FIT4REUSE

Safe and sustainable solutions for the integrated use of non-conventional water resources in the Mediterranean agricultural sector

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Brief Description	This deliverable provides a methodological framework to analyse the triple bottom line impacts of different non-conventional water reuse systems
Keywords	Sustainability assessment; non-conventional water resource; life cycle thinking; cost-benefit analysis

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DISCLAIMER

DEFINITIONS

Conventional water resources: Conventional water resources are those surface and groundwater resources commonly used for anthropic uses - including irrigation.

Non-conventional water resources: Non-conventional water resources are those that are generated as a by-product of specialized processes such as desalination or wastewater treatment; or that need suitable pre-use treatment; or pertinent on-farm management when used for irrigation; or need a special technology to collect/access water.

FIT4REUSE reclamation technologies: Reclamation technologies developed and tested in FIT4REUSE project.

Non-FIT4REUSE reclamation technologies: Any reclamation technology that is not specifically developed and tested in FIT4REUSE project.

Pilot scale-Baseline scenario: Basic scenario focusing on reclamation and reuse technologies and possible combinations at pilot scale (Task 7.2).

Full scale-Improved-upscaled scenario: Scenario including the full-scale implementation of FIT4REUSE technologies in relevant environment (local technical constraints and socio-economic context) – and its improvements in any sustainability dimension (Task 7.3).

Business as usual (BAU) situation: Situation without FIT4REUSE technologies used to be compared with FIT4REUSE technologies. It represents current practices which might be substituted if FIT4REUSE technologies are implemented.

ABBREVIATIONS

BAU: Business as usual
CBA: Cost-benefit analysis
CF: Characterization factor
E-LCC: Environmental life cycle costing
ISPRA: Istituto Superiore per la Protezione e la Ricerca Ambientale
LCA: Life cycle assessment
LCT: Life cycle thinking
NPV: Net profit value
S-LCA: Social life cycle assessment
WP: Work package
WRD: Water Reuse Day
WRF: Water Reuse Forum

EXECUTIVE SUMMARY

The project FIT4REUSE will provide safe, sustainable and accepted ways of water supply for the Mediterranean basin by exploiting non-conventional water resources. Treated wastewater and desalinated water can contribute to compensate the gap between agricultural water demand and supply and provide consistently high-quality water throughout the year.

FIT4REUSE will focus on innovative, sustainable and safe treatment technologies, and on the use of treated wastewater and desalinated water for the Mediterranean agricultural sector and for aquifer recharge. Therefore, specific methodological and assessment tools framework will be created to meet the project objectives.

The report "Holistic methodological framework for the assessment of non-conventional water resources" contains the bases to analyse the sustainability impacts (environmental, social and economic) of different non-conventional water reuse systems in FIT4REUSE project; through the application of different methodologies: life cycle thinking (LCT) methods, such as life cycle assessment (LCA), social life cycle assessment (S-LCA) and life cycle costing (LCC); and cost-benefit analysis (CBA).

The methodology utilized to design this framework combines: 1) an <u>iterative literature review</u> in the application of each life cycle thinking method and cost-benefit analysis in water management (both from conventional and non-conventional resources); 2) <u>experts' knowledge,</u> to harmonize and integrate literature findings providing specific know-how (including consensus with other FIT4REUSE partners); and 3) <u>Design a stakeholder consultation and test it through a survey</u> to drive further consultations related to the sustainability assessment of FIT4REUSE solutions. See figure 1 for the graphical representation.

The literature review was based on the analysis of different documents (books, standards, scientific papers, reports and others) which helped to set the baseline conditions to use the selected methodologies in the water management context. The outcomes of the literature review have been then integrated with experts' knowledge to fill additional knowledge gaps. The literature review and the expert's knowledge represented also the basis for the design of a survey aimed at the organization of the six steps stakeholders' consultation. The survey was tested through the Water Reuse Forum (WRF), a web platform developed within FIT4REUSE. The WRF aims at providing

voice to different stakeholders relevant for the project – as they could be affected and/or benefit from FIT4REUSE solutions – as well as to confirm or reject information already identified in the literature review but tailored to specific territorial situations. The survey will be revised according to the results of the test and opened again to further review the methodology before the sustainability assessment of FIT4REUSE solutions takes place. It will also help to understand the functioning of the WRF.

The selected combination of LCT and CBA approaches in the sustainability assessment of non-conventional water resources and water use represents: 1) a novelty as no study based on the combination of these two methodologies is currently present in the scientific literature related to water management; 2) a challenge due to the amount and quality of data needed to be performed; and 3) an opportunity as the combination of the two methodologies could provide a complete sustainability assessment to take informed decisions towards the application of new technologies.

Therefore, this methodological report provides:

- A contextualization of the application of water reuse technologies within the FIT4REUSE project.
- The rationale behind the development and application of a sustainability assessment methodology combining LCT and CBA. The opportunities and the challenges of selected methodologies are also considered.
- The design of a six steps consultation based on recognized methodologies to identify and engage stakeholders, including the development and test of a survey.
- A summary of the next project activities and their relationship with this deliverable.

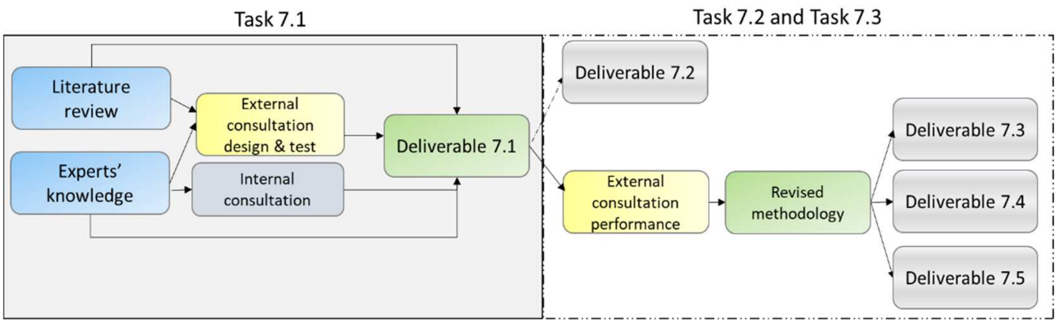

Figure 1. Workflow to design the methodological framework. Authors' elaboration.

SECTION 1 – Project background

1.1 FIT4REUSE sustainability assessment

The access to water and its sanitation are recognized human rights according to the United Nations. However, there are relevant challenges in water access and quality, such as those faced in the Mediterranean region where there are limited and irregular availability of water resources in both time and space with increasing threats by climate change and drought events (WWAP, 2017). Agriculture is the greatest user of water in the Mediterranean basin while 28 billion m^3 $year^{-1}$ of urban/domestic wastewater is produced and discharged every year (after treatment or not) into water bodies (FAO, 2018). In this sense, municipal wastewater, being also nutrients-rich, is a very precious resource and should be valorised for irrigation use. Other non-conventional water sources can be those obtained through desalination technology, which still face problems that can negatively affect their use for irrigation.

The FIT4REUSE project recognizes that the exploitation of these water resources in a safe and sustainable manner, within a context of circular economy and environmental sustainability, could bring significant benefits for the whole Mediterranean region.

However, there are known high reclamation costs, possible negative effects on human health and on the environment, and potential low public acceptance. In order to advance into the opportunities of using non-conventional water resources, the main objective of FIT4REUSE is to provide safe, locally sustainable and accepted ways of water supply for the Mediterranean agricultural sector by exploiting non-conventional water resources, namely reclaimed water and desalted water. In particular, FIT4REUSE project focuses on innovative treatment technologies and on the use of non-conventional water resources in agriculture and for aquifer recharge, with the inclusion of partners from different areas of the Mediterranean region.

The project is structured in nine work packages (WPs). WP9 is dedicated to communication and dissemination, and WP1 to the general management of the project. WPs 2, 3, 4 and 5 develop technological solutions for treatment of non-conventional water resources and test their application in relevant conditions, while WP8 develop a specific tool in order to ensure exploitation of FIT4REUSE solutions and integration of legal frameworks. Thus, WP7 assess impacts of non-conventional water resources reclamation and use from a holistic point of view.

1.2 Objectives and structure of the WP 7

This deliverable is conceptualized within the WP7 – Holistic assessment of the environmental, economic, and social impacts of the non-conventional water resources treatments and application - of FIT4REUSE project.

General objectives of WP7

FIT4REUSE WP7 wants to assess the sustainability of the diverse non-conventional water resources reclamation and reuse developed within FIT4REUSE and to identify improvement options, especially regarding the factors driving community opposition. Figure 2 provides a representation of the structure of the WP.

Specific objectives of WP7

FIT4REUSE WP7 specifically aims to:

- Develop an operational methodological framework to analyse the triple bottom line impacts of different non-conventional water resources reclamation and reuse;
- Analyse the scenarios of FIT4REUSE reclamation and reuse technologies and to identify hotspots of selected technologies and applications;
- Identify potential improvements in the sustainability of FIT4REUSE systems by assessing alternative/integrated scenarios.

