

# IDENTIFICATION OF ONE LCC ECONOMETRIC MODEL (DT2.3.1)

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Life Cycle Costing guideline for the  
CIRCE2020 project

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Version 3  
12/2018

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## TABLE OF CONTENT

1. Introduction.....	2
2. Life Cycle Costing approach for CIRCE2020 .....	3
3. Goal and scope definition.....	5
3.1. Goal definition.....	5
3.2. Scope definition.....	6
3.2.1. Functional unit.....	6
3.2.2. System boundaries.....	7
4. Economic Life Cycle Inventory .....	10
4.1. Data collection.....	10
4.2. Allocation .....	11
4.3. Externalities.....	12
4.4. LCC tools.....	13
5. Interpretation .....	13
6. Reporting and review.....	14
7. References .....	15
8. Contact.....	16



# 1. Introduction

Profiling cross-value chain industrial symbiosis business model is one of the main goal of the CIRCE2020 project according to the project plan (see WP T2). To achieve this goal the Life Cycle Costing (LCC) methodology has been selected to design and assess economic scenarios about self-sustainability of new secondary raw materials markets (see A.T2.3.). Figure 1 describes where this economic assessment is placed within the framework of the CIRCE2020 project plan.

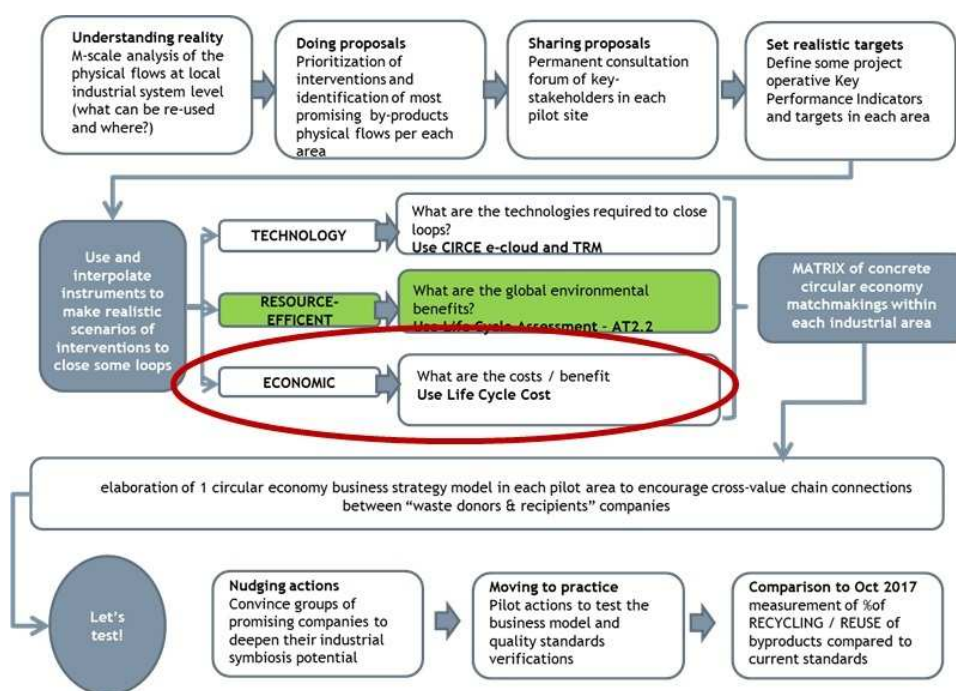


Figure 1: Economic assessment within the CIRCE2020 project plan

The present document includes an introduction about the LCC approach selected for the project (see Chapter 2) and a step by step guideline for its application (see Chapters 3-4-5-6). Considering that the LCC method needs to be applied to a wide range of waste streams and industry sectors, the guideline follows a generic approach with flexible adaptation possibilities. Where it is possible at the current status of the CIRCE2020 project, specific indications have been defined for project partners. Such specifications have been identified considering the waste management sector and the secondary raw material usage as the main application fields of the LCC method. A specific case study (production of fertilizing ammonium sulphate from landfill leachate), described by the project partner ETRA, helped the scope definition of the LCC guideline and it has been used also as an example for the clarification of certain methodological issues.

