Definition of common collection methodology

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1. Introduction

This deliverable describes the activities carried out within the WP3 and focused on the definition of a common data collection methodology, with a cross border approach, so to set up a common framework for an exhaustive and accurate data collection in the targeted territories and to grant the replicability in other ones.

The common framework consists of two sections containing indicative guidelines about:

- a survey methodology to collect data from targeted territories;
- a methodology to acquire the waste composition figure;

In addition, a general overview of Life Cycle Assessment (LCA) methodology is included in this Deliverable, since within the Project it is expected the evaluation of the environmental aspects of the implemented pilot actions, and LCA represents a structured, comprehensive and internationally standardized method in this regard.

2. Survey methodology to collect data from targeted territories

2.1 Survey structure

The survey is made up of three parts which allow to collect data from targeted territories covering all the relevant topics regarding waste production and management.

2.1.1 General figures

This section should give a geographical description of the territory, through the collection of data regarding:

1) Surface area: this figure allows to make considerations about distances which should be covered by the logistic system of waste collection;
2) Distribution of urban and rural areas: this figure allows to identify locations potentially eligible for composting activity;
3) Population, number of residents and population density in relation to different seasons in the year: these figures are useful to design the amplitude of intervention in the field of a sustainable waste management; furthermore, it is important to assess the impact of the number of tourists

with respect to the resident population. As far as the touristic flows are concerned, it is important to know:

a) number and typology of touristic infrastructures such as hotels/campsites/residences/restaurants. Moreover, for each of them: accommodation capacity, location (whether in rural, urban, coastal area), presence of a green park or agricultural soil inside the property;
b) organization of the harbour authority, number of incoming pleasure boats;

4) Geographical aspects: coast extension, nature of the beaches (if sandy or rocky), orography. These data give useful information about the accessibility of different sites spread over the targeted territories and the organization of waste plastic collection from the coast

2.1.2 Waste management

This section should give a detailed description of waste production and how the collection, logistics, treatment facilities operate in targeted territories, and also some hints about the national waste management framework.

In particular, data regarding the following has to be collected:

1) Waste production: yearly quantities of the total amount and single categories such as: packaging (made up of the following materials: paper, plastics, glass, wood,…), bulky, electric and electronic equipment,… . Waste composition of the mixed waste fraction, in order to assess the effectiveness of the kitchen waste separate collection;
2) Separate collection management. This means to give a list of different typologies of collected waste categories: single materials (food scraps, plastics, paper and cardboard,…), "mixed materials" which includes glass bottles, tin cans, plastic food containers, aluminum foil. In addition, one has to indicate the weekly frequency and the mode of collection (door-to-door, through special roadside containers, ecological common area). In case of an insular territory, it is asked if it is provided with a storage station and/or a transshipping station;
3) Logistics. It is important to know how waste shipment to treatment facilities is organized. With regard to the typology of territory, whether an island or a coastal area, waste can be land or sea transferred. It is asked to indicate the frequency of the trip on a weekly or monthly basis and the distances to be travelled by the ship in each journey, capacity load of the ship, consumed fuel (it would be preferable to provide these data on a seasonal base or at least referring to winter and

summer periods). In case of land transportation, it is asked to provide typology of collection trucks (model, fuel consumption etc.), average daily distance run by the trucks to the collection points.

4) The fate of the waste. Destination of each fraction after the collection (landfills and/or treatment plants and their localization). For each treatment plant, information about output streams (quantity and typology. For instance: compost, biogas, digestate, electricity, heat, recycled materials), energy consumption and production, emissions (whether gaseous, liquid or solid residues) and their environmental impact will be asked.

2.1.3 Costs

This section is aimed at the collection of data regarding:

1) Personnel costs in different steps (collection, transport, treatment);
2) Operating costs of transport trucks and ships, waste collection management, gate fee of the treatment facilities;
3) Maintenance costs of transport trucks and ships, of collection points, of treatment plants etc.

2.2 Survey model

Hereinafter, all the details regarding the survey contents are given in a summary table, together with information regarding the actors to be involved/able to provide data for each aspect. At the aim of ensuring the systematization of data collection, and also to enable database set up and data elaboration, the survey has been implemented in an excel file (attachment A.1)

SECTION 1 – GENERAL FIGURES

Survey item	**Relevant Institutions/companies/data sources etc.**
• Territory description (surface area km^2, number of residents)	Municipality / National Institute of Statistics
Rural, urban and coastal areas identification	Municipality
Main distances and routes among all above mentioned residential areas	Municipality (municipal technical dept. employees)

Description of touristic flows (number of tourists in summertime), number and typology of touristic infrastructures such as hotels/residences/restaurants	Municipality (municipal technical dept. employees)
Details for touristic infrastructures and schools	Municipality (municipal technical dept. employees, office of the touristic councilor employees)
Hotels (general data)	*Total number*
Hotels (specific data for each one)	*Name, Address* *Capacity (n° of guests/clients)* *Possible presence of catering services* *Opening times in the year* *Number of served meals in the year* *Presence of a backyard/agricultural ground (YES/NO)* *If YES, surface of the backyard*
Restaurants (general data)	*Total number*
Hotels (specific data for each one)	*Name, Address* *Capacity (n° of guests/clients)* *Opening times in the year* *Number of served meals in the year* *Presence of a backyard/agricultural ground (YES/NO)* *If YES, surface of the backyard*
Campsites (general data)	*Total number*
Campsites (specific data for each one)	*Name, Address* *Capacity (n° of guests/clients)* *Possible presence of catering services* *Opening times in the year* *Number of served meals in the year* *Presence of a backyard/agricultural ground (YES/NO)* *If YES, surface of the backyard*
Schools provided with kitchen and catering services (general data)	*Total number*
	Name, Address

Schools provided with kitchen and catering services (specific data for each one)	*Number of pupils and range of age* *Local canteen where meals are prepared (YES/NO)* *Presence of a backyard/agricultural ground (YES/NO)* *If YES, surface of the backyard*
Touristic Harbours	*Total number*
Details about the organization of touristic harbour activity	*Address and contacts of harbor authority* *Number of incoming pleasure boats on summer and winter* *Number of catering services*