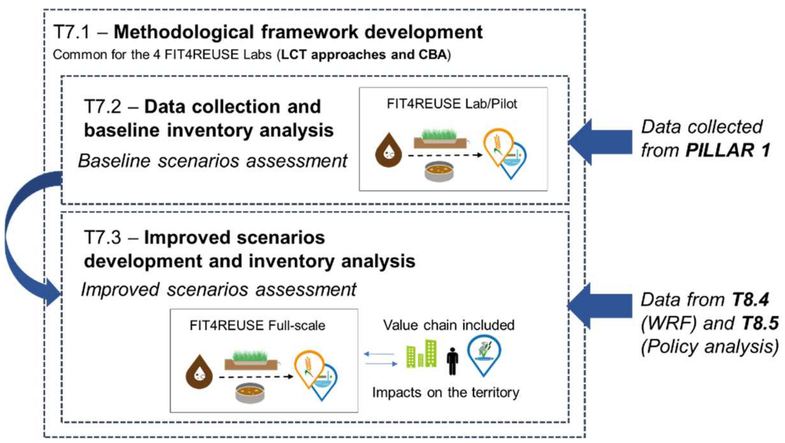

Figure 2. WP7 structure. Authors' elaboration.

The methods selected within this framework to evaluate the sustainability of non-conventional resources are life cycle thinking (LCT) and cost-benefit analysis (CBA). LCT and CBA can support each other allowing to reach a deeper understanding of sustainability hotspots.

To ensure the accomplishment of the goals of this WP, the following tasks are foreseen:

- Task 7.1 "Methodological framework development" will lead to the design of a methodological framework for the assessment of non-conventional water resources (D7.1);
- Task 7.2 "Data collection and baseline inventory analysis" will develop a protocol to ensure harmonized practices in the collection of data (D7.2) and will define the pilot scale baseline scenario for the assessment of non-conventional water resources (D7.3)
- Task 7.3 "Integrated-upscaled scenarios development and inventory analysis" will identify (D7.4) and assess (D7.5) non-conventional water resources at full scale.

Therefore, this deliverable represents the outcome of Task 7.1, referred to the methodological framework development.

1.3 Objective of this deliverable

Objective

The objective of this document is to develop a specific methodological framework based on life cycle thinking and cost-benefit analysis approaches to evaluate the environmental, costing and social impacts of different non-conventional water reclamation and reuse practices.

Implementation

The methodological framework relies on the main characteristics of the explored methodologies: LCT, disclosed into life cycle assessment (LCA), environmental life cycle costing (E-LCC), social life cycle assessment (S-LCA), and cost-benefit analysis (CBA). To ground the methodology to specific territorial aspects, a stakeholder consultation has been foreseen to take advantage of the knowledge of practitioners outside the project.

SECTION 2 – FIT4REUSE cases and scenarios

2.1 Principles of water reclamation and reuse

Water circular economy within the form of water reclamation and use of non-conventional water resources in agriculture gathers a complex group of processes and practices that often target multi-functional purposes.

Water reclamation and use in agriculture include the following main types of technologies and infrastructures:

- Urban wastewater treatment which usually takes place in conventional treatment plans (e.g. activated sludge) is intended to comply with quality standards for discharge such as Directive 91/271/EEC in Europe but do not provide sufficient quality for the reuse of the effluent (e.g. in agriculture irrigation).
- Reclamation process (any treatment needed including disinfection to reach the desired quality and volumes to fit the uses objectives). Reclamation is usually an additional treatment that complements conventional wastewater treatment. Reclamation processes can be located in the same facilities of conventional wastewater treatment or separately and closer to the point of use.
- Storage infrastructures to ensure adequacy in time between reclaimed water production and water demand.
- Water transfer infrastructures including pumping and pipes.
- Irrigation infrastructures on-field (from drippers to high-pressure sprinklers).

Figure 3 represents non-conventional water resources reclamation and use flow, while Figure 4 shows the conditions for safe and sustainable water reuse implementation.

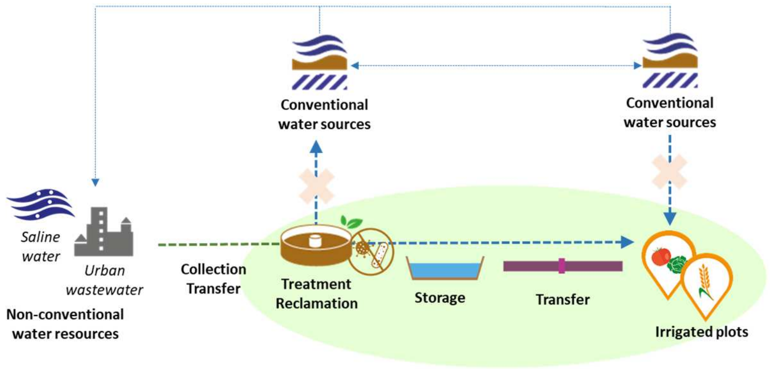

Figure 3. Example of non-conventional water resources reclamation and reuse scheme including a complete replacement of conventional water resources. Source: Ecofilae.

Figure 4. Conditions for safe and sustainable water reuse implementation. Source: Ecofilae.

The main benefit of water reuse is often seen as the supply of a new alternative water resource in water scarce areas. Nevertheless, studies in the Mediterranean region highlight that expected benefits of water reuse can be multiple and diverse according to specific local contexts (Condom N. et al., 2012; Condom and Declercq, 2017). These benefits can be related to:

- Limit the water discharge into the environment and thus pollution.
- The fertilization potential of reclaimed water.
- Preserve conventional water sources by substitution and to secure water supply.
- Have a net increase of water resources in coastal areas where treated wastewater would be otherwise discharged to the sea and not used.

2.2 Case studies description

The holistic assessment of environmental, economic and social impacts of non-conventional water resources treatment and application (WP7) focus on 4 case studies in 4 different FIT4REUSE countries. Italy, Tunisia, Israel and Greece have been selected as they represent the 4 countries where FIT4REUSE reclamation technologies are developed and tested.

Among all the FIT4REUSE technologies developed during FIT4REUSE, in the coming tasks, one water reclamation and reuse technological chain (= combination of technologies) will be selected per country and studied in this WP7. Analysis will be carried out at 2 scales: (1) at pilot scale within the *Data collection and baseline inventory analysis* (Task 7.2), and then (2) upscaled within a territorial integrated simulation/study in the *Integrated-upscaled scenarios development and inventory analysis* (Task 7.3). The 4 FIT4REUSE technologies assessed will be detailed during the first baseline analysis (Task 7.2), after discussions with FIT4REUSE local partners and with local stakeholders taking advantage of the Water Reuse Forum (see sections 4 and 5).

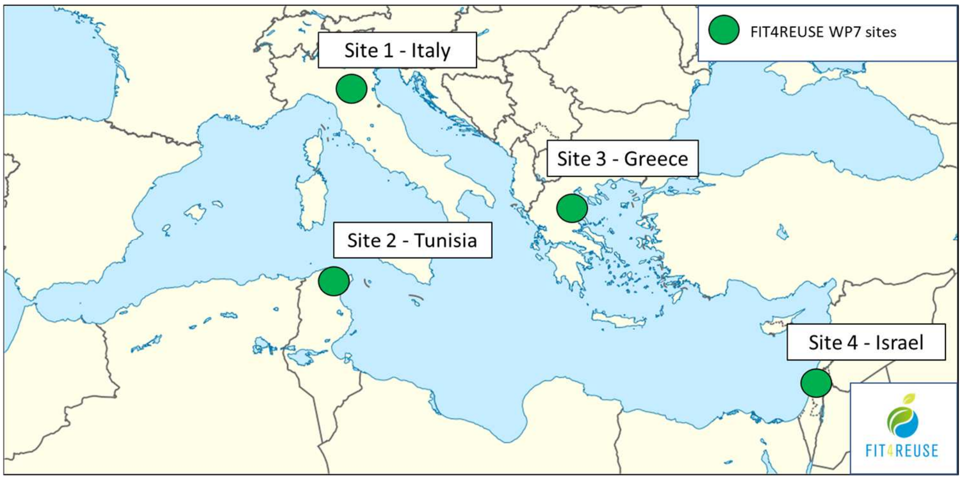

Figure 5. Country sites explored in WP7. Authors' elaboration.

SECTION 3 – General methodology

3.1 Sustainability assessment

The challenge between population growth and natural resource exploitation increases the pressure towards a transition from linear to circular supply chains, including the end of the life cycle. The circular economy aims at decoupling the economy from the consumption and at reducing the extraction of new materials while eliminating waste along the supply chain. This paradigm, developed in environmental economics, asks for a self-effective production that encompasses sustainability (Genovese et al., 2017). Although the competition over scarce resource historically represented a major focus for economics (Robbins, 1932) its urgency and the need for this transition to non-linear and less resource intensive production systems increased dramatically only recently due to the clear evidence of the impacts on the environment and human communities.