Apart from typical waste management and recovery, the CIRCE2020 project may deal also with waste prevention or other kinds of synergy developed between industrial organizations. As described above such very wide application field requested the definition of a generic LCC guideline that should be used as an internal standard document when applied for specific situations involving specific waste streams, industry sectors and circular solutions.



## 2. Life Cycle Costing approach for CIRCE2020

Even if LCC has a long history (with first applications in the 60's) there is no existing generic standard about this methodology. Distinct and different conceptual foundations and methodological approaches can be traced to its developmental roots in systems engineering. A significant variability of the existing applications depends on how exactly “life cycle” is defined. In economics it is more closely related to marketing, referring to life cycle on the markets: product development, introduction, growth, maturity, and decline. On the other hand, “life cycle” has its physical interpretation deriving from methodologies such as life cycle assessment (LCA). In this case, a life cycle is composed of production, usage and end of life of products.

Current main application of LCC technics are related to procurement [1], building sector [2] and products where use phase is typically long and costly [3].

The selection of the best LCC approach for the CIRCE2020 project started with the analysis of the project goals and with the research of available LCC literature [1-22]. The project meeting in Budapest (21-22/03/2018) offered a good occasion to clarify what exactly the project partners expect from the applied LCC and which kind of approach fits best to the project.

A major challenge within the project is related to the harmonisation of the LCC with the environmental assessment using a LCA-based method, the product environmental footprint (PEF) [23, 24]. This was one of the main reason why the physical life cycle concept has been selected for the LCC method which guarantees consistency with LCA. Within the wide LCC literature a main reference method has been identified, called Environmental LCC: a method specifically designed to be used in parallel with LCA efficiently and consistently. This LCC approach helps to avoid double work, overlaps and gaps when LCA and LCC are used in combination. The structure of the LCC is defined following the logic of the main LCA standard, ISO 14040 [25]. The main reference document is a code of practise published by SETAC, the Society of Environmental Toxicology and Chemistry [26].

According to the selected approach (see Figure 2) LCC is an assessment of all costs associated with the life cycle of a product that are directly covered by any one or more of the actors in the product life cycle (supplier, producer, user/consumer, end of life actor). Costs are the monetary value of goods and services that producers and consumers purchase, so they are real money flows, classified as:

- Internal costs: an entity (a producer, transporter, consumer or other stakeholder involved) is paying for the production, use or end-of-life expense. These costs can be treated as business expense and can be divided into costs inside and outside an organization, depending on the perspective.
- External costs cover financial costs, expressed in monetary units that are not directly borne by an actor of the product chain. Noteworthy, these costs are already priced due to their feature of being relevant for future decision-making processes. Carbon taxes or other forms of taxes on pollutants are the typical examples of external costs. [26]

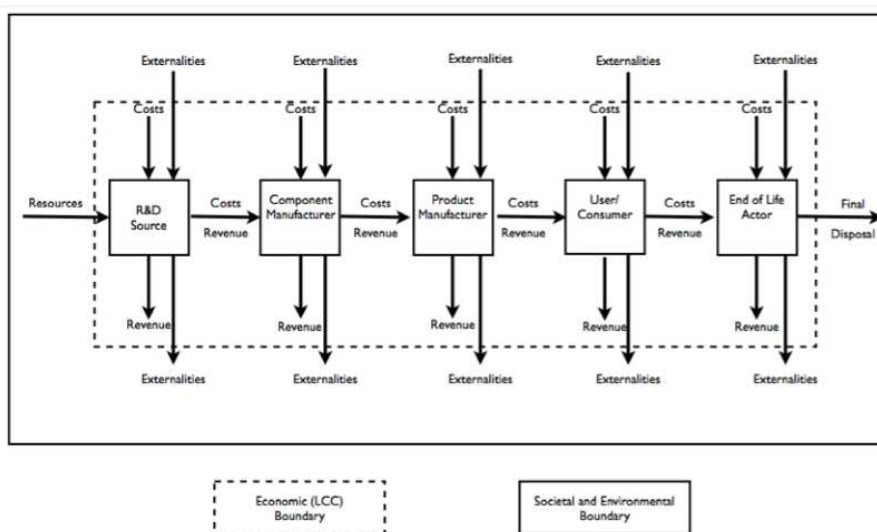


Figure 2: Conceptual framework of the selected LCC approach [26]

It is clear that the selected LCC approach is more complex compared to more “conventional” LCC approaches devoted to the assessment of only real, internal costs, sometimes even without end of life or use costs. On the other hand, there are existing LCC approaches (called Social LCC) considering not only real money flows associated with the life cycle and externalities in the decision-relevant-future but also externalities that could be monetized or even those that are difficult to monetize and may therefore only be considered qualitatively. The damage costs of emissions are possible external costs belonging to the first group, while public health and social well-being could represent externalities to be qualitatively measured. [26] The LCC approach of the CIRCE2020 project considers only optional the extension of the assessment towards social externalities because of the considerable uncertainties involved.

