to be investigated include, among others, novel propulsion systems and engines, alternative fuels, cargo handling and transfer technologies, or any kind of novel concepts relevant for multimodal corridors. It is a matter of providing a sound coverage of the most promising technologies, techniques and procedures to be applied in Green Corridors both over the different transport legs and at transhipment points, and assessing which of them would be useful to reduce the sustainability footprint of the overall logistics chain.

Transport operators, logistics providers, terminal operators, shippers and policy makers would then benefit from a comprehensive analysis of the Green Technologies, with a comparison between them on different possible applications (selected Green Corridors), on the basis of a series of what – where – how use-case scenarios.

The analysis made, including the comparison with respect to the current baseline and any other information collected in the current work package will be made available by means of a web-based data knowledge base, which will be accessible to the users and the stakeholders by means of a user-friendly wizard.

2.2 Task 3.1 - Identify Green Technologies

Task 3.1 is dedicated to the identification of Green Technologies suitable to a set of applications (i.e. selected Green Corridors as defined by the cargo owners, operators and other stakeholders involved in the project). Technologies have been grouped into different categories, which are further described in the following sections of this document.

Green technologies have been surveyed and analysed on the basis of the experience of the project partners and on past and current research projects. Data and information have been gathered in terms of the main indicators that will be used in Task 3.3 for Benchmarking purposes, such as energy consumption, green-house gases emissions, life-cycle costs, external costs, social and spatial planning aspects, etc.

3 Methodology for Task 3.1

In order to achieve the objective of identification of the Green Technologies the following main activities have been planned:

1. definition of the template to collect information on technologies: the common template for the collection of potentially interesting innovative technologies has been prepared taking into account different groups of technologies;
2. collection of the information on technologies: the collection of the information/data on the different technologies has been done with reference to the transport modes;
3. analysis of technologies: starting from the list of technologies previously collected, a first analysis has been conducted on their characteristics in order to identify those more promising according to SuperGreen scope and objectives;
4. definition of the matrix "Technologies vs. Indicators": the spreadsheet will contain different sheets dedicated to each category of technologies considered, and will be based on selected Key Performance Indicators;
5. population of the matrix "Technologies vs. Indicators".

The mentioned activities are performed during the whole project lifetime in 3 different working sessions, accordingly with the following schedule:

- 1° session of work: M1-M12
- 2° session of work: M13-M24
- 3° session of work: M25-M36

A new release of the present document is issued at the end of each session. This issue covers the whole lifetime of the project.

4 Technologies Collection

The technologies collection phases are performed accordingly with the following steps:

1. Definition of technology categories;
2. Definition of relevant indicators characterizing each category;
3. Creation of a dedicated template on the basis of the previous steps;
4. Circulation of the template to concerned partners. Three sessions of collection are performed during the project lifetime.

4.1 Definition of Categories

In order to facilitate the process dedicated to the identification of innovative technologies to be analysed in the scope of SuperGreen, it has been decided to consider the following categories:

- **Engines and propulsion systems**: innovative technologies concerning engines and propulsion systems in general, which can be applied to any kind of transport modes on Green Corridors;
- **Fuels and energy sources**: technologies related to energy production, including for instance solar panels, wind turbines and other renewable energy sources; furthermore innovative fuels will also be considered;
- **Cargo handling and transfer technologies**: technologies related to loading or unloading or cargo, transfer of loading units between different transport modes, internal handling of transport units;
- **Cargo preparation technologies**: this category is relevant to all the technologies used to prepare the cargo before it is transported, such as preservatives for perishable goods, packaging, sealing, etc;
- **Heating and cooling technologies**: this category includes innovative heating or cooling technologies embedded into transport vehicles, implemented into warehouses or used during handling and transfer operations;
- **Innovative loading units and their treatment (cleaning, etc)**: this category includes new loading units able to reduce and optimize time requested for loading/unloading and transfer operations, as well as energy consumption and pollution emissions in case they embed heating/cooling devices. It also considers any ancillary technology needed for pre or post transport treatment of the loading unit;
- **Vehicles**: new vehicle concepts with the purpose of improving transport time and reducing pollution emissions shall be reported in this category;
- **Navigation technologies**: this category is referred to technologies facilitating vehicles navigation during transport, including tracking/tracing, and automatic vehicles identification (AVI);

- **Best practices of technologies integration**: this category is dedicated to the identification of best practices derived from real use cases, related to the integration of innovative technologies on transport systems, with particular reference to their impact on energy and carbon footprint reduction, and their potential for exportability on different frameworks.

4.2 Definition of Indicators

The Green Technologies collected during the first phase of Task 3.1 shall be characterised by means of well defined indicators; this will allow the analysis of their relevant characteristics, representing the baseline for the process which will lead to the identification of the most promising technologies to be further explored in the scope of SuperGreen project.

The indicators which have been finally included in the technology template circulated to partners can be divided into two classes:

1. Information common to all the considered categories;
2. Specific indicators for each single category.

The content of both classes is explained in the following paragraphs.

4.2.1 Common technologies information

The identified set of common information describing each technology includes:

- Technology name;
- Short description;
- Transport mode;
- Provider/Manufacturer;
- Technology Readiness Level;
- Time to market;
- Needed supporting measures;
- Polluting emissions;
- Life cycle cost.

A brief description of each mentioned indicator is reported in the following paragraphs.

4.2.1.1 Technology name

It represents registered name of the technology, or the name with the technology is commonly known.

4.2.1.2 Short Description

The purpose of the short description is to provide in a few lines information concerning the most relevant characteristics, including its field of application and the foreseen potential for improvement.

4.2.1.3 Transport Mode

It informs whether the considered technology supports a specific transport mode or can be applied irrespectively.

4.2.1.3 Provider/Manufacturer

It indicates the company(ies) owing the patent for the considered technology; in case it is referred to a technology not completely developed and released to the market, it indicates the company(ies) or organization(s) which are involved in the research and/or technological development activities.

4.2.1.4 Technology Readiness Level

Technology Readiness Level (TRL) is a measure used by some United States government agencies and many of the world's major companies (and agencies) to assess the maturity of evolving technologies (materials, components, devices, etc.) prior to their incorporation into a system or subsystem.

Generally speaking, when a new technology is first invented or conceptualised, it is not suitable for immediate application. Instead, new technologies are usually subjected to experimentation, refinement, and increasingly realistic testing. Once the technology is sufficiently proven, it can be incorporated into a system/subsystem.

The readiness level is identified through a range of values from 1 to 9, as detailed in the following table:

Table 1: Technology readiness level

Technology Readiness Levels (Source: Defence Acquisition Guidebook)	
Technology Readiness Level	**Description**
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Example might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.

Technology Readiness Levels (Source: Defence Acquisition Guidebook)	
Technology Readiness Level	**Description**
3. Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is "low fidelity" compared to the eventual system. Examples include integration of 'ad hoc' hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include 'high fidelity' laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and 'flight qualified' through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended system to determine if it meets design specifications.
9. Actual system 'flight proven' through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.

4.2.1.5 Time to market

It represents the time (generally expressed in years) necessary for completing the development of the technology and make it available on the market. Along with the Technology Readiness Level, this parameter can be taken into account in order to estimate the real impact of the considered technology (e.g. a technology with a high potential but in an early research stage and foreseen to be implemented in more than 5 years might be less relevant than a similar technology with less potential but almost ready for the market).

4.2.1.6 Needed supporting measures

The implementation of a given technology might request the realization of additional measures (e.g. modification of existing infrastructures, introduction of new working procedures, implementation of other technologies, etc). This aspect might influence the effective applicability of a considered technology into a Green Corridor (or part of it); furthermore, it should be taken into account while calculating investment costs or the whole Life Cycle Cost.

4.2.1.7 Polluting emissions

The following categories of polluting emissions have been taken into account:

- Carbon footprint (CO_2 emissions);
- Sulphur emissions (SO_2);
- Nitrogen emissions (NO_x);
- Dust and particles (PM_{10}).

This indicator has been applied to all categories with the exception of "Cargo Preparation", "Navigation Technologies", and "Best Practices", as the related technologies are not concerned by emissions of pollutants.

Polluting emissions can be assessed using different units of measure, depending on the category considered, as detailed in Section 4.2.2 below.

4.2.1.8 Life Cycle Cost

The life cycle cost represents the total sum of all costs incurred for the usage of a technology, from its purchase to its disposal, including maintenance costs, operational costs, renewal/revamping costs, etc….

A precise calculation of Life Cycle Cost would require taking into account interest rates and taxation in the country where the technology will be applied. As it would be difficult to define a precise estimation of the evolution of those parameters in the near future, LCC will be calculated considering non discounted costs.

This indicator has been applied to all categories with the exception of "Fuels and sources of energy" and "Best Practices", as the life cycle cost concept cannot be applied to the related technologies.

4.2.2 Specific technologies information

The following sections describe the specific indicators identified for each of the considered groups of technologies.

4.2.2.1 Engines and propulsion systems

Energy Source

This indicator specifies if the considered propulsion system is based on the usage of electrical power or fuel, and the typology of fuel used.

Nominal power

Maximum power generated by the propulsion system during normal working conditions, expressed in kilowatts (kW). This nominal value is normally made available by the technology manufacturer, accordingly with specific industrial standards.

Efficiency

For electrical propulsion systems, the efficiency is represented by the ratio between the nominal power generated and the power consumed as input. Concerning thermal propulsion systems, the parameter is expressed by the ratio between the amount of energy generated, and the total energy contained in the fuel consumed.

The efficiency parameter is expressed as percentage.

Polluting emissions

Polluting emissions of engines and propulsion systems are calculated as emissions after the exhaust pipe, i.e. including eventual catalytic converters and other pollution abatement processes.

The mentioned indicators are referred to the energy produced by the propulsion system, and have therefore to be expressed in grams per kilowatt-hours (g/kWh).