SECTION 2 – WASTE MANAGEMENT

Survey item	**Relevant Institutions/companies/data sources etc.**
Waste management organisation at national level	National Environment Protection Agency
Public System	*YES/NO*
Managed by the extended producer responsibility	*YES/NO*
Waste production data: (yearly quantities in t/y)	*Organic waste* *Paper and cardboard* *Plastics* *Metal* *Glass* *Bulky* *Waste Electric and Electronic Equipment (WEEE)* *Mixed municipal waste* *Other categories*
Waste management organisation in the targeted territory	Municipality, local company in charge of the local waste management, office of the environment councilor, municipal technical dept
Public System	*YES/NO*
Managed by the extended producer responsibility	*YES/NO*
Waste production data: (yearly quantities in t/y)	*Organic waste* *Paper and cardboard*

Plastics
Metal
Glass
Bulky
Waste Electric and Electronic Equipment (WEEE)
Mixed municipal waste
Other categories

Description of the waste collection system
Who (institution, public or private company) is in charge for waste collection?
Is it allowed to organise an autonomous collection system for special categories of waste?
Who is in charge to receive the separate collected waste? Which subject does take the responsibility for waste collection?
How the separate collection is funded? By tax payment applied by the municipality to citizens ? Is there any difference with respect to commercial licenses, shops?

Details of the waste separate collection system

door-to-door	*Waste categories involved: organic waste, paper and cardboard, plastics, metal, glass, bulky, WEEE, Mixed municipal waste* *Collection frequency for each category: organic waste, paper and cardboard, plastics, metal, glass, bulky, WEEE, Mixed municipal waste*
roadside containers	*Waste categories involved: organic waste, paper and cardboard, plastics, metal, glass, bulky, WEEE, Mixed municipal waste* *Collection frequency for each category: organic waste, paper and cardboard, plastics, metal, glass, bulky, WEEE, Mixed municipal waste*
eco-compactors, also called "ecological islands" i.e. automated systems for the collection and	*Waste categories involved: organic waste, paper and cardboard, plastics, metal, glass, bulky, WEEE, Mixed municipal waste* *Collection frequency for each category: organic waste, paper and cardboard, plastics, metal, glass, bulky, WEEE, Mixed municipal waste* *Eco-compactor characteristics:*

compaction of waste	*Integrated access control system (YES/NO), and the related foreseen procedures for the citizen/user (i.e. personal health card, tax card,…). Data recording (are quantity and quality of the disposed waste by the single user recorded by the system?).* *Alarm/security systems (is the ecocompactor provided with a system that prevents introduction of further waste if itgets full?)*
Fate of collected waste	Municipality, waste collection company representative waste treatment companies representatives, visit to related facilities
Typology of waste treatment for each waste category	*Waste selection treatment plant, recycling plant, aerobic digester, waste-to-energy, anaerobic digester, other*
Treatment plants general information (details for each treatment plant, referred to the last available year of operation)	*Company name* *Treatment plant address* *Input capacity* *Output products* *Nominal energy consumption (i.e. electric power absorbance, MW)* *Nominal produced energy* *Solid residues* *Fate of the solid residues* *Gaseous emissions* *Fate of the gaseous emissions* *Liquid effluents* *Fate of the liquid effluents*
Treatment plants specific data (details for each treatment plant, referred to the last available year of operation)	*Quantity and typology of treated waste* *Quantity and typology of output products* *Quantities of gaseous emissions* *Quantities of liquid emissions* *Quantity of solid residues* *Produced electric energy* *Produced thermal energy* *Electric energy consumption* *Thermal energy consumption*

	Waste transport route from the collection point to the waste treatment plant
Waste transport details	*Typology of collection trucks used (model, volume/weight capacity, fuel consumption)*
Waste transport details (island case)	*Number of trips planned by the ship concessionaire* *Distance travelled by the ship in each journey* *Capacity load of the ship* *Fuel consumption (it would be preferable to provide these data on a seasonal base or at least referring to winter and summer periods)*

SECTION 3 – COSTS

Survey item	**Relevant Institutions/companies/data sources etc.**
Waste Tax amount applied to citizens Cost items of the waste tax applied to citizens (i.e. if there is a fixed and variable fraction and related percentage)	Municipal waste management regulation, meeting with the environment councilor of the municipality meeting with the responsible of the municipal technical department
Gate fee for the treatment facilities	Waste treatment plant company
waste collection personnel costs	Municipality, company responsible for the waste collection service
Operating costs of waste transport service (trucks, ships, other) Maintenance costs of waste collection points (roadside containers, ecological islands,…)	Meeting with the company responsible for the waste collection service

All the data collected through the survey will allow the baseline construction for the targeted territory, thus describing the situation as it appears before the intervention to be realised by the project. This baseline will highlight critical aspects/parameters, constituting the basis for comparisons and estimations of the benefits related to each intervention. In this regard, other information regarding each targeted area are necessary and, therefore, an additional section of the survey was provided at this aim (intended to be completed with the support of local stakeholders and authorities, such as environment councilor office, municipal technical department, waste collection service company etc. and site inspections).

SECTION 4 – TARGETED AREA DESCRIPTION

For each targeted area where the pilot action is supposed to be carried out, please indicate:	Name of the area Address of the installation of composters Define the geographical borders on a map around the selected area The related covered surface area (km^2) The number of inhabitants involved in the pilot action The presence of residential districts involved The presence of touristic infrastructures involved (which ones ? refer to the previous survey) The organic waste production due to inhabitants and to touristic infrastructures involved In the pilot action The transport route ran by the waste transport truck for organic waste collection The weekly frequency of the organic waste transportation service (in the winter and the summer season) The costs of the organic waste transportation service to serve the targeted area The tax cost for the organic waste management per inhabitant of the targeted area

2.3 Survey implementation

In order to ensure a complete and systematic data collection, the methodology should engage all the relevant actors of the territory concerned with waste production/management issues. In this regard, a two-steps approach is considered appropriate.