After having defined the LCC approach for the CIRCE2020 project it was a priority to harmonize the development of the present document with the team responsible for the LCA/PEF guideline (D.T2.2.1). It is important to highlight that the LCA/PEF guideline is based on very detailed reference documents with stringent rules [23, 24], while such reference documents do not exist for LCC. While the main challenge of the LCA/PEF guideline for the CIRCE2020 project is the simplification and applicability of the existing rigid rules, the LCC guideline has been built up based on a more flexible and generic reference. On the one hand the lack of existing strict rules for LCC can be seen as a weak-point, on the other hand it offers the possibility to easily adapt the generic indications to specific needs of project partners.

Last but not least it is important to clarify that LCC is not a method for financial accounting. It is a cost assessment and management method with the goal of estimating the costs associated with the existence of a life cycle system for comparing alternatives [26].

After the development and sharing of the first versions of the LCC guideline for the CIRCE2020 project (June-July 2018), a training was organized for the project partners (Padova, 09/10/2018). The experience of this training event helped to test and additionally improve the LCC guideline.



## 3. Goal and scope definition

### 3.1. Goal definition

In the CIRCE2020 project the following generic goals can be defined:

- to compare costs of existing “business as usual” (BAU) and new „circular economy” (CE) solutions,
- to identify costs and benefits of waste donors and/or recipients when applying CE solutions,
- to upscale the potential economic benefits of the CE solution to regional or national levels.

In the LCC studies of the CIRCE2020 project the above mentioned goals should be specified, considering that the following issues need to be clear before conducting the study [26]:

- what is the intended application,
- what is the reason for carrying out the study,
- what is the intended audience and whether the results of comparative assertions intended to be disclosed to the public.

Clear goal definition is important when costs are analysed as different actors of the life cycle chain view the costs from different perspective. In the CIRCE2020 project, the circular solutions may involve more stakeholders such as the waste donor, the waste recipient and others. When goals of the LCC study are defined it must be indicated whose perspectives are considered. (see also the “goal definition” chapter in “Deliverable D.T2.2.1 Guidelines for adaptation of LCA methodology to estimate ecological impact”)

In the following chapters a case study, described below, is used as a narrative example to clarify methodological issues. The same case study is described in the Deliverable D.T2.2.1. The present LCC guideline follows the goal and scope definition according to the perspective of the waste donor with some indications for a potential inclusion of the perspective of the waste recipient.

#### **Example case study:**

*Valorisation of landfill leachate through the production of fertiliser <sup>1</sup>*

#### **BAU solution:**

- *Management of the leachate produced by a closed-down landfill, which had treated urban and urban like waste. The leachate is sent to an external wastewater treatment (WWT).*
- *The biogas naturally generated by the landfill is internally used in the landfill for power generation (electricity).*
- *The output of the product system is the leachate which needs a further treatment in an external WWTP.*

#### **CE solution:**

- *A plant for the production of ammonium sulphate from leachate will be built next to the landfill. After an alkalization process, the liquid fraction of the leachate will be separated by settling and then heated it and passed through a stripping process for the extraction of ammonia by means of sulphuric acid. Lastly, the ammonia stream will be dried in order to reach the solid form as ammonium sulphate (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>.*

<sup>1</sup> The description of the case study was prepared by Ecoinnovazione (consultant of ETRA project partner) and reviewed by ETRA.



- *The biogas will be internally recovered for power generation (electricity) as well as for the production of the heat used in the technological system.*
- *The expected outputs generated by the product system (landfill + new technological plant) are the followings.*
  - *Solid sludge to be treated in an external landfill,*
  - *Purified leachate from stripping sent to sewage (after a pH neutralisation),*
  - *Ammonium sulphate sold as fertilizer.*

## 3.2. Scope definition

When scope of a LCC study is defined the following items needs to be described [26]:

- the systems to be studied,
- the functions of the systems studied,
- the functional unit that is consistent with the functional unit of the associated LCA,
- the system boundary that satisfies the objectives of both the LCC and the associated LCA,
- allocation procedures,
- the way the interpretation will be conducted,
- data sources and data quality requirements,
- main assumptions,
- type of critical review, if any.