Mean Time Between Failures (MTBF)

The MTBF represents the predicted elapsed time between two consecutive failures in operation of the propulsion system, providing an indication of the reliability of the system. It is expressed in hours, and it is normally made available by the manufacturer, accordingly with specific industrial standards.

Life cycle cost

In order to take into account the different size (power) of the considered propulsion system, this indicator is calculated by dividing the total cost calculated by the nominal power expressed by the system; the indicator is therefore expressed in euros per kW (€/kW).

4.2.2.2 Fuels and sources of energy

Energy source produced

It indicates the category of energy made available by the considered source (e.g. electrical, chemical…).

Renewable

It indicates whether the considered energy source is renewable or not.

Life cycle cost

In order to take into account the different size (power) generated by the considered system, this indicator is calculated by dividing the total cost calculated by the nominal power generated; the indicator is therefore expressed in euros per kW (€/kW).

Polluting emissions

Emissions of primary energy sources, if not directly known, can be derived from tables made publicly available by the European Commission and by Member States, which indicate the average emissions by country or at EU level.

The mentioned indicators are referred to the energy produced by the system, and have therefore to be expressed in grams per kilowatt-hours (g/kWh).

4.2.2.3 Cargo handling and transfer technologies

Average loading cycle time

This parameter represents the maximum number of moves which can be performed by the handling or transfer system in one hour, and is therefore expressed in moves/hour.

Cost per move

This parameter represents the total cost related to a single handling/transfer procedure, divided by the number of necessary moves, and is therefore expressed in €/move.

Mean Time Between Failures (MTBF)

The MTBF represents the predicted elapsed time between two consecutive failures in operation of the system, providing an indication of the reliability of the system. It is expressed in hours, and it is normally made available by the manufacturer, accordingly with specific industrial standards.

Power supply

It indicates the energy source (e.g. electrical, fuel…) used by the system.

Energy consumption

This parameter represents the amount of energy consumed per each tonne moved by the system. It is measured in kW/ton.

Polluting emissions

In case the considered technology makes use of electrical power, the emissions are calculated referring to the primary energy source. Average values of polluting emissions produced by primary sources can be obtained from tables made publicly by the European Commission and Member States.

The mentioned indicators are referred to the operations performed by the system, and have therefore to be expressed in grams per tonne moved (g/ton).

Life Cycle Cost

In order to take into account the different operational capacities of the considered systems, this indicator is calculated by dividing the total cost calculated by the total volume moved by the system; the indicator is therefore expressed in euros per tonne (€/ton).

4.2.2.4 Cargo Preparation technologies

Type of packaging allowed

It indicates all the typologies of packaging (e.g. pallets, boxes….) which can be handled by the considered technology.

Possibility to recycle

This parameter indicates whether the considered packaging type can be recycled or reused for several transport. In case the related technology is able to handle different packaging types, this indication will be repeated for each single type.

Special procedures applied

This indicator reports particular handling procedures allowed by the considered technology, e.g. for treating goods implying risk of explosion, of dangerous gases emissions, release of polluting substances, etc….

Life cycle cost

Life cycle cost for Cargo Preparation technologies is expressed in Euros/ton.

4.2.2.5 Heating and cooling technologies

Size

This parameter expresses the maximum energy exchange capacity of the system, expressed in kilowatt (kW). It is a nominal value made available by the technology manufacturer accordingly with specific industrial standards.

Efficiency

Efficiency is expressed by the ratio between the heating or cooling power produced and the power absorbed, and it is represented as percentage.

Power Supply

It indicates the energy source (e.g. electrical, fuel…) used by the system.

Polluting emissions

In case the considered technology makes use of electrical power, the emissions shall be calculated referring to the primary energy source. Average values of polluting emissions produced by primary sources can be obtained from tables made public by the European Commission and Member States.

The mentioned indicators are referred to the heating or cooling capacity of the considered technology, and are therefore expressed in grams per kilowatt (g/kW).

Life cycle cost

Life cycle cost for Heating and Cooling technologies is expressed in Euros.

4.2.2.6 Innovative loading units and their treatment

Transport modes served

List of all transport modes in which the considered loading unit can be used.

Dimensions

Indication of the spatial dimensions (expressed in millimetres) of the loading unit, as indicated by the technology manufacturer. Such information is reported in the following format: Width x Height x Length

Weight

Maximum weight which can be carried by the unit, expressed in tonnes (ton), as indicated by the technology manufacturer.

Space productivity

Amount of back-up land occupied per transported tonne, expressed in square meters (m^2).

Heating/cooling unit

It indicates whether the considered loading unit embeds a heating or cooling system.

Power supply

Source of power supply used for heating or cooling system (if present); the indication "Y" or "N" has to be provided.

Energy consumption

Energy consumed by the heating or cooling system (if present), by tonne of goods transported; it is expressed in kW/ton.

Polluting emissions

In case the considered technology makes use of electrical power, the emissions are calculated referring to the primary energy source. Average values of polluting emissions produced by primary sources can be obtained from tables made public by the European Commission and Member States.

The mentioned indicators are referred to the total amount of goods transported by the loading unit, and are therefore expressed in grams per tonne moved (g/ton).

Life cycle cost

Life cycle cost for loading units is expressed in Euros.

4.2.2.7 Vehicles

Mass

This indicator represents the maximum allowable mass of the fully loaded vehicle, expressed in tonnes (ton), as indicated by the technology manufacturer.

Capacity

This indicator represents the maximum loading capacity of the vehicle, expressed in cubic meters (m^3), as indicated by the technology manufacturer.

Propulsion

Typology of engine used by the considered vehicle (e.g. electrical, diesel….).

Loading units transported

List of all loading units which can be transported by the considered vehicle.

Energy consumption

Energy consumed by the considered vehicle per tonne of transported goods, expressed in kilowatt-hour per tonne (kWh/t).

Polluting emissions

Polluting emissions of vehicle systems are calculated as emissions after the exhaust pipe, i.e. including eventual catalytic converters and other pollution abatement processes.

The mentioned indicators are referred to the path travelled by the vehicle, and are therefore expressed in grams per kilometre (g/km).

Life cycle cost

In order to take into account the different capacities of the considered vehicles, this indicator shall be calculated by dividing the total cost calculated by the total weight of goods transported; the indicator is therefore expressed in euros per tonne (€/ton).

4.2.2.8 Navigation technologies

Coverage

This parameter indicates the maximum distance between the transmitting source and the receiver which allows a clear and complete reception of the signal. It is expressed in kilometres (km).

Tracking/tracing allowed

It indicates if the considered technology allows the tracking and tracing of a vehicle.

Automatic identification

It indicates if the considered technology allows the automatic vehicle identification (AVI).

TLC media

It indicates the communication media used by the technology to trace the position and communicating information from and to the vehicle.

Life cycle cost

Life cycle cost for Navigation technologies is expressed in Euros.

4.2.2.9 Best practices

Geographical coverage

It provides information concerning the area covered by the considered case, defining if it is relevant at local/regional level, national level or European level.

Transport modes involved

List of the transport modes involved by the considered use case.

Technologies involved

List of innovative technologies involved by the considered use case, with reference to the technologies included in each of the previously defined category.

Energy consumption reduction

It is necessary to provide at least an estimation of the energy consumption reduction allowed by the considered practice, taking into account all typologies of energy sources involved. It is expressed as percentage.

Carbon footprint reduction

This indicator represents an estimation of the carbon footprint (CO_2 emissions) reduction allowed by the considered practice, taking into account all sources of emissions involved. It is expressed as percentage.

Potential for transferability

This parameter provides an estimation of the possibility to replicate the procedures applied in the considered best practice into other real use cases, in order to obtain similar advantages in terms of energy consumption and carbon footprint reduction. It is assessed by means of the following set of values:

- Not possible: none of the procedures applied in the considered use case can be replicated in a different situation.
- Low: it indicates that it is possible to replicate only a minor part of the procedures applied in the use case, or that the replicable procedures are the less significant (i.e. having a minor impact on energy and/or carbon footprint reduction);
- Medium: it indicates that most of the applied procedures can be replicated in a different case, but at least one of the most relevant (i.e. having a major impact on energy and/or carbon footprint reduction) cannot be transferred;
- High: it indicates that all the considered procedures, or at least all of the most relevant ones, can be replicated in an alternative case;

The mentioned values can be selected by means of a drop-down list included in the template.

4.3 Definition of the Template

The template has been realized on the basis of a Microsoft© Excel workbook, which includes a worksheet for each of the nine technology categories mentioned in Section 4.1. Each sheet has been formatted in order to contain the relevant indicators mentioned in Section 4.2.

Technologies reported into the template have been given an identification code, which is formed by two letters providing an indication of the category to which the technology belongs to, and a two-digit progressive number. The complete list of identification codes associated to each category is reported below:

- ENgines and propulsion systems: EN;
- FUels and sources of energy: FU;
- cargo Handling and Transfer: HT;
- Cargo Preparation: CP;
- Heating and Cooling: HC;
- innovative Loading Units and their treatment: LU;
- VEhicles: VE;
- Navigation Technologies: NA;
- Best Practices: BP.

Where applicable, the Template provides *drop-down* lists, to support users in selecting the appropriate values referred to specific indicators.

4.3.1 User manual

In order to support project partners in reporting promising Green Technologies, a user manual describing the usage of the template has been prepared (see Appendix I).

The purpose of the manual is to provide indications for the usage of the template, in order to ensure an appropriate balance between the information requested and the coverage of potentially interesting technologies. It has to be taken into account that part of the mentioned indicators needs to be filled in by means of hard quantitative data, which precise value might not be known to the user; therefore, it is necessary to ensure that also in this case users are able to report promising technologies, with an adequate level of completion of related indicators. With this purpose, the following recommendations are reported in the manual:

- where possible, best estimation of the quantitative value has to be provided, accordingly with user's experience. In this case, it is requested to include a comment in the Excel cell containing the value, to indicate that the provided value is estimated;
- in case the first option is not applicable, at least a qualitative estimation of the indicator shall be provided, based on a scale from 1 to 5. The meaning of the values in such scale will depend on the characteristics of the considered indicator; as general rule, it is suggested to make reference to a well-known technology already present on the market, indicating with 1 that the performance of the innovative technology, related to the considered indicator, is much worse than the reference case. Also in this case a comment to the relevant Excel cell shall be added, to provide a brief description of the numeric value reported.