A sustainable system should be protective and respectful of ecosystems and of biodiversity, acceptable from a cultural perspective, fair, affordable, appropriate, safe, and healthy (Burlingame and Dernini, 2012). Consequently, the water supply chain should be holistically analysed, identifying and characterizing each segment of the chain, and assessing implication in the three areas of sustainability. The undeniable need for baseline information to tackle inefficient routes is fundamental when building sustainable systems.

3.2 How sustainability can be measured?

Cost-benefit analysis (CBA) is a major instrument applied to evaluate sustainability. CBA combines prices flow analysis, environmental consequences (by including externalities), and the social perspectives of different projects or policies. It mostly adopts money or welfare as a unit of reference (Hoogmartens et al., 2014). International organizations have also elaborated sustainability tools, such as The Food Agricultural Organization (2014) which designed specific guidelines for assessing the impact of food and agriculture operations on the environment and on people. Similarly, the Global Reporting Initiative wants to support businesses and governments to understand and communicate their impact on sustainability by providing a set of specific standards (GRI, 2019). The interest of investors on this topic has promoted the creation of dedicated indexes such as The Dow Jones Sustainability Index (DJSI), widely recognized in the stock sphere and considered as an acceptable proxy of sustainability (Chams and García-Blandón, 2019). Within the interest of this sustainability assessment, a methodological approach widely adopted is under the life cycle thinking (LCT) framework including life cycle analysis (LCA), life cycle costing (LCC), and social life cycle assessment (S-LCA), and the integration of the latter three into the life cycle sustainability assessment (LCSA). These techniques allow individuals and businesses to assess the impact of their decisions and production methods along with different aspects of a system or a value chain (UNEP, 2011).

The methodological framework combines LCT and CBA to assess the sustainability of non-conventional water resources practices.

3.3 Life cycle thinking (LCT)

The Life cycle thinking approach considers all the impacts of a product or service over its entire life cycle. It can be considered a decision-making tool, enabled by scientific methods such as life cycle assessment (LCA) through a quantitative perspective (UNEP, 2011). LCA is a methodology that considers and analyses a product or process over its entire life cycle to quantify its environmental impact. It is standardized by the ISO 14040:2016 which defines the principles and framework where the method should be performed (ISO, 2006, 2002).

Environmental-LCC (E-LCC) assesses costs directly covered by one or more actors during the life cycle of a product or process and can internalize externalities (De Menna et al., 2018; Hunkeler et al., 2008). Although this method is not standardized, it follows the LCA approach to provide an integrated outcome. Results are crucial to engage actors as they utilize the monetization to measure the different costs occurring along the life cycle.

S-LCA is a methodology that aims at assessing the social impacts of products, with the ultimate goal of improving human well-being. The outcomes support the adoption of better-informed choices. The UNEP-SETAC (2009) guidelines distinguishes five main stakeholders: workers, consumers, local community, society, other value chain actors (not including consumers). S-LCA is still in at early stage in its development, due to the limited case studies analysed associated with the complexity of identifying appropriate and reliable social indicators. It is designed to provide, together with LCA and LCC, the full outlook of LCSA (UNEP-SETAC, 2009; UNEP, 2011).

The addition of the results from each dimension, LCA, LCC and SLCA, can provide a unique score called life cycle sustainability assessment (LCSA) (UNEP, 2011). This must deal with indicators identification and weighing issues – as each single methodology described -, as well as trade-off between validity and applicability (Finkbeiner et al., 2010); but simultaneously it has a great potential to support stakeholders, from policy-makers to consumers, to take decisions targeting sustainability.

The 2006 ISO 14040 and ISO 14044 standards describe the principles and framework for life cycle assessment, specify the requirements and provide guidelines. ISO 14040 describe the 4 main steps to follow in the performance of LCA (figure 6).

As anticipated in previous paragraphs, the same phases will be also considered for the cost and social assessment.

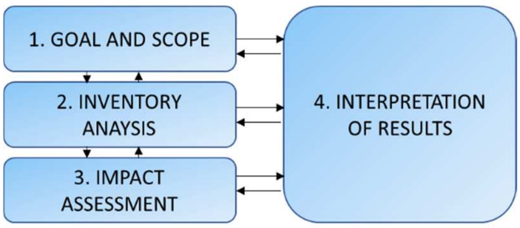

Figure 6. LCA phases from ISO 14040. Authors' elaboration from ISO.

Phases

Four phases must be carried out successively to perform the LCA:

- Phase 1: **Goal and scope**. It defines the LCA objectives and the scope of the study (functional unit, methodological choices and system boundaries). The functional unit (FU) is the definition of the service delivered (for example, to treat 1m^3 of wastewater for irrigation purposes). The system boundaries will show if the assessed system follows a gate to gate, cradle to gate, or cradle to grave approach.
- Phase 2: **Inventory analysis**. Life cycle inventory is the system modelling according to the functional unit and the list of inputs (energy, materials, water, etc.) and outputs (emissions to the air, ground, etc.) flows for the entire life cycle.

- Phase 3: **Impact assessment**. Life cycle impact assessment is the calculation of the impacts using characterization factors (CF). CF depend on the selected impact method. Each method has its own environmental indicators tailored to the reason(s) why they were created. All the environmental indicators have a CF that relates each flow to a set of impacts using cause-effect chains (Carré et al., 2017). Mid-point level or end-point level indicators can be distinguished. A mid-point indicator is a point in the cause-effect chain (Bare et al., 2000) for one category of impact. When the impact method allows aggregation of mid-points indicators and creates common categories, end-point indicators can be created and calculated.
- Phase 4: **Interpretation of results**. The found outcomes are analysed to reach the goal and scope defined in the first step. If the objectives are not accomplished or if an additional hypothesis has appeared, the cycle can be restarted from the phase 1 to phase 4.

LCA methodology, and therefore the other two methods assessing the sustainability dimensions, distinguishes two approaches, attributional LCA and consequential. Attributional LCA provides a static picture of the FU within the system. It is also called footprint as indicates the environmental impact of a certain observed product or process. Instead, Consequential LCA focuses on assessing the effects occurring on the system due to interventions or changes; the consequences of taking decisions which could cause positive or negative effects in the system.

(a) LCT applied to water technologies: A literature review

The detailed list of outcomes from the literature review can be found in Table 1 in Annex 2 of this document.

The main findings of LCA application in water management context show that most of the works focus on the tertiary treatment technology. Most of the studies are located in European regions (mainly Spain), followed by China. Regarding the application of the LCA, it was common to find mass and volume based functional units; while the system boundaries range from cradle-to-grave, to gate-to-gate. The impact categories depended on the system boundaries of the study, but they usually included global warming potential and eutrophication potential. ReCiPe has been identified as the most applied method, and it could be selected to be applied in FIT4REUSE sustainability assessment as it is coherent within the territorial needs of FIT4REUSE (Mediterranean countries) and the water sector. Some studies followed a comparative approach, as the one which will be pursued in FIT4REUSE; considering a BAU situation and different with lab or real scale technologies to be compared (conventional or non-conventional). This LCA instrument is recognized as powerful in decision making processes, but it should be combined with social and economic ones to provide a holistic picture of the sustainability features of the assessed case.

According to the findings of the SLCA literature review, this methodology can be used to individuate indicators that could help assessing the social impacts that the implementation of water reuse practices may have. Society in general is composed by different stakeholders, and to each of them, the fulfilment of several indicators could help to understand in which measure water reuse practices could influence their life. Moreover, some indicators belonging to this methodology could help to analyse social acceptance of the above-mentioned practices for a more inclusive approach.

LCC represents a valuable method to support decisions within the water reclamation and non-conventional sources, as it provides an economic perspective, which, depending on the defined system boundaries, will present the whole life cycle of a certain treatment, or of a certain value chain of water.

Examples from the literature present cases where the chain begins with the sourcing, until the wastewater treatment, and in few cases until its reuse. There are particular aspects that need to be closely regarded, both for consistency and comparability purposes, such as a clear definition of the FU (not all of the studies state it), the uniformity of the system boundaries related to other LCT methods, the definition of the typology of LCC (Common, Environmental or Societal), the presented cost categories, as well as the discounting rates and present or future value method to be applied. Authors within this review express that social acceptance of recovered water and market access for resources can be considered as of large risk for investment.

Other sustainability values such as scarcity and ecological thresholds were not always captured in their assessments and the E-LCC code of practices suggests including them.

Moreover, additional elements within the LCT must be considered as well besides the actual treatment or supply of water, such as losses and inefficiencies of the technique and supply process.

3.4 Cost-benefit analysis (CBA)

The Cost-benefit analysis (CBA) is a technique used to analyse projects to determine whether or not they are in the public's and private sector's interest thanks to the assignment of monetary value to each input and output resulting from the project (Chen and Wang, 2009; Kihila, 2014; Verlicchi et al., 2012). The CBA starts then from the premise that an investment should only be commissioned if the benefits exceed the aggregate costs (Molinos-Senante et al., 2010). Obviously, the compared benefits and costs must refer to the same situation (Young and Loomis, 2014).