Therefore, a first step will consist in the submission (e.g. via email) of the focused survey to all the subjects directly involved in waste management system (Municipality, waste management companies, etc.), so to obtain data according to the specification of previous sections.

Anyway, to support data collection, a second step consisting in a site inspection, which foresees the visit of the territory and meetings with local stakeholder (e.g. managers of touristic infrastructures), is considered a key action.
In the framework of WP3, following the methodological approach described, the survey was sent to all contact people of each partner involved in the task activity (i.e.: GAL MOLISE, CISTOCA) and of the Lead Project (ZADAR), and specific site inspection was organized in the targeted territories.

3. Guideline to acquire the waste composition figure

In order to properly identify the actual state of the art of waste management, and also to provide clear data to support the definition of strategies and methodologies for the targeted areas, the acquisition of field data is very significant.
This section is therefore focused on defining a common methodology to acquire data regarding organic and plastic waste inside the unsorted urban waste, since it represents an essential starting point to understand the opportunity to develop sustainable waste management alternative (such as small scale composting or specific procedures to allow plastics recycling).
Furthermore, in the light of defining sustainable waste management alternatives, a common methodology to sample and acquire data regarding beach litter is given in this section.

3.1 Municipal solid waste

3.1.1 Fundamentals of the methodology

The methodology consists of a waste characterization based on reference technical standards and guidelines. More in detail, the official documents considered are:

- UNI 10802:2013 “Wastes - Manual sampling and preparation of sample and analysis of eluates” [1]. This Italian National Standard applies to all types of waste (such as liquid waste, liquefied by heating, liquid sludge, past-like sludge, powders or granular waste, coarse waste and monolithic waste) and describes:
  - the process of defining a sampling plan;
  - manual sampling of liquid, granular, past-like, coarse, monolithic and sludge in relation to their different physical and short-term storage;
  - procedures for reducing the size of the samples of the waste collected in the field, to facilitate transport in the laboratory;

- documentation for the traceability of sampling operations;
- procedures for packaging, preservation, sample short-term storage and transport of samples of waste;
- procedures for reducing the size of samples for laboratory analysis;
- procedures for preparation and analysis of eluates.

- ANPA RTI CTNRIF 1/2000 "Composition analysis of municipal waste" [2], by the Italian National Agency for Environmental Protection, which provides a wide description of the most important methodologies for the characterisation of municipal solid waste, and introduces a new procedure as a reference at the national level.
- COREPLA Method AQ14, i.e. guidelines for waste plastics sampling edited by the Italian National Consortium for waste plastics packaging collection and recovery [3].

3.1.2 Sample and procedure

A large 5 m^3 container belonging to the typology used in roadside waste collection is emptied on to a floor covered with a large transparent plastic sheet.

To handle the sample and complete the procedures, involved operators should be equipped with safety dress and, in particular:

- disposable coverall;
- half mask provided with combination ABEK filters;
- disposable high resistant gloves.

Figure 1. – Emptying of the roadside container

The starting sample, therefore, consist of an of 100 kg of Mixed municipal waste obtained from roadside waste collection system. This waste fraction can contains all waste materials.

The larger size fraction has to be removed and manually and divided into the following categories: organic, plastic containers, glass, metal, paper.

Waste fragments with a size lower than 20 mm should not be considered in the analysis. At this aim, they are removed from the Mixed municipal waste through a screen similar to the screen shown in Figure 2.

Figure 2. – Removing fragments with a size lower than 20 mm

Figure 3. –screening of the Mixed municipal waste sample withdrawn from the waste container

Once separated the "unders", the Mixed municipal waste is treated by the so called "Coning and Quartering" technique ([2], [4]) (see Figure 4).

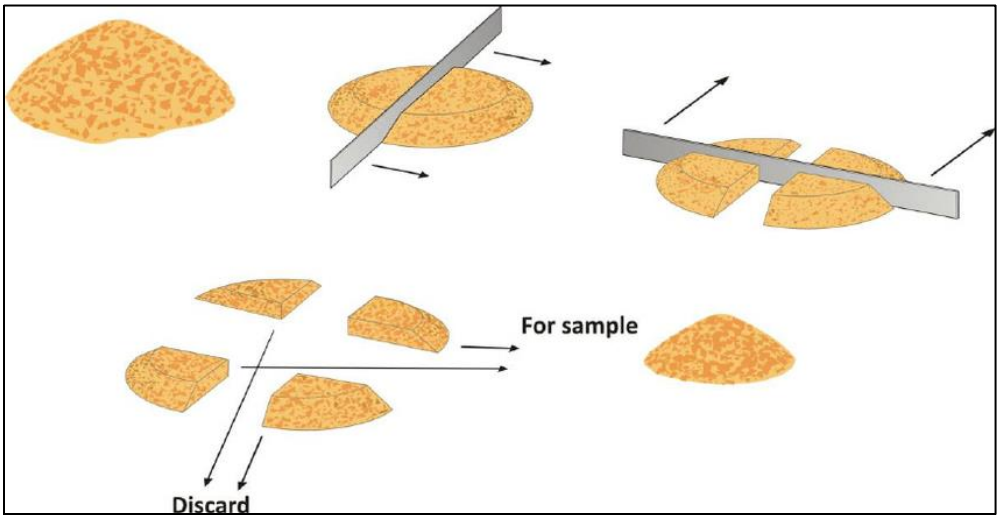


Figure 4. – coning and quarterly method

Then, the various waste category fractions are manually separated and weighed. The weight is measured by filling a bucket with a single separated waste category (i.e., organic, paper,…), hooking and weighing by an industrial hook weight meter like the one reported in
Figure 5.

Buckets

industrial hook weight meter

Figure 5. – equipment to weigh samples of single waste categories

3.1.3 Waste composition form

In order to provide clear and uniform data, and also to facilitate data elaboration in the light of defining strategies and methodologies for a sustainable waste management, results of the analysis described in the previous section should be reported in a form containing at least the following categorization.