### 3.2.1. Functional unit

The functional unit (FU) is the quantified performance of a product system, to be used as a reference unit. Functional unit and related reference flow are important elements of the LCC study. The BAU and the CE solutions can be compared only if their costs are calculated to the same FU.

As FU definition is a typical LCA-related topic, a more detailed guide about this issue is described in the D.T2.2.1. Concerning the example case study the following table describes the functional unit.

Elements of the FU <sup>2</sup>	Example case study (perspective of waste donor)
1. The function(s)/service(s) provided: “what”	Management of leachate generated from a municipal landfill
2. The extent of the function or service: “how much”	1 m <sup>3</sup> of landfill leachate
3. The expected level of quality: “how well”	Treated to reach the limits of pollutants concentration defined by the national regulation for the intake in the municipal sewage
4. The duration/life time of the product: “how long”	The duration is the one necessary for the treatment of the leachate

To guarantee full consistency of the LCC and LCA studies, the same functional unit must be applied.

### 3.2.2. System boundaries

LCC should be based on the same system boundaries as the complementary LCA. A very generic and simplified description of the system boundaries applicable in the CIRCE2020 project is described in Figure 3. Depending on the perspective, defined in goal definition, parts of these systems can be excluded (see Figure 4.).

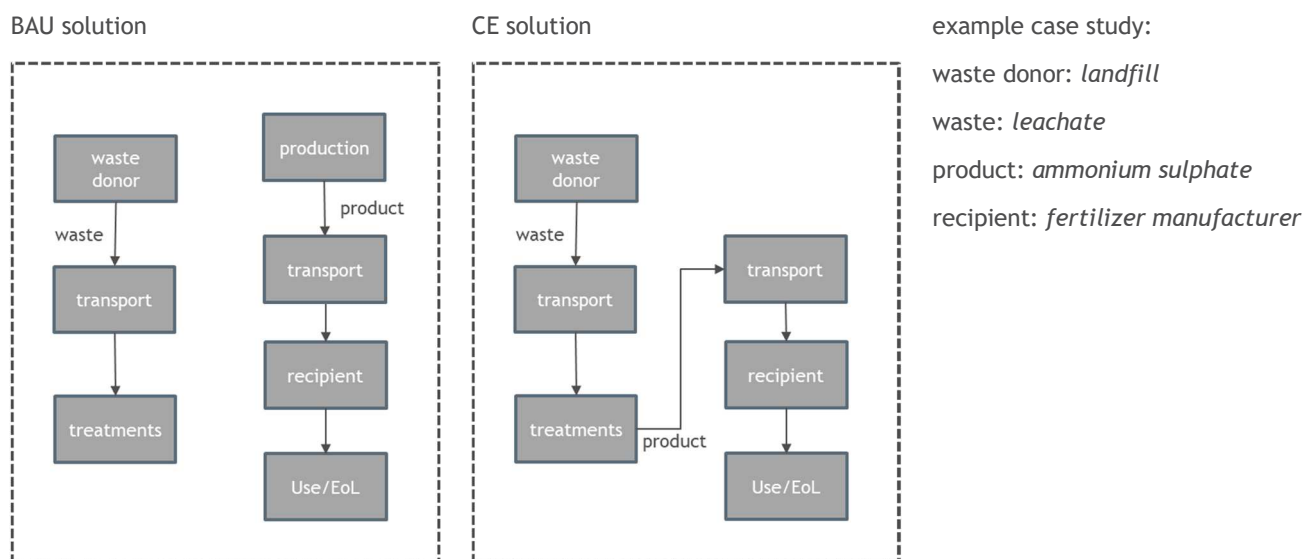
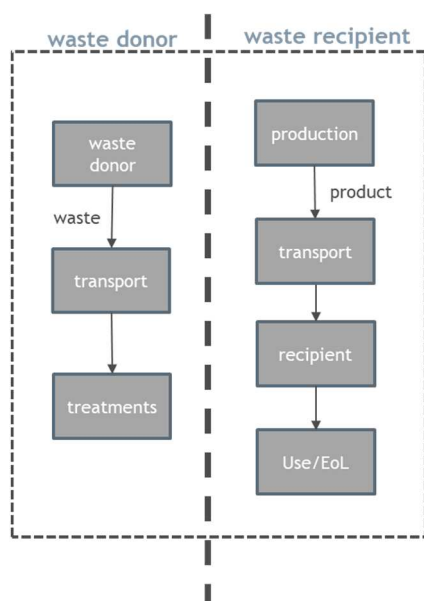