CBAs are implemented (i) to compare each other technical scenarios of non-conventional water reuse and conventional water use, (ii) to assess projects' economic profitability for a community on a specific territory, and (iii) to identify which stakeholders win/lose to draft correction actions to reach a win/win balance.

This very well-known methodology is rarely carried out for water reuse projects, or only partially. (Molinos-Senante et al., 2011) highlighted that the assessment of water reuse projects usually focuses on internal costs and benefits, and that more projects are economically viable when external benefits are integrated into a CBA analysis.

General objective of the CBA in this research is to carry out an integrated assessment (i) of the FIT4REUSE solutions profitability, and (ii) of the FIT4REUSE solutions sustainability by integrating environmental and social indirect benefits and costs within the analysis whenever possible and relevant, (iii) of the cost-benefit distribution among actors.

Phases

Several phases must be carried out successively to achieve a CBA:

- Phase 1: **Identification of alternative projects/scenarios,** technical variants in order to retain only the more supportive to the community. It is possible to consider only one scenario.
- Phase 2: **Characterization of the sphere of analysis.** This sphere corresponds to all stakeholders (including the environment) involved / impacted by the project. It's a combination of geographic and institutional characteristics, since all project funders are part of the sphere of analysis. This phase enables to

determine if the analysis shall be conducted from a private or from a social point of view.

- Phase 3: **Description of the reference scenario.** The situation of reference is the situation without project (the current situation in the case of ex-ante analysis or the situation prevailed before the implementation of the project in the case of an ex-post analysis). Beware, the reference situation is not fixed: we consider the significant changes (population growth, growing scarcity of a resource...).
- Phase 4: **Setting the time horizon.** The time horizon is the period over which realized is the CBA: from 20 to 50 years according to the level of capitalistic / private nature of the project or the level of social / collective / public character of it. The choice of the time horizon will necessarily have consequences on how to consider renewals of infrastructures and their residual value.
- Phase 5: **Identification and evaluation of the costs and benefits** of the reference scenario and of the scenarios with projects. Cost or benefit that are identic between the scenarios are not considered. Monetization or homogenization techniques for environmental and social services can be used (see section below).
- Phase 6: **Aggregation of costs and benefits and evaluation of net profit or discounted value (NPV)** for all actors in the sphere of analysis (community point of view) and for each of them.
- Phase 7: **Sensitivity analysis** of the NPV to the main parameters. Since many of the parameters are stochastic or inaccurate, a sensitivity analysis is often needed. This will be described in a dedicated section.

Discounting

Once they have been estimated, all future costs and benefits can be assessed in present value before being summed (Step 5). The discounting principle is used to integrate the preference for the present into the analysis: a discounted cost or benefit (Xd) is then calculated using a discount rate. Discounted cost or benefit calculation formula:

$$\mathrm{Xd} = Xt/(1+\mathrm{d})^{t} \qquad (1)$$

Where:

- Xt = a cost or a benefit in year t
- Xd = the discounted value of Xt
- d = discount rate

In economic analyses, the recommended discount rate is usually set between 2.5 and 3.5% for public projects and the timeline is generally set between 40 and 50 years. The timeline is set in accordance with local stakeholders and decision-makers: it depends on the temporal scale vision they have for the project. From private actors' point of view, i.e. for financial analysis, the discount rate is higher (6% to 8%, sometimes more) and the time lines shorter (20 years) (Loubier, 2015).

<u>The net present value</u>

The net present value calculated in step 6 is then equal to the sum of differences of discounted costs and benefits between the 2 compared scenarios (e.g. reuse and baseline scenarios). Its mathematical formulation is the following:

$$\mathrm{NPV} = \left(\sum Bd_{proj} - \sum Cd_{proj}\right) - \left(\sum Bd_{bau} - \sum Cd_{bau}\right) \quad (2)$$

Where:

- Bd = discounted benefits
- Cd = discounted costs
- Bau index = characterizes the business as usual scenario
- Proj index = characterizes the scenario with project

Carrying out only a single economic analysis, i.e. from the community's point of view, highlights potential advantages (NPV>0) or disadvantages (NPV<0). For profitable projects, economic analysis must be completed with financial analysis to be sure that every actor has interest in collaborating in the project. When it is not the case, the project could not be implemented even though it advantages the community. The financial analysis' aim is then to identify the corrections (subsidies, pricing, taxes…) to implement for reaching win-win solutions (Loubier, 2015). Economic (CBA) and financial analyses are based on the same concepts, but with some different parameters.

Economic homogenization

Water reuse projects are rarely subject to integrated economic analysis compared to other types of structuring projects. When this is the case, social and environmental benefits are often not properly quantified, and these projects are often undervalued, such as the results from the literature review performed revealed.

Many of the costs and benefits of a project are easy to identify and to monetize (added value, investments, expenses, etc.) but some are particularly difficult to monetize like the environmental externalities, the employment evolution in downstream chains or even the individual satisfaction. Specific, complex and time-consuming economic methods are developed to assess in detail these costs and benefits. This requires a good knowledge of economic concepts and time to carry out these analyses.

Obviously for a CBA benefits and costs must be expressed in the same units. However, in projects with environmental externalities this rarely happens. Due to the heterogeneity in the measurement units of costs and benefits especially for environmental and social impacts, it is necessary to use methods of economic homogenization to switch to monetary values (Molinos-Senante et al., 2010).

Some of the most frequently used valuation methods in the context of water reuse are (Garcia and Pargament, 2015).

- Revealed preference methods, such as hedonic price or travel cost methods;
- Cost based approaches, such as replacement or avoided costs methods;
- Stated preferences approaches, such as contingent valuation or contingent ranking.

In section 3.5, specific monetization techniques are described.

(a) CBA applied to water technologies: A literature review

In the literature, only few studies targeting CBA of non-conventional water resources projects have included the non-market valuation, and rarely health impacts. LCT studies focused mainly on products, while CBA is commonly applied to assess services and process. Table 1 in Annex 2 shows the key studies identified, and a brief description of each.

Water reclamation and reuse is a particularly appealing solution in water-stressed areas and can be used to tackle water scarcity but also to recover surface water quality (Asano, 1998; Lazarova et al., 2001). Economic considerations become of high importance when assessing the potential of water reuse projects (Asano, 1998; Jimenez and Asano, 2008). But projects' process design rarely includes a balanced economic analysis compared to other types of structuring projects and the economic feasibility of water reuse projects thus remains insufficiently studied (Molinos-Senante et al., 2011). This is partly because internal and external economic impacts are difficult to identify and quantify properly (Drechsel et al., 2015).While internal impacts may be easily translated into monetary units, externalities are not considered by the market, thus requiring economic valuation methods for externalities evaluation (Molinos-Senante et al., 2011). Consequently, the overall benefits and costs of many projects are not properly evaluated (Seguí-Amórtegui et al., 2014). Studies carried out in Mediterranean countries (Condom N. et al., 2012; Molinos-Senante et al., 2011; Xu et al., 2001) showed that when external benefits are properly quantified and integrated into the economic analysis the number of economically viable water reuse projects increases. Cost-benefits analyses (CBA) for water reuse projects are therefore of growing interest, but the methodology has scarcely been applied in France as well as in the Mediterranean area on water reuse projects.

3.5 Monetization techniques

Within the framework, monetization techniques will be used to later integrate social, economic and environmental data into the LCC and/or the CBA, providing the value (€) in a partial or integrated manner of a social or environmental good or service provided by a certain practice. The previous section describes specific characteristics considered within a CBA, while this section tries to cover both LCC and CBA. Even when there is a debate on monetizing the environment or social aspects, this practice is needed when the dominant system is an economic one. The methods can vary depending on the value to be assigned, through direct or indirect value methods, or the fact that there are similar existing values or if they hypothetically need to be calculated (Figure 7).

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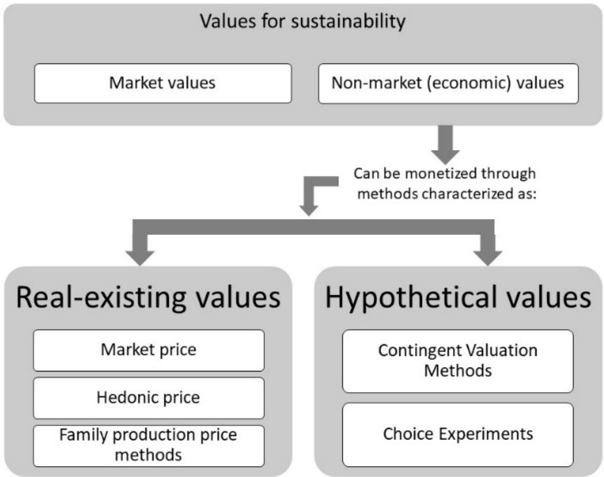

Figure 7. Methods for monetization of values for sustainability. Authors' elaboration.