Waste category	European waste catalogue number	Weight (kg)	Percentage (%)
Kitchen waste			
Yard waste			
Paper and cardboard			
Glass			
Plastics			
Metals			
Wood			
WEEE			
Hazardous waste			
Inert waste			
Residual			
Underscreen			

A more detailed classification that provides more specific categories (for instance, regarding plastics, Clear PET bottles, Green PET bottles, Mixed flexible plastic, etc.) is considered an improvement useful to define specific pre-treatment/treatment activities of the different materials.

3.2 Beach litter

3.2.1 Fundamentals of the methodology

In order to quantify and characterise litter pollution on the coastline and provide reliable data to support the definition of effective management strategies, the common methodology here presented has been based on the long-time experience of the project partners, but also considering relevant documents and, in particular:

- The "Guidance on Monitoring of Marine Litter in European Seas" by the Institute for Environment and Sustainability of the Joint Research Centre [5], which describes specific protocols and considerations to collect, report and asses data on marine litter (in particular beach litter, floating litter, seafloor litter, litter in biota and microlitter), so to provide recommendations and information needed to commence the monitoring of the Marine Strategy Framework Directive (MSFD) Descriptor 10.

3.2.2 Sample and procedure

The sampling site should have features of interest for monitoring the effects of pollution. In general, in order to consider different types of effects, 4 different coastal typologies could be considered:

- urbanized areas;
- river mouths;
- port areas;
- remote areas.

Moreover, sampling sites (i.e. beaches) should be chosen taking into account the following criteria:

- composed of sand or gravel;
- exposed to the open sea;
- accessible to samplers all year round;
- minimum length of 100 meters (50 meters for heavily polluted areas);
- clear access to the sea (not blocked by breakwaters or jetties));

- moderate slopes (15 - 45°);
- no other collection activities during the year (e.g. bathing beaches).

Sampling units – i.e. fixed sections of beach covering the whole area between the water edges (where possible and safe) or from the strandline to the back of the beach – within the chosen beach should be

- at least 2 sections of 100m on the same beach for lightly to moderately littered beaches;
- at least 2 sections of 50 m for heavily littered beaches.

Anyway different sampling units representative of the beach state can be chosen according to specific site characteristics (for instance, during the project activities in Campomarino a sampling unit 30 m long and 7 meter wide was selected).

A sieve of 20 mm should be utilised to remove all fragments under this size and the over-sieve-fraction has to be manually collected and stored into large bags or containers for further analyses and measurements. All objects found on the sampling unit should be separated according to a master list of litter categories and items (Figure 6 – Figure 8).

Marine litter on the beachside of Campomarino before Camping Corrado

Marine litter sampling operations

Delimited area for marine litter sampling operations

Marine litter sampling operations

Plastics collected from marine litter

Detail of a mussels net

Figure 6.


Plugs

Mussels nets



Sample of heterogeneous plastics fragments. The size is above 2 cm


Polyestyrene fragments Cotton bud sticks

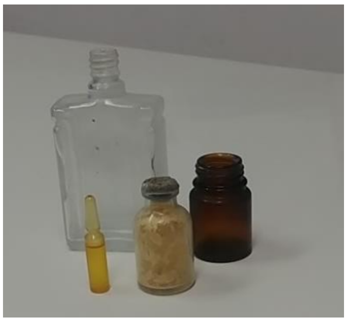
Figure 7.

Large plastic containers, jugs, hard plastic fragments

Heterogeneous plastics fragments Mix of damaged plastics and flip-flop

Lighters

Straws



Glass containers

Plastic cups

Figure 8.

3.2.3 Beach litter composition form

Collected litter should be then assessed by number, weight or volume. The assessment of the volume of litter is also difficult because it depends on the level of compression of the litter involved. On the other hand, the assessment of weight of litter is difficult because it depends on whether litter items are wet or dry and often whether they are covered with or full of sand and gravel. Moreover, some items can be directly weighed (Figure 9), while others could be even too big to be weighed and their weight must be estimated through a count and known average weights.

Plastic rope

Cigarette butts

Damaged mixed plastics

syringes

Figure 9.

In order to provide clear and uniform data, and also to facilitate data elaboration in the light of defining strategies and methodologies for a sustainable waste management, it is therefore preferably to carry out an assessment by a combination of different units: number, weight or volume. In this regard it is suggested to report the results of the analysis described in the previous section in a form like the following.

Item	Quantity (n°)	Weight (kg)		%
		Directly weighed	Estimated	
Heterogeneous plastics fragments (size above 2 cm)				
Heterogeneous plastic fragments (under 2 cm)				
Plugs				
Mussels nets				
Polystyrene fragments				
Straw fragments				
Mix of damaged plastics				
Flip flops				
Plastic cups				
Plastic bottles				
Plastic containers				
Cotton bud sticks				
Syringes				
Plastic toothbrush				
Plastic ropes				
Lighters				

Syringes

Metals

Cigarette butts

glass

Sand

TOTAL

4. Environmental assessment methodology: Life Cycle Assessment

4.1 Introduction

Within the NETWAP project, ENEA is responsible for assessing the environmental aspects of the implemented pilot actions. This task will be carried out by performing a Life Cycle Assessment (LCA) analysis.
LCA is a structured, comprehensive and internationally standardized method. It quantifies all relevant emissions and resources consumed, their related environmental and health impacts, and resource depletion issues that are associated with any good or service delivered by a process ("products"). LCA takes into account a product's full life cycle from "cradle to grave": the extraction of resources, through production, use, recycling, up to the final disposal of process waste and product after its useful life. Early forms of LCA were used in the United States in the late 1960s for defining corporate environmental strategy, and later in the 1970s by government agencies as an aid for developing public policy. The Society for Environmental Toxicology and Chemistry (SETAC) in 1991 published "A Technical Framework for Life Cycle Assessments", the first attempt at an international LCA standard. It explicitly outlined the components of contemporary LCA: goal definition, inventory assessment, impact assessment and improvement analysis. SETAC paved the way for the use of LCA as a comprehensive decision support tool. In the late 1990s, LCA emerged as a worldwide environmental management tool in the form of the ISO 14040 series. The International Organisation for Standardization (ISO) released the ISO 14040 series on LCA as an adjunct to the ISO 14000 Environmental Management Standards. The series included standards

for goal and scope definition and inventory assessment (ISO 14041), impact assessment (ISO 14042), and interpretation (ISO 14043), as well as a general introductory framework (ISO 14040). The second edition of ISO 14000 standards (2006) replaced the previous versions and delivered the standards ISO 14040:2006 [6] and ISO 14044:2006 [7] where all the previous statements were included, with updates and improvements. The LCA methodologies were originally developed to create decision support tools for distinguishing between products, product systems or services on environmental grounds. During the evolution of LCA, a number of related applications emerged. Some examples are:

- Internal industrial use in product development and improvement.
- Internal strategic planning and policy decision support in industry.
- External industrial use for marketing purposes.
- Governmental policy making in the areas of Ecolabelling, Green Procurement, Environmental Product Declaration, Integrated Product Policy, and waste management opportunities.

The list is not exhaustive, but indicates that there is a wide variety of applications. This variety is also reflected in the level of sophistication and to some extent in the choice of methodology as well. In order to produce a general guide on the environmental implications of the whole supply-chain of products, the European Commission released a handbook on best practices in Life Cycle Assessment. The International Reference Life Cycle Data System (ILCD) Handbook [8] allows to support governments and business with a detailed description of quality and consistency of data, phases, methods and assessments of the life cycle, thus providing technical guidance for detailed Life Cycle Assessment based on and consistent with the ISO 14040 and 14044 standards.

In such a framework, Life Cycle Assessment (LCA) becomes a tool to assess each and every impact associated with all the stages of a process from "cradle to grave" or better from "cradle to cradle", including recycling and reclamation of degraded environmental resources. It includes consideration of re-use or recycling options in order to achieve a "zero emission" strategy for maximum resource use and minimum waste production. Evaluating the full range of effects on the environment of the investigated systems (process or products), LCA represents one of the tools for:

- identifying opportunities to improve the environmental performance of products at various points in their life cycle;
- informing decision-makers in industry, government or non-government organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign), for the selection of relevant indicators of environmental performance, including measurement techniques;
- marketing (e.g. implementing an ecolabelling scheme, making an environmental claim or producing an environmental product declaration).

This definition underlines that LCA consists of both analytical and procedural aspects: LCA helps not only to study the expected environmental impacts of a given process or product (analytical part), but also to ensure that the results of such a study can actually influence the decision making process concerning the investigated system and its product(s) (procedural part). The analytical aspects involve methods and techniques that are required to assess the environmental impacts of a product (or process). Such methods and techniques have been proposed by academics, experts and practitioners and usually collected in guidelines, handbooks (for instance ILCD Handbook), and continuously improved. The procedural aspects define the role, giving a comprehensive transparency and consistency overview of the investigated system. Results shall be presented in sufficient detail to allow the reader (technical or non-technical expert) to understand the complexities and trade-offs inherent in the study and LCA in general. LCA is regulated by a common regulative framework (ISO 14040, 14044:2006) around the world that allows to have a standard set of organised stages leading to the generation of a formal procedure. The next sections describe the LCA stages and the role played by the different actors in detail.

4.2 Phases of an LCA

The International Organisation for Standardization (ISO 14040, 14044: 2006) established four phases for an LCA:

- Goal and scope definitions
- Inventory analysis
- Impact assessment
- Interpretation

This scheme has been more recently amended splitting the first stage into two separate phases [8] with the aim to emphasize the importance of a clear and detailed definition of the goal and scope steps. The basic structure of an LCA follows the scheme in **Pogreška! Izvor reference nije pronađen.**10.

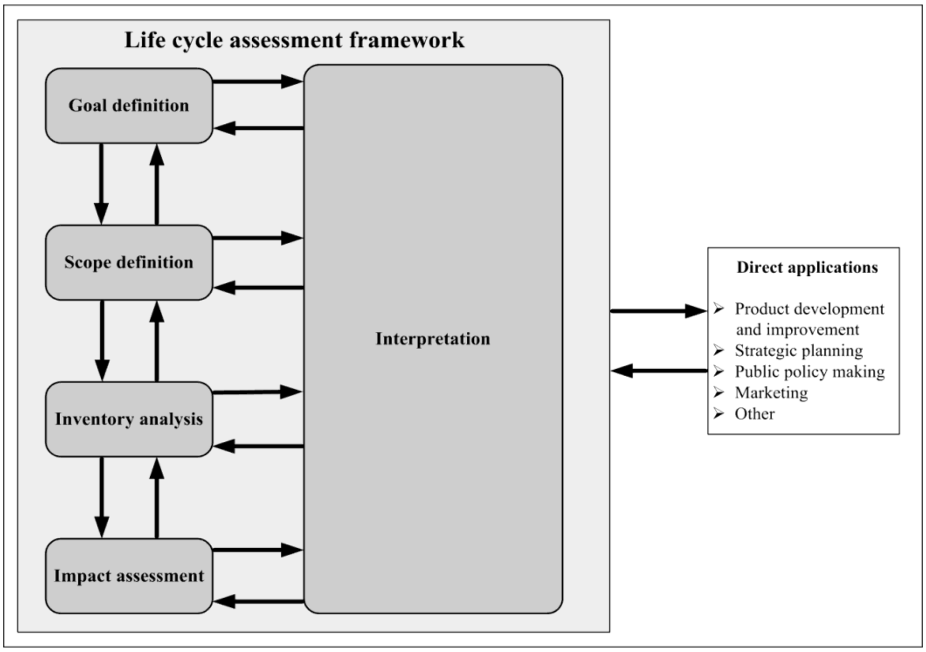


Figure 10 - Framework for life cycle assessment (from [3]).