Figure 3: Simplified description of system boundaries in the CIRCE2020 project

<sup>2</sup> Elements and example of the FU were described by Ecoinnovazione (consultant of ETRA project partner). Please check D.T2.2.1. for the FU defined according to the perspective of the waste recipient.

BAU solution



CE solution

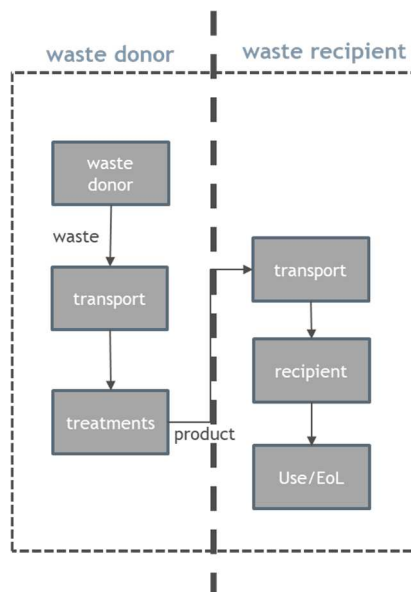
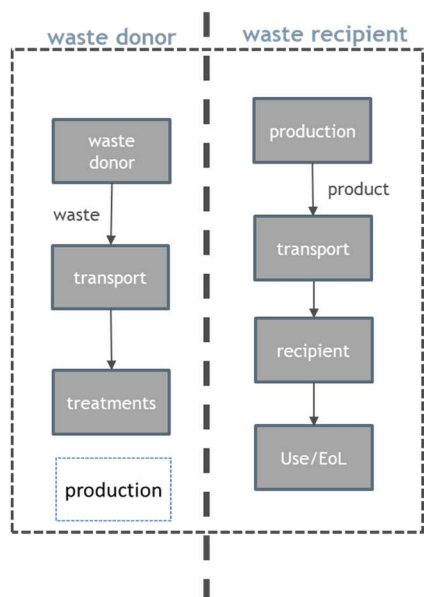


Figure 3: Modified system boundaries in the CIRCE2020 project depending on the perspective (waste donor or waste recipient)

According to D.T2.2.1. (PEF guideline, Chapter 3.3) “system expansion” is needed to guarantee the same functions when the perspective of waste donor is selected to guarantee the same functions. (see Figure 4.)

BAU solution



CE solution

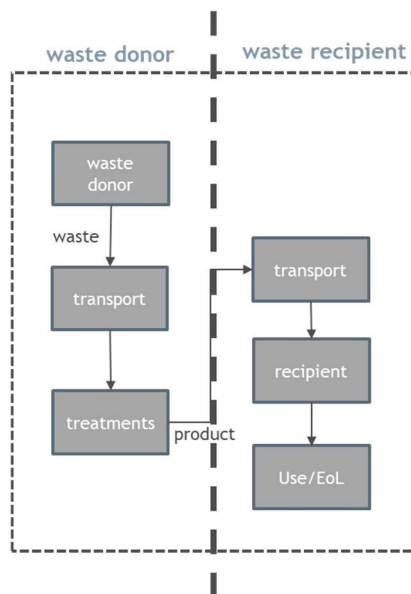


Figure 4: Modified system boundaries in the CIRCE2020 project depending on the perspective, applying system expansion



In specific cases, the list of all product life-cycle stages and processes that are part of the product system shall be described together with a diagram of the system boundaries.