(a) Real-existing values

- Market prices: if there are already existing market prices for the identified elements, this price can be used to estimate the marginal value of the good or service within the intended analysis; however, when it comes to environmental or exosystemic services it is rather unusual to have conventional market exchanges providing a price.
- Hedonic price: it is used to explain the price of a differentiated product (or factor of production) and to estimate the implicit, shadow prices of its quality characteristics. The basic idea of hedonic pricing models is that the price of a unit of a good on the market varies according to its characteristics and, thus, price differences between goods reflect differences in utility-bearing characteristics (Bosbach and Maietta, 2019).
- Family production price methods
    - Travel cost model: it entails the willingness of a certain consumer to pay for a service or good. The travel cost model provides an estimate of the benefits individuals receive from visiting a site by observing their travel-related expenses. In other words, the method consists of estimating the cost of enjoying the environmental amenity and use it as a proxy to value of the environmental product or service to be valuated. It requires a demand curve calculation. An example of its application has to do with

ecotourism; therefore, a demand curve establishes a function between the price of a good (or visit) and the quantity of the good consumed. It is usually downward sloping as at higher prices, fewer people will visit, while at lower prices, the number of visitors is greater. The consumer surplus, or area under the demand curve but above the price, is a measure of the ecotourism value of this reserve or site (Menkhaus and Lober, 1996).

- Defensive, avoided costs and changes in productivity: This is and indirect estimation method. First, the effect of the product or service on the production of the final intended product must be determined, through *dose-response* functions. Once the physical impact in production is known, it can be presented as the equivalent in monetary terms, and explained as avoided costs, or required defensive costs to maintain that impact. In this case, the environmental service or good does not have a direct market value but is related to an effect in a product that is marketed and therefore has a price, hence the environmental product/service and the market product/service are substitutive. Consequently, the method is based on the premise that individuals will be willing to invest money to avoid the consequences of an environmental degradation or risk.

(b) Hypothetical values

- Contingent valuation methods: they are known as a simple and flexible, yet strongly criticized non-market value method, and with numerous examples of applications in CBA and environmental impact assessments (Venkatachalam, 2004). This method will not be applied in FIT4REUSE project as it is highly resources consuming (time). It is executed through the application of a questionnaire that present an opportunity to the respondents to make an economic decision on a non-market good, deriving in a value obtained through the elicitation of the respondents' willingness-to-pay to prevent damages to natural resources, or restore damaged ones. This method is also regarded as a 'stated preference' method. Careful selection of sampling procedure, and appropriate data collection (questionnaire, avoidance of biases, etc.) is required to later analyse the obtained information using appropriate statistical/econometric methods (Geleto, 2011).

- Other techniques, such as choice experiments can be used within the hypothetical value group of monetization techniques.

3.6 Sensitivity analysis

Some differences may exist in the analysis between the original plan and the observed situation. The variables with highest contribution to the final impact or level of uncertainly (due to data source) will be tested by performing different sensitivity analysis to assess the robustness and the flexibility of the deterministic calculated results (e.g. see step 7 of CBA methodology).

This exercise will then be performed in LCT and CBA by modifying the range of inputs, or by applying the Monte Carlo method.

A Monte-Carlo consists in carrying out a succession of thousands of random draws for the values of some key but uncertain parameters (defined by its minimum and maximum values) and then in analysing the related results dispersion.

A good example of the importance of carrying a sensitivity analysis is given by (Garcia and Pargament, 2015) (in this case a Monte-Carlo analysis in CBA).

The outcomes of the sensitivity analysis will be examined to prove the robustness of the results and its flexibility referred to the selected variables.

3.7 Stakeholder consultation: Design and test

To ground the methodology to specific territorial aspects, a stakeholder consultation has been foreseen to take advantage of the knowledge of practitioners outside the project following a citizen science approach. Citizen science refers to the general public engagement in scientific research activities when citizens actively contributing either with their intellectual effort, surrounding knowledge or with their tools and resources (Wiederhold et al., 2013).

Considering the platform characteristics, which implies that participants must have a minimum level of online and computer literacy, the **first step** to build the approach is the identification of the relevant stakeholders. The **second step** is the design of the survey, the **third step** foresees a test of the accessibility of the survey and of the platform. The **fourth step** includes the invitation of the stakeholders and the submission of the survey. The **fifth step** comprehends data collection and analysis, and the **sixth step** is represented by the revision of the methodological framework taking advantage of the response of the stakeholders engaged in the consultation.

(a) Step 1 – Stakeholders' identification

Stakeholders' identification follows the quintuple helix model (Carayannis et al., 2012). This paradigm recognizes the role of academia, industry, political system, media (including culture), and environment (natural and societal), as subsystem of knowledge creation and innovation. Figure 8 shows an example of helix model adapted from Carayannis et al. (2012).

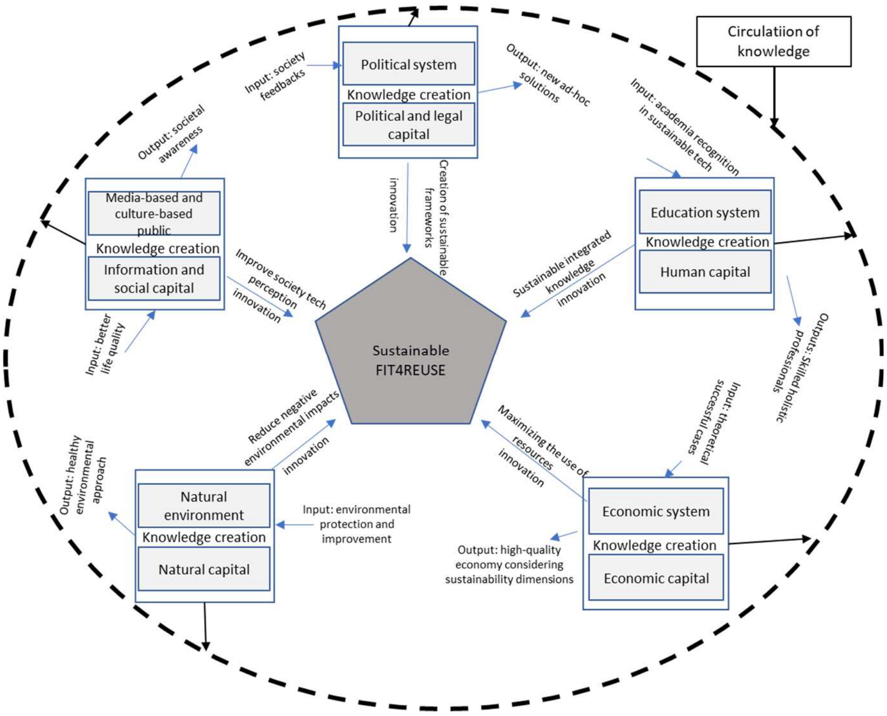

Figure 8. Example of the Quintuple Helix model and its functions applied to the sustainability of FIT4REUSE. Authors' elaboration from Carayannis et al. (2012).

The 5 stakeholders' groups consulted within the WP7 participatory framework could include:

1. **Education**: experts from higher education and academia (researchers). Their expertise mainly lies in the implementation of non-conventional water practices, the role of water in the society and rural farming.

2. **Economic**: experts from the private sector, targeting different business model sizes (from start-ups to consolidated firms). Specific sectors as those dealing with water technologies and rural farming will be included.

3. **Environment** (natural and social): experts from water and its related challenges, such as climate change; or the role of women in the water and agricultural sector will be consulted. This function should be completed by identifying the environment as a key stakeholder being affected positive and negative by the FIT4REUSE technologies.

4. **Media and culture**: local organized stakeholders such as farm cooperatives, local NGOs, citizens' organizations dealing with nature, and local/national media specialized on water sustainability will be consulted through the WRF.

5. **Political system**: actors from local to national level coping with decision making in the areas tackled by FIT4REUSE.

WP7 would like to include a strong diversity focus, in terms of age, gender and roles, to be contained within in the societal sustainability dimension, therefore experts on these matters would be valued.

Once the stakeholders have been identified, a performance measurement system will be applied in order to assess potential challenges for each of the helix/groups. This measurement consists in defining for each helix a general objective of interest related with the implementation of the project. From the general objective, critical successful factor will the then extracted, which will be measured by a key performance indicator.

Once that all the challenges are listed, it will be possible to understand on one hand which group/helix may be greatly affected or benefit by the development of the project, and on the other hand, which group/helix could be the greater contributor in knowledge sharing.

(b) Step 2 – Survey design

The survey will be divided in three parts: 1) a glance of project aim, 2) direct questions to be answered in a structured form, and 3) semi-structured questions to get new insights.

Questions will include a first glance to territorial characteristics (including the social dimension), as well as a self-assessment water knowledge.