Performing an LCA is an iterative process: once the goal of the work is defined, the initial scope settings, that define the requirements on the subsequent work, are derived. However, as more information becomes available during the life cycle inventory step of data collection and the subsequent impact assessment and interpretation steps, the initial goal and scope setting will typically need to be refined and sometimes also revised. The double arrows between phases (**Pogreška! Izvor reference nije pronađen.**) indicate the typical interactive nature of LCA, that contributes to the comprehensiveness and consistency of the study and the reported results. These main characteristics of the tool can be recognized in that there is no one way to make a life cycle assessment and also that the technique can be applied with different levels of sophistication, as long as the life cycle approach to assess choices is retained. Irrespective of the chosen level of sophistication, there are basic requirements to the LCA, i.e. clear and explicit statement of study purpose and goal and reference to the methodology used (e.g. definition of functional units, system boundaries, allocation criteria etc.). These requirements can be summarised as a need for transparency in the study, in order to make the abovementioned conditions clear to the readers of the LCA report.

4.3 Goal definition: Identifying purpose and target audience

The goal definition is the first, decisive phase of any life cycle assessment. During the goal definition, the decision-context of the study and the intended applications of the results are defined. Moreover, the targeted audiences are named and in turn the frame for LCA work is set. A clear, initial goal definition is hence essential for a correct later interpretation of the results. This includes ensuring as far as possible that the deliverables of the LCA study cannot unintentionally and erroneously be used or interpreted beyond the initial goal and scope for which it was carried out. The goal of an LCA shall:

- describe the intended application(s) of the LCA results in a precise and unambiguous way;
- describe limitations due to the method, assumptions and impact coverage;
- explain the reasons for carrying out the LCA study, name drivers and motivations, and especially identify the decision-context;
- identify the target audience of the study (i.e. to whom the results of the study are intended to be communicated);
- list explicitly the results in comparative assertions intended to be disclosed to the public;
- name who commissioned the study.

Sometimes, elements of the goal definition are, possibly inadvertently, performed in a way that leads to misleading results. In order to avoid confusion, goal definition has to be very specific and condensed in a way that leads the reader not to misunderstand, misinterpret or generalize.

4.4 Scope definition: What to analyze and how

According to ILCD Handbook and ISO 14044:2006, during the scope definition phase the object of the LCA study (i.e. the exact product or other system(s) to be analyzed) is identified and defined in detail. This shall be done in line with the goal definition. The main task of the scope definition is to derive the requirements on methodology, quality, reporting and review, in accordance with the goal of the study (i.e. the reasons for the study, the decision-context, the intended applications, and the addresses of the results). The scope should be sufficiently well defined as to ensure that the breadth, depth and details of the study are compatible and adequate to address the stated goal.

The scope includes the following items:

- product system to be studied;

- functions of the product system or, in case of comparative studies, of the systems;
- functional unit;
- system boundary;
- allocation procedures;
- life cycle inventory analysis (LCIA) methodology and types of impacts;
- interpretation to be used;
- data requirements;
- assumptions;
- value choices and optional elements;
- limitations;
- data quality requirements;
- type of critical review, if any;
- type and format of the report required for the study.

The system's function and functional unit are central elements of an LCA (Table 1). Without a proper definition of these two items, a meaningful and valid comparison, especially of products, is impossible. Within an LCA, "function" means to quantitatively and qualitatively specify the analyzed object. This is generally done by using the functional unit that names and quantifies the qualitative and quantitative aspects. All data collected in the inventory phase will be related to the functional unit. It is important to note that not all systems have clear or unique functional units, and that the number of possible applications and hence functional units is sometimes extremely large to virtually indefinite. In such cases where one or few relevant functional units cannot be given, it is crucial to clearly and both quantitatively and qualitatively identify the reference flow, as well as the detailed name of the product, plus further information that identify its relevant characteristics and the location-type. Another important aspect is to define the system boundaries so that unit processes (and all related inputs and outputs) can be included within the LCA. It is helpful to describe a system using a process flow diagram showing the unit processes (input and output flows) and their inter-relationships. No specific rules are given in the ISO standards about diagrams. In a comparative study, the equivalence of the systems being compared shall be assessed before interpreting the results. Consequently, the scope of the study shall be defined in such a way that the systems can be compared. The same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures, decision rules on evaluating inputs and outputs and impact assessment, will be used for the systems analyzed. Any difference between systems regarding these parameters will be identified and reported in the critical review.

Table 1 - Key Terms and definitions of scope phase (from [2]).

Key terms	Key definitions
Input	Product, material or energy flow that enters a unit process.
Output	Product, material or energy flow that leaves a unit process system boundary: set of criteria specifying which unit processes are part of a product system.
Co-product	Any of two or more products coming from the same unit process or product system.
Allocation	Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.
Functional unit	Quantified performance of a product system for use as a reference unit.
Critical review	Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment.

4.5 Life cycle inventory analysis (LCI): quantifying resource consumption and emission

Within an LCA, the Life Cycle Inventory (LCI) phase requires the highest efforts and resources for data collection, acquisition and modelling. The inventory stage involves the collection of the following typologies of data: elementary flows (such as resources and emissions but also other interventions with the ecosphere such as land use), product flows (i.e. goods and services both as "product" of a process and as input/consumables) and waste flows (both wastewater and solid/liquid wastes). The collected data, whether measured, calculated or estimated, are utilized to quantify the inputs and outputs of a unit process. In this phase the resource depletion (raw material, water, and recycled products), the energy use and the airborne, waterborne and soil emissions (making a mass balance) are also identified. A life cycle inventory requires (**Pogreška! Izvor reference nije pronađen.**):

- drawing unspecific process flow diagrams that outline all the unit processes to be modeled, including their interrelationships;
- describing each unit process in detail with respect to factors influencing inputs and outputs;
- listing flows and relevant data for operating conditions associated with each unit process;
- developing a list that specifies the units used;
- describing the data collection and calculation techniques needed for all data;
- providing instructions to clearly document special cases, irregularities or other items associated with the data provided;
- refining the system boundary;
- calculating and validating results;
- solving multi-functionality of processes in the systems by: dividing the process (subdivision); expanding the system boundaries (substitution); using the allocation.

Data collection is often the most demanding part of a LCA, especially if site-specific data are required for each single process in the life cycle. In many cases, average data from literature (often deriving from previous investigations of the same or similar product or material) or data from trade organisations are used.