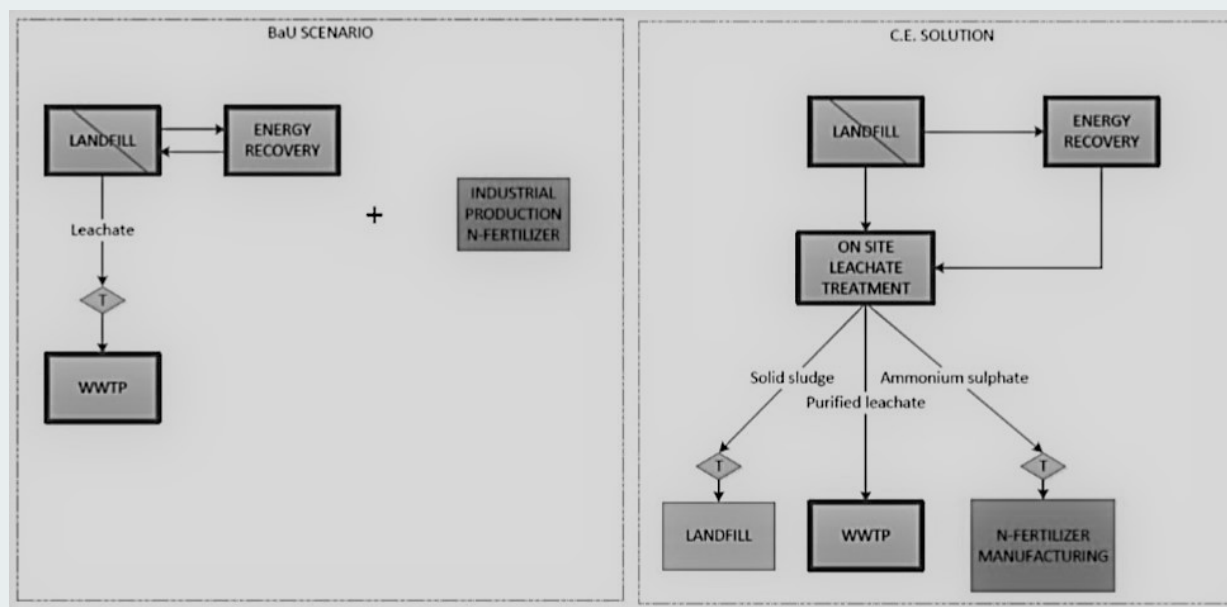
However, LCC and LCA may exclude parts of the systems based on differing cut-off limits in financial or environmental significance. For example, research and development involves cost demanding thought and calculation processes, laboratory and testing work but no large, environmentally significant production volumes. Other examples are marketing activities or infrastructure and machinery which is often excluded in LCA but may be included in LCC if their cost is relevant in a life cycle perspective. [26] Even if R&D costs and investments should be not relevant as the CIRCE2020 project does not aim to develop new technologies this issue needs to be checked in specific cases and carefully handled.

In LCC studies when alternatives are compared, such as those foreseen in the CIRCE2020 project, the analysed life cycle systems (the BAU and the CE solutions) may have identical parts while differences arise in activities occurring in specific processes. In this case there is a chance to exclude identical parts and so the assessment of cost differences might suffice. [26]

Time is an important factor when long-life products with significant costs during their use phase are analysed. LCC studies bring forward all future costs to the current decision using an assumed discount rate. However if the duration of the product system under study is less than 2 years then discounting can be neglected [26]. Currently we presume that products analysed in the CIRCE2020 project have less than 2 years use phase with no relevant costs, so discounting issue is not handled in detail in the present document.

#### Example case study:

The following figure describes the system boundaries.<sup>3</sup>



The LCC requires some additional considerations:

The leachate treatment plant is still under construction, so it is not a readily available technology. It would be reasonable to include the cost of planning and construction into the system boundaries of the LCC. It is important to scale also these costs to the selected functional unit.

<sup>3</sup> The figure was prepared based on diagrams created by ETRA and Ecoinnovazione. Please check D.T2.2.1. for the system boundaries defined according to the perspective of the waste recipient.