In case none of the proposed approaches can be applied to a specific indicator, it is suggested to include anyway the relevant technology in the template, leaving the corresponding cell blank. Users are requested to report all promising technologies they consider relevant, although it is not possible to find or estimate some of the requested indicators.

4.4 Sources

The green technologies have been collected and assessed by partners on the basis of different sources:

- Literature review;
- Research projects (both national and at European level);
- Personal know-how.

4.4.1 Literature review

Documental sources have been used both for identifying potential technologies indicated in the collections, and to complete the information concerning indicators for technologies derived from other sources.

The complete list of all the documental sources used is reported in Table 2 below; the information collected from the mentioned documents has supported mainly the collection of technologies related to road and inland waterway transport modes.

Table 2: List of documental sources

Author	Document Title
Adamkiewicz, A., Kolwzan, K	"Marine Power Plant Pollutant Emissions"
Blomberg, J	Power generation concepts for generic FPSO vessels
Concawe/Eucar/JRC	Well-to-Wheels analysis of future automotive fuels and power trains in the European context Tank-to-Wheels report version 3, October 2008
Corbett, J., Koehler, H	Updated emissions from ocean shipping
European Commission	Directive 2009/28/EC on the promotion of the use of energy from renewable resources
European Commission	Environmental Impact of Inland Navigation – Final Report
Econ	Potensialstudie for flytende biobrensel (Study of the potential for liquid bio fuels)
Häkkinen, P	Laivan koneistot (Ship Machinery Systems)
Hyytiäinen, M	Matkustajaaluksen propulsiokoneiston suunnittelu (Design of passenger ship's propulsion machinery)
Kettunen, A	Voimalaitoksen ajotavan vaikutus DATaluksen elinkaaritalouteen ja turvallisuuteen avovedessä (The effect of power plant usage on life cycle economy and safety of DAT vessel in open sea)
Lehtinen, J	Risk Analysis for the Operation of Dual Fuel Electric Machinery in LNG Carrier
Russell Hensley, Stefan Knupfer, and Dickon Pinner	Electrifying cars: How three industries will evolve
Man B&W	Exhaust Gas Emission Control Today and Tomorrow Application on MAN B&W Two stroke Marine Diesel Engines
U.S. Energy Information Administration (EIA)	The Impact of Increased Use of Hydrogen on Petroleum Consumption and Carbon Dioxide Emissions
Eurelectric	Eurelectric environment and sustainable development report 2007-2008

Author	Document Title
Helland, Å.	Well-to-wheel CO_2 analysis of electric and ICE vehicles: are global CO_2 emission reductions possible?, Int. J. Global Warming
IMO	Guidance on the application of AIS binary messages
IMO	Guidance on the use of AIS binary messages
International Energy Agency (IEA)	Energy Technology Essentials 5. Hydrogen production and distribution
International Energy Agency (IEA)	Advanced Motor Fuels (IEA-AMF)
IFEU Heidelberg Öko-Institut IVE / RMCON	EcoTransIT World. Ecological Transport Information Tool for Worldwide Transports. Methodology and Data. 2nd Draft Report
Kytö, M. et.al	Effect of heavy fuel oil quality on particulate emissions of a medium speed diesel engine
Kytö, M., Erkkilä, K., Nylund	Heavy-duty vehicles: Safety, environmental impacts, and new technology "RASTU"
Murtonen, T. Nylund	Fuel effects on emissions from non-road engines
P.A. Ioannou, E. B. Kosmatopoulos, H. Jula, A. Collinge, C.-I. Liu, A. Asef-Vaziri	Handling Technologies
Pauli, G.	The greening of inland navigation – The case of Rhine navigation
PLANCO Consulting GmbH/BFG	Economical and Ecological Comparison of Transport Modes: Road, Railways, Inland Waterways
Porthin, M., Zetterberg, R. and Sonninen, S.	AIS Binary Messages – Developments in the Baltic and progress in IMO
Simola, N.	Risteilyaluksen propulsiokoneiston valinta (Propulsion machinery evaluation for cruise ship)
Sipilä, T	Single Screw Low Speed Machinery Alternatives for Modern Ice Class Aframax Tankers
Tikkanen, O	LNG:n käyttö polttoaineena matkustajaaluksissa (Use of LNG as a fuel in passenger vessels)
Various Authors	Technical support for European action to reducing Greenhouse Gas Emissions from international maritime transport

Author	Document Title
Wayne, W.S., Hodgson, M.	The Options and Evaluation of Propulsion Systems for the Next Generation of LNG Carriers
Winners, H., Fridell, E.	Particle emissions from ships: dependence on fuel type
Nesccaf, ICCT, Southwest Research Institute, TIAX, LLC	Reducing heavy -duty long haul combination truck fuel consumption and CO_2 emissions. Final Report
Monica Ringvik	IP Green Heavy Duty Engine (GREEN)
Woxenius, J. Avhandling, Inst. för transportteknik, Chalmers Tekniska Högskola, Göteborg	Development of small-scale intermodal freight transportation in a systems context,1988.

4.4.2 Research Projects

The activities performed and the results achieved in the scope of the following projects, co-founded by the European Commission within the 6th and 7th Framework Programme, have been analysed:

- Railenergy - Innovative Integrated Energy Efficiency Solutions for Railway Rolling Stock, Rail Infrastructure and Train Operation;
- GHG TransporD – Reducing greenhouse gases emissions in transport;
- Cleanest Ship;
- CREATING;
- PLATINA – Platform for the implementation of NAIADES;
- PROMIT – Promoting Innovative Intermodal Freight Transport.
- METHAPU
- PLUG
- HERCULES
- MC-WAP
- FASTRCARGO
- INNOTRACK
- CLEANENGINE
- GREEN
- FELICITAS
- TRIMOTRANS

4.4.2.1 Railenergy

The overall objective of Railenergy is to cut the energy consumption within an optimised railway system thus contributing to a reduction in the life cycle costs of railway operation and of CO_2 emissions per seat/kilometre or tonne/kilometre. The project target is to achieve a 6% reduction in the specific energy consumption of the rail system by 2020, assuming that traffic volumes double in comparison with current figures.

To reach its goal, the project analyzed energy saving potential of a selected number of technologies, by considering the following domains:

- Energy needs and key performance indicators;
- Energy efficient management;
- Trackside;
- On-board components;
- On-board traction;
- On-board electrical equipment topologies.

The publicly available results of Railenergy project allowed to identify greening technologies related to the railway transport mode, with particular reference to vehicles category.

4.4.2.2 GHG TransPoRD

The project aims at developing an integrated European strategy that links R&D efforts with other policies and measures to achieve substantial GHG emission reductions in transport that are in line with the overall targets of the EU. As part of this strategy, the project will propose GHG reduction targets for transport as a whole as well as for each transport mode for 2020 and 2050.

The project will back cast from existing GHG emission reduction targets set at the level of the overall economy to the contribution required from the transport sector. As a starting point, GHG-TransPoRD will describe the European innovation system of the transport sector considering the global context as well. At the same time it will analyse the GHG emission mitigation potentials offered by a broad portfolio of transport technologies and measures. The desk research will be complemented by a model-based comparison of ambitious technology pathways with present policies and measures. This will also reveal areas with a largely under-exploited mitigation potential. GHG-TransPoRD will then further assess the R&D and other measures that can mobilise additional reduction potentials so as to achieve GHG emission reductions in line with the overall EU commitments until 2050.

The results of GHG TransPoRD project allowed to identify technologies related to maritime, railway and road transport modes, covering the categories fuels and sources of energy, engines and propulsion systems, vehicles, loading units and navigation technologies.

4.4.2.3 CREATING and Cleanest Ship

CREATING was a research project within the 6th Framework Programme of the European Commission, comprising 23 partners from 9 European countries. Its objective was to stimulate inland waterborne transport in an economical way and improve its competitive position versus road transport. An important part of maritime cargo is transported to the hinterland via inland waterways. Continental cargo, however, is still mainly transported by road. The ever increasing transport flows, road congestion and air pollution require the exploration of other transport solutions.

Cleanest Ship represents a demonstration project for the results achieved in the scope of CREATING. The project is carried out on the motor tank vessel “Victoria”, owned by BP and managed by Verenigde Tankrederij (VT). The vessel, now on long term charter to BP Marine Lubricants, is operating in the Port of Rotterdam and Antwerp areas. Lasting one year till the end of 2008, the demonstration was launched in November 2007. Fuel consumption, energy output of the main engine in kWh, distance sailed in km and NO_X emissions are directly measured; CO_2 and SO_X emissions are calculated from fuel consumption and energy output in kWh, whereas particulate matter emissions are evaluated using the emission reduction potential estimated on the test stand. The latter is done because accurate measurement of particulate matter emissions at service conditions is difficult.

The information gathered from those two projects have been used for identifying technologies related to Inland Waterway transport mode, with particular reference to the calculation of polluting emissions.

4.4.2.4 PLATINA

The NAIADES action plan is an initiative of the European Commission to enhance the use of inland navigation as part of intermodal freight solutions, in order to create a sustainable, competitive and environmentally friendly European wide transport network.

This objective was embraced by the inland navigation sector, which, together with the Commission have created PLATINA, an FP7 project consisting of 22 partners from nine different countries, in order to accelerate the achievement of the NAIADES aims. This multi-disciplinary knowledge network will allow PLATINA to create the momentum necessary to achieve the NAIADES objectives.