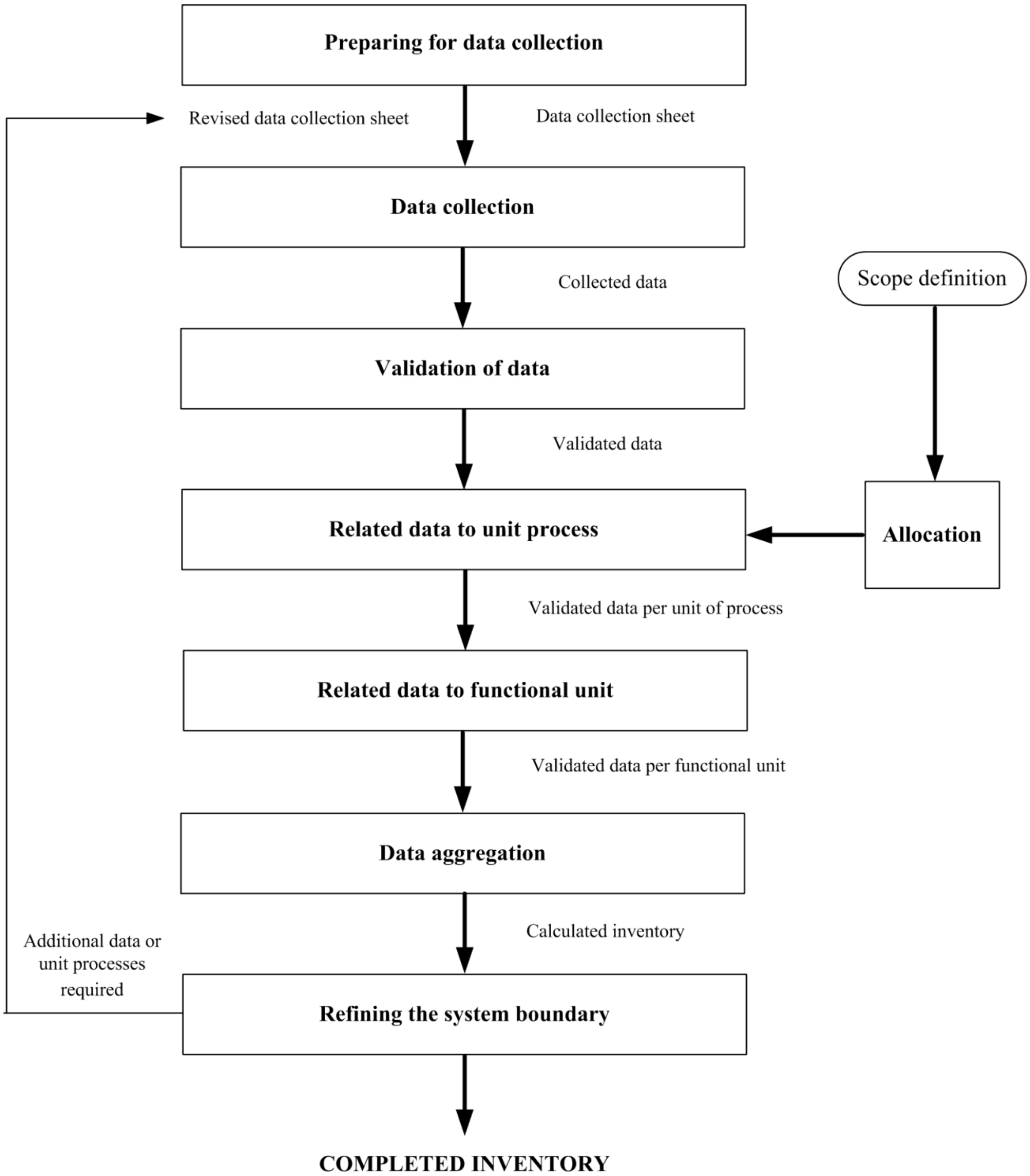


Figure 11 - Simplified procedures for inventory analysis (modified from [8]).

The LCA method is based on a single system (mono-functional processes) and aims at determining the specific environmental impact which can be related to its life cycle. The complication created by a multifunctional process (two or more products) can be avoided by: 1) dividing the unit process into two or more sub-processes and collecting the input and output data related to these mono-functional processes (subdivision); 2) expanding the product system to include the additional functions related to the co-products, taking into account their requirements (substitution); 3) using, as last option, the allocation. There is not a reference rule for the allocation: the starting point is a good knowledge of the productive process. The allocation can be done in several different ways: mass allocation is based on the mass of different products; economic allocation, widely used, is based on the economic value of different products; energy allocation is based on the energy content of different products. Production costs and burdens of products are calculated by dividing the allocated support flows by the mass, energy or money value of each kind of product. In conclusion, drawing up an inventory is a critical phase and it must be done taking into account also the following information:

- the time period to which the data refer;
- the geographical region wherein the data were collected;
- the type of technology to which the data refer (i.e. outdated, worst-case, average, modern, best-available, future prediction);
- the representativeness of the data (i.e. obtained from a single process, average of several similar processes, theoretical calculation);
- the source of the data (a clear reference);
- the allocation rules adopted in case of by-products.

4.6 Life cycle impact assessment (LCIA): quantifying potential environmental impacts

Life Cycle Impact Assessment (LCIA) is the fourth phase in an LCA where all input and output flows, that have been collected and reported in the LCI phase, are translated into impact indicators related to human health, natural environment and resource depletion. The results of LCIA should be seen as potential environmentally relevant impact indicators, rather than predictions of actual environmental effects [3]. According to [3], an LCIA is composed of mandatory and optional steps. The LCIA phase shall include the following mandatory elements:

- selection of impact categories, category indicators and characterization models;
- assignment of LCI results to the selected impact categories (classification);
- calculation of category indicator results (characterization).

Whenever impact categories, category indicators and characterization models are selected in an LCA, the related information and sources shall be referenced.