*Some costs are identical in the two analysed solutions (BAU and CE) that could be excluded from the LCC as already indicated in the above figure for the landfill process. If the perspective of the waste recipient would be included, also the fertilizer manufacturer may have identical energy, labour and administration costs independently of the usage of ammonium sulphate from BAU suppliers and from leachate treatment. It is recommended to check with fertilizer manufacturer the potential cost differences when the CE solution is applied compared to the BAU one.*

*No discount rate is necessary as there is no long usage phase.*

## 4. Economic Life Cycle Inventory

### 4.1. Data collection

Because everyone is familiar with currency units, costs data can create a false sense of certainty even if economic life cycle inventory faces many of the same data access and quality issues of a LCA. In fact, the cost data will usually come from different sources and developing a consistent data set for a study can be challenging. Some cost information are available nearly everywhere some are protected as business confidential. Different industry sectors have developed customized cost models and terminology that may have to be reconciled in constructing the inventory. Yet, another challenge is that cost data can be more volatile than physical units, varying over time and geographic regions, and the analyst must exercise caution when updating or smoothing cost data to ensure consistency across the full inventory. [26]

Considering all these potential difficulties costing should be undertaken with the aim to provide the target audience with the best available understanding of the reported figures and the quality of underlying data. For example, typically it is difficult to obtain detailed cost data from material or energy suppliers. A possible simplification is to consider the final price of the item. Strictly speaking such prices do not only comprise costs but also revenues for the producer but as this price occurs as a cost for the customers it can be considered and accurately documented as such [11].

The following cost categories are recommended to be included in the CIRCE2020 studies:

- materials, water, energy (electricity, thermal)
- transports
- administration, commercialisation
- depreciation
- labour
- other cost types, identified as significant in the specific case.

Reference time and reference currency of the LCC study have to be defined. It is preferable to collect cost data directly from balance sheets and income statements of the different stakeholders (waste donor, waste recipient, other actors). When such data collection is not possible other data sources and estimations can be used. The crucial issue is to document the quality of the data applied in the LCC study such as source, reference year and potential uncertainties. The more the cost data quality documentation is detailed the more understandable are the LCC results.

LCC data collection can be harmonised with LCA data collection to avoid double work even if it is not necessary to have a one-to-one correspondence between cost and environmental data. The LCC data collection should result in a Cost Breakdown Structure (CBS) including each life cycle stage considered and the different cost types. [26]



**Example case study:**

*A first screening identified the following main cost types to collect about the CE solution:*

- *Chemicals: sodium hydroxide, iron chloride, poly ammonium chloride, sulphuric acid*
- *Energy: electric, thermal*
- *Transport: sludge to disposal, ammonium sulphate to fertilizer producer*
- *Disposal: sludge, purified leachate (WWTP)*
- *Labour: operation and maintenance*
- *Market value of the produced ammonium sulphate*

*Additional cost types can be included (administration, depreciation) or excluded if they are not significant. The key issue is to transparently document each cost data that has been excluded for some reason (significance, availability etc).*

*If the perspective of the waste recipient would be included cost differences of the fertilizer manufacturer (compared to the BAU solution) and costs of included transport processes have to be identified and collected.*

## 4.2. Allocation

Allocation is the process of assigning costs to particular cost objects. It is a classic topic in LCA but also in traditional cost accounting and the allocation approaches are not always consistent.

The best solution is always to avoid allocation by dividing unit processes. If the processes can be decomposed into subprocesses with defined inputs and outputs then costs can be assigned directly and allocation is not necessary.

Another option to avoid allocation in a LCA study is system expansion by including additional functions related to the co-products. If the complementary LCA study applies such system expansion then extreme care must be exercised to ensure that the LCA and LCC have consistent system boundaries and to interpret the final results correctly.

If there are indirect costs that cannot be traced directly to co-products than alternative cost allocation bases needs to be analysed. Accepted accounting principles such as traditional costing (assigning indirect costs to departments and locations) or activity based costing can be useful for appropriate allocation. Depending on the principle, costs of cost centres (departments or activities) are allocated to co-products based on a selected allocation base (physical measures as mass, volume etc. or market value). Instead of such complex allocation procedures the simplest costing system assigns indirect cost to co-products using a single overhead rate. [26]

The selected allocation method needs to be accurately documented. In the complementary LCA study the allocation method should be as consistent as possible with the allocation applied in the LCC study. Potential inconsistencies needs to be documented and considered when final LCA and LCC results are compared.