Parts 2 and 3 will be preliminary tested with selected FIT4REUSE partners to understand the clarity of the questions. Once the questions are validated, they will be translated in different FIT4REUSE countries languages (English, French, Italian and Spanish) and uploaded to the WRF. The access to the consultation will be private, and the stakeholders will need specific credentials which will be provided by FIT4REUSE partners by invitation. The consultation can be found in Annex 1.

(c) Step 3 – Survey and platform test

The survey was submitted to selected stakeholders to collect feedbacks regarding its content and structure as well as about the overall functioning of the FIT4REUSE web platform. The summary of the results obtained after analyzing the feedbacks received with the rest are included in Box 1.

Box 1. Results of the survey and platform test

Survey content and structure

Water scarcity is a relevant matter in the Mediterranean area. Water reclamation for irrigation purposes, if accomplish with biological and physical-chemical characteristics regulated by recognized institutions, could be positively perceived. Water reuse could help to alleviate water pressure in the agricultural sector as well as guarantee that wastewater is treated and not discharged causing damages, such as when it is discharged in the sea.

Even this overall positive evaluation, there are certain concerns perceived in the environmental and economic dimensions. These are the energy requirements needed to treat this wastewater, as it could affect in a negative impact regarding greenhouse gases emissions, and extra costs due to the increment of resources (such as energy) needed. When dealing with water governance, it must include all affected groups, paying special attention in those less advantaged, including the gender perspective.

Platform

The usability of the platform should be improved - both for external and internal users - as well as its layout that should be more friendly with the aim to engage stakeholders in an active participation.

Furthermore, to this external consultation, internal consultations were developed to agree on the methodology with other FIT4REUSE partners. It helped to validate the methodology, as well as to show them the directions towards a sustainability assessment.

(d) Step 4 – Stakeholders' invitation and survey submission

The criteria to invite stakeholders to the WRD will consider the classification mentioned in the step one of this subsection. The link with the invitation and the instructions –

step 1 and 2 - will be provided by ISPRA institution by email to FIT4REUSE partners. The invitation link will redirect directly the consultation webpage.

Additional actors might be included if they are relevant for other WPs. FIT4REUSE partners will share the invitation to join the WRF to their key stakeholders (see above some examples). The invitation will include an announcement to be forwarded to other stakeholders, following the snowball approach.

The survey will be available online for 3 weeks. In case the number of answers will not be satisfactory (i.e. at least 50% of participation covering all countries in the scope of this research) an extension will be organized specifically targeting the countries with a lower rate of response. Privacy data will be managed following Deliverable 1.3 "Protocol on ethical principles for the management of personal data".

(e) Step 5 – Data collection and analysis

The consultation outcomes will be analysed following an Interpretive Structural Modelling (ISM) approach (Attri et al., 2013). The methodology allows to identify connection among specific items, which define a problem or an issue helping to identify drivers and inconsistencies in different consulted topics.

(f) Step 6 – Sustainability assessment revision

The results will be integrated to review the methodological framework before its application to deliverables D7.3, D7.4 and D7.5.

3.8 Other participatory activities supporting the development of the methodological framework

FIT4REUSE will organize three Water Reuse Days (WRD) during the project under the WP9. They aim at reaching the wider public and expanding the size of the local reuse forums by bringing additional stakeholders in contact with the project, and further developing of its results. During the WRD, it is expected to organize different activities, from workshops to training, where WP7 will benefit from other stakeholders' expertise to unveil unrecognized sustainability aspects in the literature review and to reinforce or readjust other findings.

SECTION 4 – Main conclusions

This report brings the methodological framework to perform a sustainability assessment of non-conventional water resources technologies. It explores life cycle thinking and cost-benefit analysis as promising methodologies to obtain a full sustainability assessment from different timeframe and boundaries perspectives.

It will be applied following different approaches – **attributional** in the analysis of baseline inventory (Task 7.2); and **consequential** and **multi-functional** in the alternative scenarios' development and inventory analysis (Task 7.3). - to analyse BAU and FIT4REUSE scenarios and potential consequences of the use of non-conventional water resources for agricultural practices or aquifer recharge. Therefore, it considers the FIT4REUSE practices characteristics, the water destination, and the territorial features which affects the sustainability of the project. Figure 9 represents the methodological structure and task in WP7.

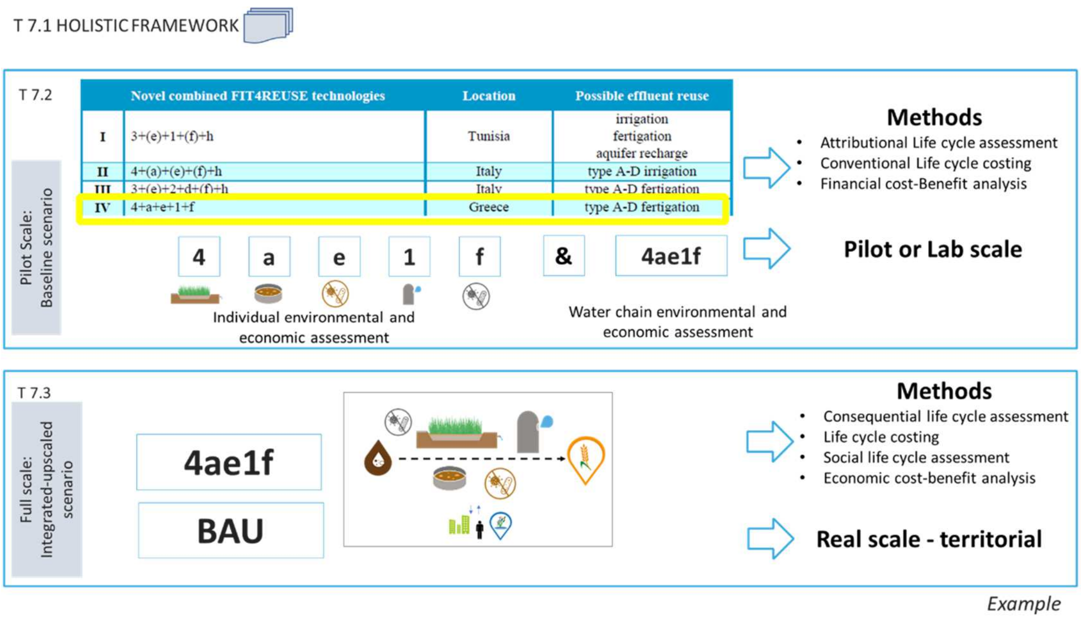

Figure 9. Methodologies applied in WP7 tasks. Authors' elaboration.

The methodological challenges explored in the previous section shows that LCT is widely applied to product assessment, while is not commonly applied to projects or services. This aspect would be key when performing the assessment of non-conventional water resources as it combines product related assessment with the

FIT4REUSE solutions and processes understood as the water treatment and use in agriculture and aquifer recharge. The processes' assessment will be carefully addressed and built in the few scientific evidences identified in the literature review.

On the other hand, CBA of water reuse projects can be difficult to execute even when mastering the basic economics concepts because of the complexity of the topic. Often water reuse will intervene in substitution of another resource, totally or partially, and therefore alter the qualitative and quantitative status of the whole water bodies concerned. One difficulty comes from the assessment, the quantification and the monetization of the associated costs or benefits. There is a risk of transformation of a qualitative problem into a quantitative problem (lower flows in river cause lower water quality for example). Another difficulty specific to water reuse projects concerns the lack of knowledge of physical effects such as fertilizer substitutions, salinization and sanitary safety. The identified difficulties will be integrated into the key considerations when designing the next deliverables regarding to data collection protocol and matrix described in the next section.

FU should be carefully identified as it is desirable to be common in all the explored sustainability dimensions. It must be adapted to each task in order to provide a better understanding of the environmental, cost and social impacts of the analysed situation. Task 7.2 could probably consider a water volume unit, such as 1m^3 of reclaimed water as most of the previous studies facilitated, while in Task 7.3 other units could be utilized as it will follow a territorial or multi-functional approach. It is important to remark that in Task 7.2 the followed approach would be attributional, capturing the static image of selected utilization of FIT4REUSE solutions; while Task 7.3 will follow a consequential approach modelling the effects of interventions at real scale in the system. The addressed stakeholders will be defined through internal (with FIT4REUSE partners) and external consultations. It will ponder the territorial characteristics, from local to supranational, as well as the relevance to the project.

Primary data collection will be always prioritized, while secondary data will be utilized when the primary are not available or reliable (in the case of pilots under specific characteristics).

This methodological framework was co-designed through a participatory approach, in order to address some challenges identified at social level. Such challenges can be social acceptability, as well as the perception of benefits and barriers from different nature in the non-conventional water resource application.

The areas of consultation comprehended:

- Territorial definition, mainly to understand the socio-economic implications of the tested technologies.
- Risk management in terms of data availability and data sources quality.
- The role of gender and risk minorities in the socio-economic sphere.
- Current local and institutional drivers and barriers to implement the technologies.

The platform WRF, as well as the WRD briefly described in section 2, will be utilized during the next task of this WP to shape some outcomes derived from a first analysis, as well as to stimulate the discussion about the application of FIT4REUSE solutions and bring new insights.