As above mentioned, all the input materials and emissions from LCI have been classified into different impact categories, according to the type of impact that they may have on the environment. The classification of the environmental impact categories can be split in two broad sets: those that are focused on the amount of resources used per unit of product ("upstream" categories), and those that deal with the consequences of the system's emissions ("downstream" categories). Among the former, the following (or some variations thereof) are the most commonly addressed:

- Abiotic Resource Depletion
- Biotic Resource Depletion
- Water Resource Depletion
- Commercial Primary Energy Resource Requirement
- Land Use

Among the "Downstream" impact categories, the focus is most commonly placed on:

- Greenhouse Effect Enhancement (Global Warming)
- Acidification
- Stratospheric Ozone Layer Depletion
- Water Body Eutrophication
- Photochemical Oxidation and Tropospheric Ozone Formation
- Human Toxicity
- Eco-toxicity

Since a single input or output can often potentially affect more than one environmental impact category, this classification results in several long lists in which the same items may appear several times. The calculation of indicator results (characterization) involves the conversion of LCI results to common units and the aggregation of the converted results within the same impact category. Impact in the upstream categories is usually assessed by multiplying each input item by the total amount of primary resources (i.e. water, non-renewable primary energy, etc.) that is necessary for the production and delivery of one unit of that particular input. The resulting total is a cumulative indicator of the system's impact in the considered category. For downstream categories, on the other hand, the impact indicators are calculated by summing together the category-relevant system's outputs (emissions and wastes), prior multiplication by appropriate characterization factors. The latter are numerical multipliers representing the amount of a given reference compound (e.g. SO_2 for the Acidification category) which, if emitted, would have a quantitatively comparable effect on the environment to one unit of the actual system emission being considered.

In addition to the mandatory elements, other optional ones can be included:

- normalization: calculating the magnitude of category indicator results relative to reference information;
- grouping: sorting (e.g. by characteristics such as inputs and outputs or global regional and local spatial scales) and possibly ranking (e.g. high, medium and low priority) the impact categories;
- weighting: converting and possibly aggregating indicator results across impact categories using numerical factors based on value-choices;
- data quality analysis: better understanding the reliability of the collection of indicator results using uncertainty analysis, sensitivity analysis etc.

The application and use of normalization, grouping and weighting methods shall be consistent with the goal and scope of the LCA and it shall be fully transparent, by documenting all methods and calculations used. Normalisation and weighting are of particular importance to demonstrate the robustness of the analysis and to help in the interpretation phase.

Normalization, in which multiplicative factors are assigned to all the considered impact indicators, facilitates the interpretation of the results by providing the end user with an indication of the comparative relevance of the environmental impact caused by the system under study in the different impact categories.

Lastly, normalized indicators can be multiplied by additional weight factors and then summed together, to produce one or more "super-indicators" of overall environmental impact. Such weighting phase is of course the most arbitrary step of the whole LCA procedure, since many of the different impact categories are really irreducible, and the choice of the weighting factors is to a large extent a political one, which bears very little if any scientific relevance.

A great variability is embedded in many aspects of LCIA as defined by [3]. In particular, the choice of the impact assessment method to be employed is left to the analyst, who is free to select that or those methods which according to his/her own experience are the most suitable for the process being studied. In so doing, the LCIA analyses can be limited to a few impact categories, and fail to take into consideration other possibly equally important aspects of the environmental performance of the process or system under study. It is appropriate to underline that there are many difficulties in valuing the final data because, at the moment, many methodological frameworks are available but no one is univocal and, as a consequence, there is a very high level of subjectivity for different impact assessments. On the other hand, the lack of a strict standardization was probably meant to provide flexibility and updatability to the LCA procedure.

4.7 Life cycle interpretation

The last stage of LCA, i.e. life cycle interpretation, is the phase where the results of previous phases are considered collectively and analysed in the light of the assumptions made throughout the LCA study. In life cycle interpretation, the results of the life cycle assessment are appraised in order to answer the questions posed in the goal definition. The interpretation phase relates to the intended applications of the LCA study and is used to develop recommendations.

The aim of interpretation is to reduce the number of quantified data and/or statements of the inventory analysis and/or impact assessment to the key results to facilitate a decision making process based on the LCA study, among other inputs. This reduction should be robust to uncertainties in data and methodologies applied and give an acceptable coverage and representation of the preceding phases. The results, data, methods, assumptions and limitations shall be transparent and presented in sufficient detail to allow the reader to comprehend the complexities and trade-offs inherent in the LCA. The report shall also allow the results and interpretation to be used in a manner consistent with the goals of the study.

In accordance with [3], there are three levels of classical reporting with different (increasing) requirements, with relation to both project reports and data set files:

- Report for internal use: not intended for disclosure to any external party outside the company or institution that has commissioned or (co)financed the study or performed the LCA work.

- Third party report: intended to document and/or communicate the results of the LCA to a third party (i.e. an interested party other than the commissioner or the LCA practitioner performing the study). It is not required to include confidential information that however needs to be available for reviewers under confidentiality agreement.
- Report on comparative studies to be disclosed to the public: it involves a comparison of products and the results are intended to be spread out. This may or may not involve reaching the conclusion of the superiority of one product or equality of the analysed products. Therefore, it can be a "comparative assertion disclosed to the public" or a non-assertive comparative study that shall be treated the same as a comparative assertion.

In conclusion, if carefully implemented and performed, a Life Cycle Assessment can be an invaluable tool for ecological management. Countless examples can be made about the ecological relevance of analysing the performance of a human-dominated (e.g. agro-industrial or industrial) system over its whole life cycle: direct and indirect processes that require water can negatively affect the local ecosystem, both on the supply side (lowering the water table, increased soil erosion, etc.) and also inevitably on the release side (pollution of water bodies, eutrophication, etc.); acidic gaseous emissions can have a strong impact on local forested land, especially in the case of low-buffer-capacity podzol-type soils; the dramatic loss of biodiversity in tropical areas is often closely linked to strip mining processes, which can be clearly identified as the main culprit within the framework of an LCA of the finished products, whereby the analyst can trace the international pathways that the various inputs followed and consequently highlight the associated environmental impacts.

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