### 4.3. Externalities

As described in Chapter 2, also external costs, expressed in monetary units that are not directly borne by an actor of the life cycle chain, can be included in the LCC study. It is recommended mainly if a decision maker anticipates that some external costs may come into play during the time of the decision relevant future such as taxes, fees and new regulations. Some examples, selected from LCC literature are the following:

- Costs related to CO<sub>2</sub> emissions to be internalized by the producer in the decision relevant future at the current prevailing price of CO<sub>2</sub> in the European Union market. [17]
- Costs related to road transport emissions are acknowledged by the European Commission within the Clean Vehicles Directive (2009/33/EC) [19]:

Pollutant	EUR/kg
CO <sub>2</sub>	0,03-0,04
NO <sub>x</sub>	0,0044
NMHC	0,001
Particulate matter	0,087

- Data for air pollutants causing health effect were estimated in the European ExternE project [26]:

Pollutant	Health impact \$/kg
CO <sub>2</sub>	0,12
VOC	0,79
CO	0,02
NO <sub>x</sub>	17,66
PM <sub>2.5</sub>	180,00
SO <sub>x</sub>	11,25

These examples shows clearly that the selection of cost data to estimate externalities is affected by a considerable uncertainty. If relevant cost externality factors are identified in a CIRCE2020 LCC case study than the selected cost assessment method has to be documented in detail considering its uncertainty when results are interpreted.

If an analyst of the CIRCE2020 project wants to avoid uncertainties deriving from quantitative literature data then a clear and detailed qualitative description of significant externalities might suffice. Such description may include a transparent quantification of the pollutants and their potential environmental and/or health impact without estimating the related external costs.



## 4.4. LCC tools

Management of numerous data from the different processes of a life cycle and their calculation to the same functional unit can be a challenging task. If a life cycle is not extremely simple than usually specific software systems are applied in LCA studies. Even if the considered life cycle system could have the same complexity in a LCC study, only one data type (cost) has to be collected instead of the numerous environmental data of a LCA (resources, emissions). Considering this limited complexity of LCC the studies of the CIRCE2020 project could be carried out by using the calculation functionalities of common spreadsheets (such as Excel).

Some LCA software have also LCC functionalities or at least can be adopted to cost analysis. If such software system is used than the project partner needs to assure that the study is in compliance with the present LCC guideline.

## 5. Interpretation

Results of a LCC within the CIRCE2020 project need to describe:

- a cost comparison of existing BAU and new CE systems referring in both cases to the functional unit,
- separate cost and benefit breakdown of the actors whose perspective is considered: these are usually the waste donor and potentially the waste recipient and other actors.

These results should support the identification of the most relevant costs within the analysed systems and the decision about the most preferable solution from a cost perspective. As the functional unit applied in the LCA is the same, the results of the environmental assessment refer to the same waste quantities and they can be considered together when final decision is taken. Any inconsistencies between LCA and LCC due the potential differences in system boundaries or allocation procedures must be declared and considered for accurate interpretation of results.

A circular solution developed in the CIRCE2020 project may potentially have a wider application in future, so an additional useful result can be the upscaling of its cost benefits to regional/national level. Such extrapolation has to be done with great care based on realistic and well documented quantities of the reference waste flow.

A final assessment about the quality of the LCC study also needs to be carried out. Consistency and completeness have to be checked and described in a qualitative way. Any significant inconsistencies or incompleteness have to be clearly stated for the correct understanding of the results.

Additional focus needs to be applied on cost data which might contain the highest uncertainties due to the involvement of assumptions and expected variations. A sensitivity analysis has to be carried out to identify the potential change in the life cycle cost result as a function of variation in the input cost data and whether changes in assumptions or data alter the ranking of results of the life cycle alternatives compared [26]. It is recommended to make these sensitivity calculation in a quantitative way or otherwise describe the highest uncertainties and their possible effects on the results in a qualitative manner.



## 6. Reporting and review

The LCC report has to describe each phase of the study according to the content of the present document:

- goal and scope definition, with a clear description of the perspective and the system boundaries,
- economic life cycle inventory, by describing the collected data with their accurate documentation and the potential allocation procedure,
- interpretation of the results including an evaluation about the quality of the LCC study.

If the comparative results of the analysed alternatives are intended to be disclosed to the public, a critical review of the LCC is recommended. A good guideline for such reviewing is the ISO 14040-44 standard [25, 27].



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## 8. Contact

The present document has been prepared by Balázs SÁRA, external expert on behalf of the CIRCE2020 project partner Bay Zoltán Nonprofit Ltd for Applied Research.

Contact details:

tel +39 328 9243978 +36 30 6134662

email: bsaranet@gmail.com