The combination of methodologies – LCT and CBA – provides a comprehensive sustainability assessment of the selected non-conventional water resources in specific territories.

SECTION 5 – Further steps

5.1 Data collection matrix

A data collection matrix and protocol (Deliverable 7.2) will be designed to gather primary data from the WP responsible of each FIT4REUSE technology, as well as from other team members involved in the studied area of influence.

This matrix includes input flows, mainly to identify environmental impacts (such as material, energy, or cost), and outputs (emissions, waste, etc.). Secondary data from relevant literature and databases will also be included in case of missing information, especially on specific cost items, and environmental impact categories.

The outcomes of this matrix will be allocated into the functional unit identified for LCT application.

This matrix will be developed to each technology and territorial area, identifying a local spokesperson inside the project per FIT4REUSE technology and area. The data collection matrix will be shared together with the protocol, to guide the user in the compilation. A schedule for a skype call to explain the aim of this research and what it is expected from each spokesperson will be communicated as well.

5.2 Second round of data collection

The outcomes collected from the matrix will be complemented with a literature review and stakeholders' consultation. It is expected a round of consultation during the first WRD (WP9) with key experts to discuss the results of Task 7.2., while the platform offered under the WRF will be utilized to address uncovered questions from the matrix or acquire additional information.

5.3 Data analysis

Each technology will be characterized according to its technical profile as well as specific location. The LCT will follow the methodology described in the section 3; therefore, the goal and scope identification, inventory, impact assessment and interpretation of results will be executed The CBA will follow the steps described in section 3 as well.

5.4 Consultation approach

The participatory methodology described in section 3 will be conducted through the WRF. Participation will allow to confirm certain socio-economic-environmental patterns and to identify and to select territories to be used as case studies for simulations and analysis at territorial scale in Task 7.3, while recognizing unveiled patterns to perform the life cycle thinking method and cost-benefit analysis.

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ANNEX 1 – Stakeholders' survey

FIT4REUSE Participatory consultation

FIT4REUSE - Safe and sustainable solutions for the integrated use of non-conventional water resources in the Mediterranean agricultural sector

The project FIT4REUSE will provide safe, sustainable and accepted ways of water supply for the Mediterranean basin by exploiting non-conventional water resources.

Treated wastewater and desalinated water can contribute to compensate the gap between agricultural water demand and supply and provide consistently high-quality water throughout the year.

FIT4REUSE will focus on innovative, sustainable and safe treatment technologies, and on the use of treated wastewater and desalinated water in agriculture and for aquifer recharge. Also, specific methodological and assessment tools will be created to meet the project objectives.

This survey ***aims to reinforce and unveil socio-economic and environmental characteristics*** *which might be relevant when performing a* ***sustainability assessment*** *associated to this project. Territorial characteristics within the water reuse context would be pointed out to guide further project activities. The role of diversity, understood under vulnerable risk groups, gender and age features, is explored to enrich the comprehension of those actors in the water reuse and water policies framework.*

All inputs will contribute to the development of the methodological framework of the holistic sustainability assessment. For further information, or additional comments, please feel free to contact anytime at: fit4reuse@unibo.it

Background notes

Conventional water resources are those surface and groundwater resources commonly used for anthropic uses - including irrigation.

Non-conventional water resources are those that are generated as a by-product of specialized processes such as desalination or wastewater treatment; or that need suitable pre-use treatment; or pertinent on-farm management when used for irrigation; or need a special technology to collect/access water.

General Demographic information:

a) Gender (please tick where appropriate):

Male	Female	Non-binary	Not disclosed

b) Birth year: ___________

c) Country: ___________

d) Highest level of formal education (please tick where appropriate):

None	Elementary	High school	Bachelor	Master	PhD

e) Current occupation: ____________

f) Group of stakeholders you belong to (please tick where appropriate):

Education (e.g. scientific community, higher education…)	Business (e.g. industry, investors…)	Environment (natural and social) (e.g.water/gender experts…)	Media and local organized stakeholders (e.g. NGO, general public, civil society, media…)	Government or public organization (e.g. policy makers…)	Others

If others, please specify:

Self-evaluation knowledge about water. Please, from 1 low to 5 high, indicate how deep is your understanding of **water management issues**:

1	2	3	4	5

Please, from 1 low to 5 high, indicate how deep is your understanding of **water reuse issues**:

1	2	3	4	5

1. Which is the major water issue in your area / country? Please, provide the name of the area in case it is a specific region within a country.

2. How this water issue is impacting in your area/country? Please, provide the name of the area in case it is a specific region within a country.

3. In your personal opinion, is a food product produced with water from non-conventional resources potentially safe to be consumed? Please, provide a detailed answer.

4. In your opinion, if the food product is produced with water from non-conventional resources that fulfil the National Regulations Standards, or any Standard, is perceived as safe to be consumed? Please, provide a detailed answer.

5. In your opinion, does the utilization of water from non-conventional resources improve the quality of the ecosystems? Please, rank from 1 low improvement to 5 high.

6. In your opinion, does the utilization of water from non-conventional resources improve the recycling of nutrients from wastewater to be used in feedstock, proteins or biofuels production? Please, rank from 1 low improvement to 5 high.

7. In your opinion, does the utilization of water from non-conventional resources improve the implementation of circular economy practices? Please, rank from 1 low improvement to 5 high.

8. In your opinion, does the utilization of water from non-conventional resources reduce pollution since wastewater is no longer discharged into the environment? Please, rank from 1 low reduction to 5 high.

9. In your opinion, does the utilization of water from non-conventional resources increase water security for the society? Please, rank from 1 low increasement to 5 high.

10. In your opinion, does the utilization of water from non-conventional resources increase the amount of potable water available for the population? Please, rank from 1 low increasement to 5 high.

11. In your opinion, does the utilization of water from non-conventional resources provide additional water availability for recreational use, such as swimming, fishing, etc.? Please, rank from 1 low availability to 5 high.

12. Do you have in mind other benefits water from non-conventional resources might have? If not, please write “not applicable”

13. In your opinion, do first investments for technology development represent a challenge on the utilization of water from non-conventional resources? Please, rank from 1 low challenge to 5 high.

14. In your opinion, does financial support to scale up pilot and small project represent a challenge on the utilization of water from non-conventional resources? Please, rank from 1 low challenge to 5 high.

15. In your opinion, does the regulatory framework to insert the water treated in the market represent a challenge on the utilization of water from non-conventional resources? Please, rank from 1 low challenge to 5 high.

16. In your opinion, does the level of water quality (odors, color…) represent a challenge on the utilization of water from non-conventional resources? Please, rank from 1 low challenge to 5 high.

17. In your opinion, does public acceptance represent a challenge on the utilization of water from non-conventional resources? Please, rank from 1 low challenge to 5 high.

18. In your opinion, does willingness to pay to consumers (farmers) represent a challenge on the utilization of water from non-conventional resources? Please, rank from 1 low challenge to 5 high.

19. Do you have in mind other challenges water from non-conventional resources might have? If not, please write “not applicable”

20. Do you know a success case on water reuse in your area? Please, provide a detailed answer, including the site location.

21. Do you know in your area a specific site with a high opportunity for water reuse? Please, provide a detailed answer, including the site location.

22. Do you think that water policies implementation and communication consider vulnerable groups, gender and age characteristics? Please, provide a detailed answer.

23. Do you think that water policies should consider vulnerable groups, gender and age characteristics? Please, provide a detailed answer.

24. This consultation has been forwarded to the following groups of interest: academia (researchers and faculties), policy-makers, groups of citizens, local NGOs, enterprises (start-ups, medium and large scale) and media and cultural representatives. Would you suggest any other? Please name the group of interest they belong to, and forward this consultation-link to them.

Thank you very much for your contribution!