One of the most relevant objectives of the project is represented by the development of an Innovation Database, based on the “Wiki” approach, with the objective of collecting and making publicly available information on innovating technologies related to Inland Waterway transport mode. Though being still in a preliminary development phase, the PLATINA database represented a very useful source of information, in particular for completing indicators information concerning technologies collected from other sources.

4.4.2.5 PROMIT

PROMIT (www.promit-project.net) is a European coordination action (CA) for intermodal freight transport initiating, facilitating and supporting the coordination and cooperation of national and European initiatives, projects, promotion centres, technology providers, research institutes and user groups related to this most complex transport form. The strategic PROMIT objective is to contribute to a faster improvement and implementation of intermodal transport technologies and procedures and to help promoting intermodal logistics and mode shift by creating awareness on innovations, best practices and intermodal transport opportunities for potential users as well as for politicians and for the research community. PROMIT allowed to raise synergies in the European intermodal community and contribute to policy initiatives on national and European level supporting the shift of transports from road to Intermodal transport modes.

The final outcomes of PROMIT project allowed to identify technologies related to innovative units, heating and cooling technologies and cargo handling and transfer categories.

4.4.2.6 METHAPU

The METHAPU Project(www.methapu.eu) is supported by funding under the 6th Research Framework Programme of the European Union. The project aims at facilitating the introduction of international regulations concerning the use of methanol as a fuel onboard ships. It induces innovation activities on fuel cells, methanol fuel bunkering, distribution and storage technology.

The strategic objectives of the METHAPU project are as follows:

- Assess the maturity of methanol using technology on board a commercial vessel;
- Validate marine compatible methanol running solid oxide fuel cell technology;
- Innovate necessary technical justifications for the use of methanol on board cargo vessels involved in international trade in order to support the introduction of necessary regulations to allowing the use of methanol as a marine fuel;
- Assess short-term and long-term environmental impacts of the application;
- Enable future research activities on larger marine compatible solid oxide fuel cell (SOFC) units and methanol based economy.

4.4.2.7 PLUG

PLUG (Power Generation during Loading and Unloading) is a new concept of power interface between LNG or container carriers, using electric propulsion and terminals, which allow them to provide or receive power from the local grid. PLUG is focused on the development and qualification of a quick connect/disconnect 6 600 volts ‘hands off’ concept and its associated power line with a power exchange capability of up to 25 MW.

4.4.2.8 HERCULES

The HERCULES Project (High Efficiency R&D on Combustion with Ultra Low Emissions for Ships, http://www.ip-hercules.com/article/english/2/index.htm) is a large scale cooperative project on marine engine R&D supported by the European Commission and the Swiss Federal Government.

The project developed new technologies to drastically reduce gaseous and particulate emissions from marine engines and concurrently increase engine efficiency and reliability, hence reduce specific fuel consumption, CO_2 emissions and engine lifecycle costs.

These objectives were attained through interrelated developments in thermodynamics and mechanics of “extreme” parameter engines, advanced combustion concepts, multistage intelligent turbocharging, “hot” engines with energy recovery and compounding, internal emission reduction methods and advanced after treatment techniques, new sensors for emissions and performance monitoring, adaptive control for intelligent engines. Advanced process models and engineering software tools have been developed, to assist in component design. Prototype components have been manufactured and rig-tested. Engine experimental designs have been assessed on test beds to validate the new technologies and confirm the achieved objectives. Full scale shipboard testing of chosen systems demonstrated the potential benefits of next-generation marine engines.

4.4.2.9 MC-WAP

The Project MC-WAP (http://www.mc-wap.cetena.it/home.htm) aims at the application of Molten Carbonate Fuel Cells (MCFC) technology on-board large ships, as Ro-Pax, Ro-Ro and Cruise, and fast vessels for auxiliary power generation purposes.

The main objective of MC-WAP lies in the development and design of power plants based on molten-carbonate fuel cells technology, to be integrated on board large ships.

Molten carbonate fuel cells have advantages linked to their high operating temperature, their environmentally friendly characteristics and the cost reduction potential, which makes them one of the most promising technologies to give a significant contribution to the objectives of sustainable energy generation. Besides, if low temperature fuel cells are mostly tailored to small boats or passenger ships, either fuelled by pure hydrogen or by reformate gases, high temperature fuel cells are more appropriate for large ships where their higher specific weight disadvantage is over-compensated by the higher APU system efficiencies they can enable.

4.4.2.10 FASTRCARGO

The Project FASTRCARGO (http://www.fastrcargo.eu/), a co-funding project under the 6^{th} Research Framework Programme of the European Union, aims at developing the fastest transhipment system with the potential of a significant impact on rail innovations for 2010 and beyond.

It aims at automatic loading and un-loading of standardised intermodal transport units to standardised rail wagons and trucks below active power lines and vice versa. The equipment will also allow parallel load processes. This rail innovation offering new and attractive transportation services will definitely support new rail production methods, thus contributing to the re-balancing of transport mode.

4.4.2.11 INNOTRACK

The INNOTRACK Project (http://www.innotrack.eu/) is a joint response of the major stakeholders in the rail sector for the development of cost effective high performance track infrastructure, aiming at providing innovative solutions towards significant reduction of both investments and maintenance of infrastructure costs.

The project provides a methodology for life cycle cost calculation and assessment of reliability, availability, maintainability and safety through research on four key topics: track support structure, switches and crossings, rails and logistics for track maintenance and renewal.

4.4.2.12 CLEANENGINE

CLEANENGINE (http://www.crfproject-eu.org/) is a European project on advanced technologies for highly efficient Clean Engines working with alternative fuels and lubes.

CLEANENGINE is focused on developing modern clean internal combustion engines based on liquid biofuels coming from biomass (biodiesel and bioethanol) and environmentally friendly and ash-free lubes and/or lubrication concepts. The objective is to increase efficiency and minimise harmful emissions.

4.4.2.13 GREEN

GREEN (GREen heavy duty Engine (http://green.uic.asso.fr/introduction.html)), is a co-funding project under the 6th Research Framework Programme of the European Union and promote future advanced heavy duty engine technologies to achieve lower emissions, lower fuel consumption and improved sustainability for future fuels.

The main objective of the project is to develop an intelligent flexible HD engine system able to achieve a maximum fuel conversion efficiency of 45%, while complying with a zero-impact emission level. As fallout of the achieved knowledge and realised technologies of such an integrated combustion system, innovative HD diesel and gas engines, to be considered as by-products of the GREEN research, are developed. These by-products will allow Europe to maintain the leadership in the production of internal combustion engines in the years 2012 - 2016, while allowing the completion of the integrated combustion system in an innovative powertrain.

4.4.2.14 FELICITAS

The Integrated Project FELICITAS (http://www.felicitas-fuel-cells.info/project-description.html) is part of the 6th Framework Programme of the European Research Area. The main challenge is the development of fuel cell (FC) drive trains capable of meeting the exacting demands of heavy-duty transport for road, rail, and marine applications.

The two FC technologies considered by FELICITAS are:

- Polymer Electrolyte Fuel Cell (PEFC) technology;
- Solid Oxide Fuel Cell (SOFC) technology.

4.4.2.15 TRIMOTRANS

The main objective of the project TRIMOTRANS (http://www.zaft.htw-dresden.de/trimotrans/index.php?change=1&lang=en) is the development of new technical solutions for intermodal loading units including containers, dedicated adaptors and mobile internal fixtures in order to shift the main transportation route for goods from the road onto rail and inland waterways in a sustainable way.

4.5 Collection Process and Results

4.5.1 First work session (M1-M12)

During the first session of work in Task 3.1 three rounds dedicated to the collection of greening technologies have been organized.

During the first round, the template for the collection of Green Technologies has been distributed to partners involved in Task 3.1, along with the dedicated user manual. In order to ensure a good coverage of all transport modes, including multimodality, partners have been requested to provide inputs on technologies referred to the domain in which they have major experience.

The first round led to the identification of a preliminary list including around 108 promising technologies proposed by partners. An analysis of the list of technologies has been conducted, in order to assess the quality of coverage considering the selected categories (see Section 4.1), and the completeness of the information reported for the requested indicators (see Section 4.2). Partners involved in the collection have been further contacted, with the purpose of completing the missing indicators and proposing additional technologies in order to have a more complete collection.

The list has been re-circulated to all concerned partners, with the purpose of completing and expanding the coverage achieved in terms of number of technologies collected and completeness of indicators reported; the additional information gathered during this second round of collection allowed to expand the number of collected technologies up to 135.

After the second round, it has been decided to extend the collection process by involving also SuperGreen beneficiaries not directly involved in the activities of Task 3.1; such extension was necessary in order to ensure that the relevant knowledge in terms of greening technologies, owned by SuperGreen consortium in general, was fully taken into account within the list of technologies collected within the scope of the Task.

Moreover, the collection has been updated with two important issues: the addition of a new modality for waterborne transport and the indication of the transport mode associated to the technology. In fact, following a suggestion received during the PCM meeting held in Helsinki, the transport mode “Inland waterway” has been added to the list of available transport mode. Moreover the collection has been upgraded by adding the general indicator “transport mode” associated to each single technology in the collection.

Following the addition of the indicator “transport mode”, the total number of technologies collected per category increased, as some technologies have been considered applicable to two or more different transport modes.

The third round of technologies collection, involving all the beneficiaries participating to SuperGreen, ensured an improvement of the technologies list in terms of transport mode coverage, as well as concerning the completeness of the information provided to detail the most relevant characteristics of the proposed technologies.

Table 3 below provides the summary of the results achieved after the conclusion of the third round of collection, indicating the number of technologies collected detailed per category, considering each different transport mode.

Table 3: List of technologies collected within the first work session

Transport mode	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
Inland Waterways	2	10	3	0	0	0	4	1	0	**20**
Maritime	10	18	26	0	0	2	3	14	2	**75**
Railway	5	12	3	0	0	1	9	3	7	**40**
Road	5	18	0	0	1	1	13	2	1	**41**
Multimodal	0	2	14	0	2	3	0	0	0	**21**
TOTAL	**22**	**60**	**46**	**0**	**3**	**7**	**29**	**20**	**10**	**197**

Table 4 provides a synthesis of all the technologies collected in each considered category, regardless the transport mode. It has to be underlined that the totals identified within the two tables do not match, as a single technology could have been considered applicable to more than a single transport mode.

Table 4: Synthesis of technologies collected within the first work session

	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
Technologies	21	24	32	0	3	5	28	16	9	**138**

4.5.2 Second work session (M12-M24)

The working sessions planned for the second year of the project had the purpose of guaranteeing an expansion and/or refinement of the technology list identified within the first round of collection and implementing suggestions and recommendations proposed during the previous working phase.

Consequently, this second session about the collection of new green technologies and information included three major activities:

- Activity 1: Filling in of missing information for green technologies already identified in the first round. The second working sessions allowed to expand and complete, where necessary, the information concerning indicators for technologies already collected.
- Activity 2: Identification of more technologies by reviewing material addressed by SuperGreen partners beyond task 3.1.
- Activity 3: Identification of more technologies on the basis of partners'background.

At the end of the second session of data collection on technologies, new data on technologies have been collected and 53 new technologies have been identified.

Table 5 below provides the summary of the results achieved at the end of the second session of work, indicating the number of technologies collected detailed per category, considering each different transport mode.

Table 5: List of technologies collected within the second work session

Transport mode	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
Inland Waterways	9	0	0	0	0	0	0	1	0	**10**
Maritime	1	3	3	0	0	0	0	0	0	**7**
Railway	3	5	1	0	0	12	3	0	3	**27**
Road	2	0	0	0	0	0	3	1	0	**6**
Multimodal	0	1	2	0	0	0	0	0	0	**3**
TOTAL	**15**	**9**	**6**	**0**	**0**	**12**	**6**	**2**	**3**	**53**

In this second round of collection each technology can be applicable to only one transport mode.

In the following Table 6 the summary of the full list of technologies identified in the first two years of the project is reported.

Table 6: Full list of technologies collected within the first and second work sessions

Transport mode	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
Inland Waterways	11	10	3	0	0	0	4	2	0	**30**
Maritime	11	21	29	0	0	2	3	14	2	**82**
Railway	8	17	4	0	0	13	12	3	10	**67**
Road	7	18	0	0	1	1	16	3	1	**47**
Multimodal	0	3	16	0	2	3	0	0	0	**24**
TOTAL	**37**	**69**	**52**	**0**	**3**	**19**	**35**	**22**	**13**	**250**

4.6 Third work session (M25-M36)

The working sessions planned for the third year of SuperGreen project had the purpose of guaranteeing refinement of the technology list identified during the first two rounds of collection.

In particular during the last year of the project, a particular effort has been spent to identify technologies concerning the following categories:

- “Cargo Preparation” category that did not include any technology;
- “Heating and Cooling” category that included only few technologies.

A specific topic has been also opened on different social networks (i.e. LinkedIn and Facebook) in order to collect external input and information on technologies.

Furthermore, the third working session allowed to complete, where necessary, the information concerning indicators for technologies already collected in the previous working sessions of Task 3.1. In fact, a special focus has been given to the merged technologies (category D) and the technologies that lacked information in the first analysis (category X) (description of the categories is reported in Session 5).

At the end of the third session of data collection on technologies, new data on technologies have been collected and 13 new technologies have been identified.

Table 7 below provides the summary of the results achieved at the end of the third session of work, indicating the number of technologies collected detailed per category, considering each different transport mode.

Table 7: List of technologies collected within the third work session

Transport mode	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
Inland Waterways										**0**
Maritime					1					**1**
Railway									1	**1**
Road					1		1			**2**
Multimodal				6	3					**9**
TOTAL	**0**	**0**	**0**	**6**	**5**	**0**	**1**	**0**	**1**	**13**

In the following Table 8 the summary of the full list of technologies identified in the whole project is reported. It has to be underlined that a single technology could have been considered applicable to more than a single transport mode.

Table 8: Full list of technologies collected within the whole project

Transport mode	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
Inland Waterways	11	10	3	0	0	0	4	2	0	**30**
Maritime	11	21	29	0	1	2	3	14	2	**83**
Railway	8	17	4	0	0	13	12	3	11	**68**
Road	7	18	0	0	2	1	17	3	1	**49**
Multimodal	0	3	16	6	5	3	0	0	0	**33**
TOTAL	**37**	**69**	**52**	**6**	**8**	**19**	**36**	**22**	**14**	**263**

The complete list of technologies identified by SuperGreen partners within Task 3.1 of the project is reported in Appendix II to this document.

At the end of the project, when the data collection was already closed, other suggestions for green technologies have been provided by partners not involved in the data collection.

Unfortunately the suggestions arrived too late to be analysed and eventually used for the following activities as the benchmark (Task 3.3). Although these technologies are considered good solutions and it has been decided to mention them in the document:

- **Triple E class** produced by Maersk: this is family of large, fuel-efficient container ships. The name "Triple E" is derived from the class's three design principles: "Economy of scale, Energy efficient and Environmentally improved". These ships are expected to be not only the world's largest ships in service, but also the most efficient containerships per twenty-foot equivalent unit (TEU) of cargo. The ships will be 400 meters (1,312 ft) long and 59 meters (194 ft) wide. While only 3 meters (9.8 ft) longer and 4 meters (13 ft) wider than E-class ships, the Triple E ships will be able to carry 2,500 more containers. With a draft of 14.5 meters (48 ft), they will be too deep to use any port in the Americas or cross the Panama Canal, but will be able to transit the Suez Canal when sailing between Europe and Asia.
- **Air Lubrication System:** the air-lubrication of a ship’s hull really does pay off with significant fuel savings. Results on a trial period of two-years in a variety of normal operating conditions have confirmed an average of 6% reduction in fuel consumption. The experiments with the air-lubrication system (supported by

classification society ClassNK and the Japan government) have been designed to verify fuel reduction; to examine the behavior of the air bubbles supplied to the vessel bottom under various operational and sea conditions; to examine the relationship between the amount of air supplied and its effect, and to validate CO_2 reduction. Earlier tank tests and sea trials had suggested a 10% reduction in CO_2 emissions was to be expected, but these trials in all sorts of vessel conditions, in a variety of sea and weather conditions confirmed somewhat less, 6%, nevertheless a meaningful energy saving.

- **Slow steaming** is a practice to save fuel in order to maximize profit. When the vessel is full loaded with lower rates, the vessel speed is lowered. The opposite happens in the case of high rates. In order to slow down the service speed, the schedule of the ship is reconfigured with respect to the contractual obligations of the operator. The optimal speed depends on the main engine operation at low loads and the percentage of fuel costs to the total operating costs.

Moreover, some of the navigation technologies identified within the three rounds of data collection are ICT technologies and, due to their nature, they could have been identified also in SP4. The data/information collected on these technologies in the two work packages are different and useful to have a complete description of the technologies.

5 Analysis and selection of Technologies

Subsequent to the collection of all data on the different types of technologies by the partners described above, an analysis and selection of the most relevant technologies for the project was carried out with reference to the technologies identified within all the sessions of work.

The analysis of technologies started from the list of technologies previously collected. This first analysis has been conducted in order to identify technologies that are promising accordingly with SuperGreen scope and objectives. The analysis divided the technologies into 6 different categories:

A – Very important. These technologies are believed to have a large impact on the greening potential of cargo transportation in a transport corridor. The technologies are mature and are considered to influence the greening potential in near future.

B – Important. These technologies are believed to have an impact on the greening potential of cargo transportation in a transport corridor. The technologies are mostly mature and are considered to influence future greening.

C – Low importance. These technologies are believed to have less impact on the greening potential of cargo transportation in a corridor or are less mature than those found in category A or B but are still considered valuable to the project.

D – Merged. These technologies are regarded special cases of the technologies that are placed in the A, B or C category, and are considered as valuable information to the project in this phase.

X – Need information. More information is necessary to evaluate these technologies.

Z – Not relevant. These technologies are regarded as not relevant for SuperGreen project and are not included in the final selection.

During the second and third working sessions the analysis and selection already done with reference to the technologies identified during the previous working sessions has been reviewed and updated. In few cases the class of importance of the technology has been changed.

Moreover, some technologies names have been changed with more anonymous titling in order not to use their specific brand names.

The results achieved by applying the methodology above described for the selection of the technologies are detailed in the following tables (from Table 9 to Table 12). In the Appendices III all the technologies identified during all the rounds of collection are reported with comments collected for the assessment and selection.

Table 9: Impact levels for identified technologies collected within the first work session

Technology classification	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
A – Very important	5	4	4	0	0	0	4	3	2	22
B – Important	2	3	3	0	1	0	3	6	3	21
C – Low importance	1	5	1	0	0	0	0	2	0	9
D – Merged	4	8	4	0	0	0	7	2	2	27
X – Need info	2	0	8	0	1	4	3	0	1	19
Z – Not relevant	7	4	12	0	1	1	9	3	1	38
-	0	0	0	0	0	0	2	0	0	2
TOTAL	**21**	**24**	**32**	**0**	**3**	**5**	**28**	**16**	**9**	**138**

During the first round of collection 2 technologies were identified that have been then darkened because they are protected by access rights of the company owner. These two technologies have not been taken in consideration during the selection phase.

Table 10: Impact levels for identified technologies collected within the second work session

Technology classification	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
A – Very important	1	1	0	0	0	0	0	0	0	2
B – Important	2	1	0	0	0	2	1	2	0	8
C – Low importance	6	2	0	0	0	1	1	0	0	10
D – Merged	2	0	1	0	0	4	0	0	0	7
X – Need info	4	5	5	0	0	5	4	0	3	26
Z – Not relevant	0	0	0	0	0	0	0	0	0	0
TOTAL	**15**	**9**	**6**	**0**	**0**	**12**	**6**	**2**	**3**	**53**

Table 11: Impact levels for identified technologies collected within the third work session

Technology classification	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
A – Very important									1	1
B – Important					1		1			2
C – Low importance				5	4					9
D – Merged										0
X – Need info				1						1
Z – Not relevant										0
TOTAL	**0**	**0**	**0**	**6**	**5**	**0**	**1**	**0**	**1**	**13**

The following Table 12 reports the full overview of technologies identified within the first two round of collection.

Table 12: Impact levels for identified technologies collected within the whole project

Technology classification	Engines and Propulsion Systems	Fuels and Souces of energy	Cargo handling and Transfer	Cargo Preparation	Heating and Cooling	Innovative units and Treatment	Vehicles	Navigation technologies	Best practices	TOTAL
A – Very important	6	5	4	0	0	0	4	2	3	24
B – Important	6	4	7	0	3	2	5	9	3	39
C – Low importance	7	7	5	5	4	5	6	2	0	41
D – Merged	6	8	5	0	0	4	7	2	2	**34**
X – Need info	4	5	5	1	0	5	2	0	4	26
Z – Not relevant	7	4	12	0	1	1	9	3	1	**38**
TOTAL	**36**	**33**	**38**	**6**	**8**	**17**	**33**	**18**	**13**	**202**

The tables below show the technologies believed to have the largest potential for the SuperGreen project and show technologies that were placed in either A, B or C category at the end of the project. The tables present the most relevant technologies grouped into the main areas described in 4.1.

Table 13: Most relevant technologies for "Engines and propulsion systems"

ID	Category	Technology Name	Transport Mode	Description
EN02	A	Directly driven propeller	Maritime	Slow speed engine directly connected to propeller shaft, 20 year life time, running 5500 h/a.
EN03	A	Mechanically connected propeller	Maritime	Medium speed engine connected by a reduction gear to the propeller shaft, 20 year life time, running 5500 h/a
EN07	A	Diesel-mechanic propulsion with high speed engine	Maritime	High speed engine connected by a reduction gear to the propeller shaft, 20 year life time, running 5500 h/a.
EN16	A	Full/parallel hybrid	Road	Electrical support of engine power by saving and re-use of break-energy; combination of 6 cylinder engine plus electrical engine
EN21	A	Exhaust abatement system	Inland Waterways	Emission reduction system comprising a reactor for selective catalytic reduction of NO_X and a reactor containing a particulate matter filter for reduction of particulate matter
EN39	A	Gas engines	Inland Waterways	Engines running on natural gas (different solutions available, pure gas engines, gas-diesel engines, dual fuel engines)
EN06	B	Mechanical azimuthing thrusters	Maritime	The engine runs generator. An electric motor is located inside the ship where it runs propeller shaft. 20 year life time, running 5500 h/a.
EN18	B	Fuel cell technology	Road	> 3,5 ton transporter running on renewable fuel cell technology
EN 15	C	PG Engine Diesel Locomotives	Railway	A propulsion system for a four-axle, standard-gauge, centre-cab locomotive using a liquefied petroleum gas (LPG) engine instead of conventional diesel
EN42	C	CCNR I Engine	Inland Waterways	Most existing engines comply with CCNR I Standard
EN45	C	CCNR II Engine	Inland Waterways	Today new engines have to comply with CCNR II standard
EN48	B	CCNR III Engine	Inland Waterways	Still under negotiation
EN51	B	CCNR IV Engine	Inland Waterways	Still under negotiation
EN54	C	Kaplan propeller in nozzle	Inland Waterways	Nozzle around Kaplan propeller creates additional thrust; highly effective at large propeller loads, Source DST;
EN57	C	High screw propellers	Inland Waterways	Nozzle around high skew propeller creates additional thrust; highly effective at large propeller loads, Source DST;
EN61	C	Contra rotating propeller	Maritime	Thrust system consisting of a pair of propellers behind each other which rotates in opposite directions, so that the aft propeller recovers some of the rotational energy in the slipstream from the forward propeller

ID	Category	Technology Name	Transport Mode	Description
EN62	C	Diesel turbo compound	Road	Turbo compound systems can be used to affect engine operation using the energy in exhaust gas that is driving the available turbocharger. A first electrical device acts as a generator in response to turbocharger rotation. A second electrical device acts as a motor to put mechanical power into the engine, typically at the crankshaft. Apparatus, systems, steps, and methods are described to control the generator and motor operations to control the amount of power being recovered. This can control engine operation closer to desirable parameters for given engine-related operating conditions compared to actual.
EN11	B	Diesel-Electric propulsion with dual fuel engine	Maritime	Medium speed engine using LNG (Liquefied Natural Gas) as primary fuel and HFO (Heavy Fuel Oil) or MDO (Marine Diesel Oil) as pilot fuel. The engine runs generator. An electric motor runs propeller shaft. 20 year life time, running 5500 h/a.
EN24	B	Improved Gas Engine	Road	Integrated approach using electronic valve motion management, enhanced cylinder head cooling, near-to-valve port fuel injection system, advanced integrated control

Table 14: Most relevant technologies for "Fuels and sources of energy"

ID	Category	Technology name	Transport Mode	Description
FU02	A	Ethanol and bio-diesel	Maritime Road	Investigation about using alternative fuels.
FU03	A	CGN (compressed natural gas)	Multimodal	Cleaner fuel for yard handling equipment (Prime movers)
FU08	A	LNG	Multimodal	Liquefied natural gas
FU18	A	Biogas	Multimodal	Biogas is mainly produced from bio-waste, agricultural residues and residues from sewage treatment plants
FU25	A	Sky sails system	Maritime	It uses large towing kites for the propulsion of the ship. The tractive forces are transmitted to the ship via a highly tear proof, synthetic rope.
FU05	B	AMP	Maritime	Alternative Maritime Power is a shore-side power source, that transforms the shore-side power voltage to match the vessel power system
FU06	B	Wind energy	Maritime Inland Waterways	Wind turbines which will generate clean energy to power 14 Container Terminal Quay cranes, reefer containers, repair workshops and other power consumption needs
FU13	B	Electricity	Road Railway	Electricity is today produced from fossil fuels, nuclear energy and renewable energy sources
FU26	B	Waste heat recovery system	Maritime	It passes exhaust gases from the ship's main engine through a heat exchanger to generate steam for a turbine driven generator the electrical power generated assists ship propulsion or supplies shipboard services.
FU01	C	Ultra-low sulphur diesel	Maritime Inland Waterways Railway Road	Switch from industrial diesel oil (IDO 0,5% sulphur) to ultra-low sulphur diesel (ULSD 0,005%) for PMs and RTGs.

ID	Category	Technology name	Transport Mode	Description
FU04	C	Solar power network	Multimodal	A 6.600 square-meter solar panel able to generate clean energy which will reduce reliance on oil and cut electricity-related greenhouse gas emissions
FU07	C	HFO	Maritime Railway Road	Heavy fuel oil
FU14	C	Hydrogen	Road Inland Waterways	Hydrogen is today mainly produced from steam reforming of fossil gas - some production from electricity and renewable sources
FU23	C	Nuclear Power	Inland Waterways Maritime	Nuclear Power
FU30	C	Flettner rotor	Maritime	It is a vertical cylinder rotating around its axis that converts prevailing wind into propulsive energy.
FU29	C	Fuel cell hybrid system	Multimodal	Develop fuel-cell systems that are capable of meeting the demands of heavy-duty transport for road, rail and marine applications. These systems will be:-Highly efficient, above 60%-Power dense,-Powerful units of 200kW plus,-Durable, robust and reliable. The two FC technologies considered are: -Polymer Electrolyte Fuel Cell (PEFC) technology and -Solid Oxide Fuel Cell (SOFC) technology. The scientific and technological approach is based on: -FC CLUSTERING -FC HYBRIDISATION

Table 15: Most relevant technologies for "Cargo handling and transfer"

ID	Category	Technology Name	Transport Mode	Description
HT01	A	Diesel to electric power convertor (RTGs)	Maritime Multimodal	RTGs fitted with electrical components in place of traditional hydraulic parts. Conversion will eliminate black emissions and lower noise levels of engines
HT03	A	Hybrid hydraulic drive Terminal tractors	Maritime	Storing braking energy into hydraulic system for acceleration and system
HT07	A	Low emission engines	Multimodal	Euro III/ IV compliant engines burn diesel more efficiently, reducing emission of CO_2 and providing up to 5% reduction on fuel consumption
HT10	A	Horizontal container (un)loading	Railway	Metrocargo is an innovative solution for containers cargo handling in overhead electrified railways, it's a containers horizontal movement system from an automated platform to train wagons. This technology is ready to experimentation. Metrocargo will be tested on new Maersk's Platform in Vado Ligure (SV), Italy.
HT06	B	MP-RTGs	Multimodal	Mains-powered RTGs transfer the power generation from the engine of the yard crane to a far more efficient power station. Power station can be up to 40% more efficient than equipment engine.
HT11	B	Cargo Cassette and Translifter	Maritime	Wheel less cargo cassette is a loading platform which is used together with a translifter in a cassette system. Translifter is a steerable lifting trailer which together with cassettes replaces roll trailers in Ro-Roand StoRo handling.

ID	Category	Technology Name	Transport Mode	Description
HT28	B	Automatic RoRo cargo unit handling	Multimodal	The concept is based on self (un)loading of units using a roll-on/roll-off system with a special train of platform cars, called a train loader. The performance of a train loader is often limited by the operation of the stockpile and reclaim system and the capacity of the train loader surge bin. While both are separate systems, they operate in concert to achieve a given performance. Poorly designed reclaim systems, or insufficient train loader surge capacity can significantly downgrade train-loading performance.
HT24	C	FCT	Maritime	The Floating Container Terminal collects and distributes containers originating from small calls, and bundles these currents with containers
HT08	B	ZF transmission systems	Multimodal	Installation in the new PM (prime movers) of new transmission system operating based on Automatic-Manual transmission concept. Reduction of fuel consumption by 10% when compared with older existing transmission systems
HT09	B	Green schemes to improve RTGs emissions and noise	Multimodal	Addition of a super-capacitor on RTGs. When RTGs engine is running, it charges the super capacity at the same time, and when super capacitor is fully charged, it will supply
HT20	B	Barge Express (BEX)	Inland Waterways	BEX is an integrated concept for large scale barge container transport aiming at automated handling at barge terminals
HT36	B	FlexiWaggon	Railway	Flexiwaggon can combine lorries, buses, cars, containers on one and the same waggon. Individual loading and unloading of waggons. Loading and unloading is done horizontally which means no consideration is necessary for overhead contact lines. The emissions will be reduced by 75%, including carbon dioxide emissions
HT05	C	Timing device for engine start-stop	Multimodal	Applied on yard equipment (Straddle carriers) to shut down the engine after a period of inactivity. This is a timing device that controlls engine shutdown and start-up depending on activity level.
HT32_a	C	River-Sea Push Barge System	Maritime	The river-sea push barge is a transport system in which one and the same push barge is used for the sea- and the river leg in a transport chain.
HT33	C	Combined Traffic Carrier Ship/Barge (CTCB)	Maritime	A shortsea concept based on a new type of shortsea vessel: the Trans Sea Lifter (TSL). This vessel is able to carry floating unit load carriers, in particular barges generally used in inland navigation, between inland waterways that are separated by the open sea.
HT34	C	Intermodal loading unit	Multimodal	New technical solutions for intermodal loading units including containers, dedicated adaptors and mobile internal fixtures in order to shift the main transportation route for goods from the road onto rail and inland waterways in a sustainable way. The technical activities will be focused on the development and design of large ISO containers and ISO compatible roll-off containers with the dimensions of 2 550 x 2 900 x 7 450 mm. These dimensions comply with the recommended directive of the European Commission for intermodal loading units.

Table 16: Most relevant technologies for "Cargo Preparation"

ID	Category	Technology Name	Transport Mode	Description
CP01	C	Cardboard pallets	Multimodal	ecological and sustainable being made of recycled materials and completely recyclable, have low weight but good strength
CP02	C	Modularized Boxes	Multimodal	Containers modularized and standardized worldwide in terms of dimensions, functions and fixtures. Easy to handle, store, transport, interlock, load, unload, construct and dismantle, compose and decompose. Environment friendly materials with minimal off-service footprint.
CP03	C	Passive controlled atmosphere system	Multimodal	Passive controlled atmosphere system in which the fruit itself creates the desired environment. Lower oxygen levels slow down the respiration process of the fruits.
CP04	C	Cargo hold tank coatings	Multimodal	Innovative cargo hold tank coatings to reduce abrasion and corrosion.
CP05	C	Software for optimal pallet configuration	Multimodal	Software for optimal pallet configuration to reduce shipping costs. The user enters primary package or box dimensions and rapidly assembles optimal pallet configurations.

Table 17: Most relevant technologies for "Heating and cooling"

ID	Category	Technology Name	Transport Mode	Description
HC02	B	Intelligent temperature unit	Multimodal	Current refrigerated boxcars will be built with energy efficient cooling systems, GPS (Global Positioning System) tracking, fresh air exchange and the ability to remote monitoring the systems, sometimes from thousands of km away on a network. RFID (Radio Frequency Identification) for tracking services are the main support in management systems of perishable goods.
HC03	B	Temperature control units	Road	CryoTech: Liquid CO2 modules for temperature for multi temperature control (cooling/heating)
HC04	B	RFID tag antenna with temperature alarm sensor	Multimodal	RFID tag antenna with ultra-low cost temperature alarm sensors which is capable of detecting temperature violations above a critical temperature threshold.
HC05	C	Natural refrigerants	Multimodal	Natural refrigerants are chemicals which occur in nature's bio-chemical processes. They do not deplete the ozone layer and make negligible contribution to global warming. Their high efficiency means they make a much lower, indirect contribution to global warming than many synthetic refrigerants.
HC06	C	Systems to Reduce Heating Costs in Cold Climates	Multimodal	The project will investigate two cooling approaches during the compression process. In one approach, relatively large amounts of oil are injected into the compressor to absorb heat generated throughout the compression stage. In the second approach, a mixture of liquid and vapor refrigerant from the expansion stage is injected at various points during compression to provide cooling. The added steps improve the compression process while also reducing energy losses due to friction in the expansion stage.

ID	Category	Technology Name	Transport Mode	Description
HC07	C	Software program QUEST	Maritime	QUEST is a CO2 emission friendly software with focus on maintaining a constant cargo temperature. It regulates the return air temperature and allows the supply air temperature to fluctuate without exposing the cargo to chill damages.
HC08	C	Truck Refrigeration Unit TDJS35HP	Road	Truck refrigeration unit enables simultaneous temperature control of two separate cargo compartments with different temperature settings entirely by heat pump.

Table 18: Most relevant technologies for "Innovative units and treatment"

ID	Category	Technology Name	Transport Mode	Description
LU13	B	Braking energy recovery	Railway	Recovery of dynamic braking energy and restitution to national grid / Reversible DB Substation
LU14	B	Onboard energy storage systems	Railway	Supercaps, batteries, flywheels, hybrid storage; A flywheel is a mechanical device with a significant moment of inertia used as a storage device for rotational energy. Flywheel energy storage, or the rotational energy of a flywheel, and rechargeable electric traction batteries are also used as storage systems. Batteries are electrochemical energy storage systems. A supercapacitor is a tool offering very high electrical capacitance in a small package. A hybrid train is a locomotive, railcar or train that uses an onboard rechargeable energy storage system (RESS), placed between the power source (often a diesel engine prime mover) and the traction transmission system connected to the wheels
LU11	C	APU (Auxiliary Power Unit)	Railway	An auxiliary power unit (APU) is a device on a locomotive whose purpose is to provide energy saving and to reduce the polluting emissions. Locomotive engines cannot use antifreeze in their cooling systems for technical reasons related to reactions of antifreeze chemicals on internal engine parts. Therefore, during cold weather, a locomotive engine must either be working to transport freight or idling to prevent freezing. The APU keeps the main engine warm, reducing fuel consumption and emissions while the main engine is shut down and also APU reduces railway noise levels
LU02	C	SECU unit	Multimodal	The SECU (Stora Enso Cargo Unit) is ISO certified for 93.5 gross tonnes. The dimensions are 3.6 x 3.6 x 13.8 m
LU03	C	Loading plate	Maritime	Actiw LoadPlate was developed to meet customer demands for quick loading of standard cargo space: sea containers, trailers. Solution is suitable for loading difficult cargo that is hard to containerise.
LU04	C	Trailer stand	Maritime	Simple system to lash trailers
LU05	C	2,5 wide container	Multimodal	Allows two pallets to be loaded side by side

Table 19: Most relevant technologies for "Vehicles"

ID	Category	Technology Name	Transport Mode	Description
VE02	A	Electric Locomotive	Railway	NS 999 is an entirely electric locomotive that uses a lead-acid energy storage system without the use of a diesel engine and with zero exhaust emissions.
VE03	A	Hybrid Truck	Road	Support engine plus auxiliary drive to operate an elevating platform of the truck; combination of 6 cylinder engine plus electrical engine
VE09	A	Electric vehicles	Road	Battery-electric vehicles
VE10	A	Euro VI vehicles	Road	Euro VI is compulsory for new trucks from 2013, replacing Euro V
VE01	B	Hybrid Locomotive	Railway	Hybrid Locomotive was developed with the goal of creating the cleanest, most fuel-efficient high-horsepower diesel locomotive ever built.
VE22	B	Road-rail cargo interchange	Railway	The Flexiwagon rail project will allow containers to be moved by road and by train by loading trucks onto railcars.
VE25	B	Brake energy recovery system	Railway	Reversible DC Substation for recovering of dynamic braking energy and restitution to national grid
VE29	B	Aerodynamic drag improvements	Road	Aerodynamic mirrors, cab side extenders, integrated cab roof fairings, aerodynamic front bumper, full fuel tank fairings, trailer side skirt fairings, trailer gap fairing, rear mounted trailer fairing. Ref to the "Reducing heavy -duty long haul combination truck fuel consumption and CO_2 emissions report" http://www.nescaum.org/documents/heavy-duty-truck-ghg_report_final-200910.pdf/
VE33	C	Low rolling resistance tires	Road	Tires which are designed to minimize the energy wasted as heat as the tire rolls down the road
VE35	B	Electrification of Trucks on Highways	Road	The eHighway concept introduces the idea of diesel-electric hybrid trucks which can work like a electric trolley when overhead electric lines are available and work as a diesel
VE04	C	Fuel Cells	Road	3,5 ton F-Cell Sprinter is a transporter running on renewable fuel cell technology.
VE20	C	River-Sea Push Barge System	Inland Waterways	The river-sea push barge is a transport system in which one and the same push barge is used for the sea- and the river leg in a transport chain.
VE21	C	Combined Traffic Carrier Ship/Barge (CTCB)	Maritime, Inland Waterways	A shortsea concept based on a new type of shortsea vessel: the Trans Sea Lifter (TSL). This vessel is able to carry floating unit load carriers, in particular barges generally used in inland navigation, between inland waterways that are separated by the open sea.
VE31	C	Innovative bogie	Railway	New-generation of powered bogie with axles directly driven by synchronous motors is already available for light rail vehicles. Traction, running gear and braking technologies are combined in the bogie in order to form a highly integrated mechatronic system.

ID	Category	Technology Name	Transport Mode	Description
VE32	C	Friction control measure	Railway	Some energy expended by the train is lost to wheel-to-rail friction. Reductions in wheel-to-rail resistance can be made via improved lubrication. Efficient lubrication systems, such as top-of-rail lubrication systems, reduce wheel and rail wear and reduce fuel consumption

Table 20: Most relevant technologies for "Navigation technologies"

ID	Category	Technology Name	Transport Mode	Description
NA02	A	Automatic Identification System (AIS)	Maritime	Ship-to-ship, ship-to-shore and shore-to-ship system. Main purpose is collision avoidance, ship tracking and tracing. Works on VHF (Very high frequency, 30–300 MHz) radio frequency.
NA15	A	WiMax	Maritime Railway Road	Worldwide Interoperability for Microwave Access. Long range, high bandwidth wireless Internet
NA01	B	Train Control System	Railway	Train control and tracking system based on a special GPRS method.
NA05	B	ECDIS	Maritime	An Electronic Chart Display and Information System (ECDIS) is a computer-based navigation information system that can be used as an alternative to paper nautical charts. Integrates position information from GPS and other navigational sensors (radar, AIS). It may also give Sailing Directions and fathometer.
NA12	B	GEO satellites	Maritime	Geosynchronous Satellite whose orbital track on the Earth repeats regularly over points on the Earth over time. If such a satellite's orbit lies over the equator and the orbit is circular, it is called a geostationary satellite.
NA13	B	LEO satellites	Maritime	A low Earth orbit (LEO) is generally defined as an orbit within the locus extending from the Earth’s surface up to an altitude of 2,000 km. Given the rapid orbital decay of objects below approximately 200 km, the commonly accepted definition for LEO is between 160 - 2,000 km (100 - 1,240 miles) above the Earth's surface.
NA14	B	Inmarsat	Maritime	British satellite telecommunications company, offering global, mobile services. It provides telephony and data services to users worldwide, via portable or mobile terminals which communicate to ground stations through eleven geosynchronous telecommunications satellites.
NA16	B	ATM	Inland Waterways	The advising Tempomaat (ATM) is a computer program advising the skipper on the most economical combination of route and speed, enabling the vessel to arrive on time with a most efficient use of fuel leading to a reduction of fuel consumption and emissions.
NA17	B	River Information Services (RIS)	Inland Waterways	River Information Services (RIS) are customized information services for inland waterway transport and make it possible to coordinate logistical processes with actual transport situations on a constant basis. RIS play a key role in making cargo transport and passenger services on waterways more efficient leading to a reduction of fuel consumption by approximately 5 %, while at the same time increasing traffic safety.

ID	Category	Technology Name	Transport Mode	Description
NA18	B	Predictive cruise control (PCC)	Road	The PCC assistance system uses map and satellite-based route previews and saves substantial amounts of fuel. Unlike a conventional cruise control system that tries to maintain a preset speed, regardless of how the terrain changes, the PCC system looks for its route a mile in advance and adjusts engine output to the uphill and downhill gradients ahead. Based on this information, the on-board computer calculates the optimum speed to use the momentum of the truck to maximize fuel economy.
NA07	C	Global Navigation Satellite Systems or GNSS	Maritime Railway Road	Global Navigation Satellite Systems (GNSS) is the standard generic term for satellite navigation systems ("sat nav") that provide autonomous geo-spatial positioning with global coverage. GNSS allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few metres using time signals transmitted along a line-of-sight by radio from satellites.
NA11	C	LRIT	Maritime	The Long Range Identification and Tracking (LRIT) of ships. It consists of the ship borne LRIT information transmitting equipment, Communications Service Providers (CSPs), Application Service Providers (ASPs), LRITDataCenters, the LRIT Data Distribution Plan and the International LRIT Data Exchange.
NA15	B	WiMax - Worldwide Interoperability for Microwave Access	Maritime	Long range, high bandwidth wireless Internet

Table 21: Most relevant "Best practices"

ID	Category	Technology Name	Transport Mode	Description
BP04	A	Traffic Flow Management	Railway	A system for online optimization of rail traffic flow to have minimum delays and minimum energy consumption, developed by Emkamatik on behalf of SBB
BP07	A	Carbon-free rail freight transport	Railway	DB Schenker Rail replaces the electricity required for your freight transport with regenerative energy that comes 100% from renewable sources in Germany. This helps to avoid carbon emissions right from the outset. Even the smallest quantities can be transported in this way without carbon emissions, on a national and international scale.
BP02	B	TDS	Railway	Train Control System based on a GPS application method
BP03	B	GEKKO	Railway	A system to provide guidance to energy efficiency driving and timetable optimization, developed for Danish State Railways
BP08	B	Integrated shortsea transport	Maritime	The concept of Coaster Express (CoEx) is a short sea transport concept directed to bundling the transport flows, scaling-up the short sea facilities and standardization and automation of the transition processes.

ID	Category	Technology Name	Transport Mode	Description
BP35	A	EREX (ERESS)	Railway	The Erex system, has been designed by the European Railway Energy Saving Solution (ERESS), to help railways to save money and reduce CO2 emissions by providing exact energy consumption data. It provides an efficient, reliable, and flexible energy settlement process, enabling railway undertakings to understand their use of energy and thereby save energy and costs. Erex has been configured with a virtual platform with almost unlimited capacity.

6 Definition of the "Technologies vs. Indicators" Matrix

In the third year of the project the subtask regarding the creation of the benchmark of green technologies (Task 3.3) started and specific data and information on technologies became necessary.

For the benchmarking of the green corridors with green technologies, indeed, a two-stage approach is followed. In the first stage, the SuperGreen KPIs are analysed into factors individually influencing the overall value of the KPI. This factorisation supports the creation of an interface between the KPIs and performance metrics of the green technologies.

On the basis of the KPI factorization identified in Task 3.3 a specific template for the Technologies vs. Indicators matrix has been defined and data have been collected.

The matrix has been filled in with reference to the final list of technology selected as "Very important" and "Important" (Category A and B, Chapter 5) because these are the two categories of technologies used for the benchmark (Task 3.3).

In the following Table 22 the factorization of KPI used for the data collection is reported. It is necessary to underline that due to the fact that some technology are still under design or development phase, specific data related to onsite applications are not available yet.

Table 22: Factorization of KPI for the "Technologies vs Indicators" Matrix

	Factorization of KPI
Relative Cost	% cost saving compared with the baseline
	% fuel saving compared with the baseline
	% resources saving compared with the baseline
Emissions	% CO2 saving compared with the baseline
	% SOx saving compared with the baseline
Service & Bottlenecks	% operational or infrastructural delays reduction
	% of frequency of service *potential* improvement due to delays & bottlenecks reduction
	% of reliability improvement due to delays & bottlenecks reduction
	Do the tech influence some problems and/or bottlenecks? If YES put the % of mitigation
	Identification of problems and/or bottlenecks

The result of this activity represents the starting point of the factorisation analysis performed in Task3.3 where a more detailed description of factors has been done according to the needs of the benchmarking exercise. In fact, a more detailed analysis has been performed with reference to the Service & Bottlenecks KPIs.

The results of this activity are reported in Appendix III to this document.

7 Influence of Technologies on KPI

This activity is referred to the assignment of a specific class of influence to each technology with reference to each KPI.

In fact, a qualitative approach is applied considering that specific data on Green Technologies are not available in order to allow a quantitative approach. This is mainly due to the fact that many technologies are under design and/or development and reliable data related to onsite application are not available.

Therefore the classes of influence are assigned with reference to a ranking between -2 to +2 as describe below:

- -2 means a very bad influence of the technology on a KPI;
- -1 means a bad influence of the technology on a KPI;
- 0 means the technology is not relevant for a KPI;
- 1 means a good influence of the technology on a KPI;
- 2 means a very good influence of the technology on a KPI.

The first indication of the influence of the technology on the final set of KPI has been collected while collecting information on the applicability of technologies (Task 3.2).

These information have been then considered as an input of the present activity of the Task 3.1.

The activity performed in Task 3.2 has been done per corridor, instead the activity performed in Task 3.1 is performed per mode of transport. The technologies have been allocated to partners on the basis of the mode of transport and according to the partner expertise. This method allows defining the influence of the technology on KPI based on the expert judgment of partners.

This activity has been performed within the third year of the project and results are included in D3.1 as Appendix IV.

8 Conclusions

The activities performed in Task 3.1 – Identify Green Technologies have been mainly dedicated to achievement of the following objectives:

- identification of macro categories to facilitate the identification of potential Green technologies;
- selection of dedicated indicators for each category, in order to characterise the proposed technologies and facilitate the analysis and selection phase;
- creation of a template to support the collection of greening technologies proposed by beneficiaries, along with a manual to clarify its usage;
- organization of three different rounds of collection involving beneficiaries participating to Task 3.1 and to SuperGreen Project;
- identification of 263 green technologies associated to the following transport mode:
  - waterborne transport (inland waterway and maritime);
  - railway transport;
  - road transport;
  - multimodal transport.
- identification of the most relevant green technologies for the project and collection of the indicators needed for the benchmark of the technology in Task 3.3;
- definition of the criteria for the assignment of specific classes of influence on KPI to each technology.

In particular the collection rounds led to the identification of 263 potential technologies proposed by project participants. This list of technologies has been assessed in the scope of the task, in order to verify that it ensures a proper coverage of both the selected categories and the considered transport modes, and to verify that each technology is sufficiently described and characterized by means of the information provided by involved partners filled in the requested indicators.

A detailed analysis has been conducted on the full set of collected technologies, in order to identify the most promising ones suitable for applications into the Green Corridors identified in the scope of SuperGreen. In particular, the potential technologies above mentioned have been divided into 6 groups according to their potential impact, from “Very important” to “Non relevant”; this allowed to identify, for each of the categories mentioned in Section 4.1, the technologies having the most relevant impact in terms of greening potential.

Appendix I: User Manual for Technology Template

Appendix II:
Collection of Green Technologies

Appendix III:
Selection of Technologies

Appendix IV: Technologies vs Indicators Matrix

Appendix V:
Green Technologies
Influence on KPI