ANNEX 2 – LCT and CBA literature review

Table 1. LCT and CBA literature review outcomes

LIFE CYCLE ASSESSMENT	
Title and authors	Holistic life cycle assessment of water reuse in a tourist-based community (Santana et al., 2019)
Type of document	Scientific article
Geographic area	Spain
Tech/practice	This study holistically compares four water management scenarios for the tourism-dependent city of Lloret de Mar (Spain). One scenario serves as a base scenario and the other scenarios are water reuse scenarios at different scales of technological implementation.
LCT applied	LCA
FU and SB	The functional unit was set to one year of operation of the entire water management system of Lloret de Mar. Cradle to grave approach.
Impact categories	Carbon footprint (kg CO2-eq/year), marine eutrophication (kg N-eq/year), metals depletion (kg Fe-eq./year), and water footprint (m3/year).
Title and authors	Life cycle assessment case study: Tertiary treatment process options for wastewater reuse (Carré et al., 2017)
Type of document	Scientific article
Geographic area	South of France
Tech/practice	Five tertiary treatment trains were studied: 1) sand filtration + storage followed by ultraviolet (UV) dynamic reactor disinfection (SF-UVD), 2) sand filtration (SF) + UV batch reactor disinfection (SF-UVB), 3) ultrafiltration (UF), 4) ultrafiltration and UV batch reactor disinfection (UF-UVB), 5) microfiltration (MF) and storage followed by dynamic UV disinfection (MF-UVD). This study was conducted on an industrial pilot.
LCT applied	LCA
FU and SB	To supply 1 m3 of water with a quality in compliance with the highest standard of the French reuse regulation. The system is decomposed into the following steps: pilots manufacturing, transport, utilization, and end-of-life. Transport of the pilot units to the experimental site, and transport when dismantling, are considered within the boundaries. However, during the modelling, the impacts due to the transportation, the energy mix, and the materials composing the storage tanks have been considered individually because they can vary according to the local conditions.
Impact categories	HTP, IR, PhO, GWP, ETP, MEP, FEP, AP, FD, MD and PEC as most appropriate indicators based on previous studies. AP=terrestrial acidification; ETP=ecotoxicity (measured as 1,4-Dichlorobenzene, 1,4-DB equivalents); FD=fossil resources depletion; FEP=fresh water eutrophication; GWP=global warming potential; HTP=human toxicity; IR=ionizing radiation; MD=metal depletion; MEP=marine eutrophication; PEC=primary energy consumption; PhO=photochemical oxidation (measured as kg of Non-Methane Volatile Organic Compounds, NMVOC).
Title and authors	Life cycle assessment of water supply in Singapore — A water-scarce urban city with multiple water sources (Hsien et al., 2019)
Type of document	Scientific article
Geographic area	Singapore
Tech/practice	Public water supply, which consists of NEWater (highly purified recycled water) and tap water
LCT applied	LCA

FU and SB	The functional unit is 1m3 of water (NEWater or tap water) delivered to the consumer. The system boundary for tap water includes water abstraction from river and reservoirs, treatment at waterworks, desalination, wastewater collection, treatment at water reclamation plants, treatment at NEWater plants, and water distribution.
Impact categories	Eight relevant midpoint impact categories were considered: climate change (CC), ozone layer depletion (OD), photochemical oxidation (PO), human toxicity (HT), particulate matter (PM), terrestrial acid- ification (TA), fossil depletion (FD), and water depletion (WD).
Other	The ReCiPe method was used with the Hierachist perspective (Goedkoop and Huijbregts, 2013) as it provides a comprehensive set of indicators, including water depletion, which is highly relevant in Singapore's water scarce context.
Title and authors	Life cycle assessment and costing of wastewater treatment systems coupled to constructed wetlands (Resende et al., 2019)
Geographic area	São Paolo, Brazil
Tech/practice	This study evaluates the environmental and economic performance (ecoefficiency) of two decentralized, small- scale, wastewater treatment systems coupled to constructed wetlands. System One comprises a vertical and a horizontal flow wetland. System Two comprises a vertical subsurface flow wetland with artificial aeration. Pilot scale.
LCT applied	LCA and LCC
FU and SB	The functional unit was one cubic meter of treated wastewater and the lifetime of the facilities was 20 years. System boundaries comprise unit processes related to construction, operation and decommissioning.
Impact categories	Freshwater Eutrophication, Freshwater Ecotoxicity, Human toxicity, Terrestrial Acidification, Photochemical Oxidants formation.
Other	The systems were modeled in open LCA software, with the aid of Ecoinvent 3.3 data, and the impact assessment was based on the ReCIPe method.
Title and authors	Hotspot analysis and improvement schemes for capacitive deionization (CDI) using life cycle assessment (Shiu et al., 2019)
Type of document	Scientific article
Geographic area	NA lab case
Tech/practice	The aim of this study was to obtain comprehensive knowledge on the improvement of CDIs from environmental aspects. Life cycle assessment (LCA) was utilized to evaluate the environmental friendliness of the CDIs. Five lab-scale design schemes, including CDI, membrane capacitive deionization (MCDI) and scale-up MCDI stacks, were investigated in this study.
LCT applied	LCA
FU and SB	The functional unit is 1 m3 of desalinated product water, which provides a quantified reference for comparing the desalination and environmental performance of the CDI stacks. The system boundary comprised inputs and outputs of energy and resources for manufacturing, operation and waste/wastewater disposal.
Impact categories	ADP for abiotic depletion potential; AP for acidification potential; EP for eutrophication potential; GWP for global warming potential; ODP for ozone layer depletion potential; HTP for human toxicity potential; FAETP for fresh water aquatic ecotoxicity potential; MAETP for marine aquatic ecotoxicity potential; TETP for terrestrial ecotoxicity potential; PCO for photochemical oxidation.
Other	CML 2 Baseline 2000 (CML 2000), a widely used method for the LCA of wastewater treatment, was used to evaluate the environmental impacts of CDI. World 1995 values, the recommended references for regional assessment of undefined systems, were selected as normalization factors. SimaPro 8 software with EcoInvent version 3.1 databases was used.
Title and authors	Environmental impacts of resource recovery from wastewater treatment plants (Hao et al., 2019)
Type of document	Scientific article
Geographic area	China

Tech/practice	In this work, a scheme with highly efficient energy and resource recovery (especially for thermal energy) is proposed and evaluated. The environmental impact of a conventional WWTP in comparison with the scheme proposed here, with energy/resource recovery included, was calculated, and discussed with reference to LCA methodology.
LCT applied	LCA
FU and SB	The function unit (FU) used in this study is defined as person equivalent (p.e.) for a period of 1 year, which is most commonly used in similar studies. The base-case scenario covers the construction, operation, and demolition stages of the targeted WWTP (Pennington et al., 2004; ISO, 2006b). All of the energy/materials input/output between the influent and effluent were considered in the LCA application.
Impact categories	Global warming potential (GWP), Eutrophication potential (EP), Acidification potential (AP), Abiotic resources depletion potential (ADP), Human toxicity potential (HTP), Black and odor potential (BOP), Landfill space depletion potential (LSD), Freshwater use (FWU).
Title and authors	Evaluation of potential environmental benefits from seawater toilet flushing (Liu et al., 2019)
Type of document	Scientific article
Geographic area	Fourteen cities in China
Tech/practice	Environmental performance of the SWTF system by comparing SWTF with other alternative water resources including desalinated seawater, desalinated wastewater effluent, centralized wastewater reclamation and on-site greywater reclamation systems, while the conventional long-distance imported water scenario is set as the baseline for comparison. This evaluation is first conducted in the Southern District and North New Territory in Hong Kong, which is the only alternative water resource application approach with environmental impacts comparable with the conventional long-distance imported water scenario.
LCT applied	LCA
FU and SB	The functional unit in each water scenario is defined as 1 m3 of water production. Only the operation phase is evaluated for the existing water components, while additional construction phases are also considered for the newly built facilities. The demolition phase is excluded from this study as its contribution to the entire life cycle is negligible.
Impact categories	Climate change (CC), human toxicity (HT), photochemical oxidant formation (POF), ozone depletion (OD), terrestrial acidification (TA) and particle matter formation (PMF).
Title and authors	Environmental impacts of an advanced oxidation process as tertiary treatment in a wastewater treatment plant (Arzate et al., 2019)
Type of document	Scientific article
Geographic area	Almeria, Spain
Tech/practice	The goal of this study is to compare the two tertiary treatment options, municipal wastewater ozonation and photo-Fenton, for MP removal under the current Almeria wastewater management.
LCT applied	LCA
FU and SB	The functional unit, the "quantified performance of a product system for use as a reference unit", was assumed to be the disposal of 1 m3 of secondary effluent. The system boundaries include the materials for the construction of the infrastructure of the tertiary treatment, as well as its final disposal, and the operation phase of the tertiary treatment. The pipes needed to send the reclaimed water from the WWTP plant to the sea or to the crops are not considered.
Impact categories	Human Health; water depletion; climate change; natural land transformation; ecosystem; resources; Human toxicity – cancer; human toxicity – non-cancer; freshwater ecotoxicity.
Other	Impacts with ReCiPe and USEtox as life cycle impact assessment (LCIA) methods.
Title and authors	Life cycle assessment of water reuse systems in an industrial park (Tong et al., 2013)
Type of document	Scientific article
Geographic area	China

Tech/practice	Environmental impacts quantification of reusing treated wastewater at industrial parks under different scenarios through a comparative life-cycle assessment (LCA). Four scenarios are assessed: wastewater is treated and discharged, 20% and 99% of wastewater is treated and reused as industrial process water, and treated wastewater is used for horticulture.
LCT applied	LCA
FU and SB	The function of the water recycling system is to treat wastewater to the required quality for its application. 1 m3 of wastewater treated is used as the functional unit (FU). System boundaries only operation phase of the treatment system is considered because the collection system is the same under different scenarios.
Impact categories	The calculated impact indicators include abiotic depletion potential (ADP elements), acidification potential (AP), eutrophication potential (EP), fresh water aquatic ecotoxicity potential (FAETP), global warming potential (GWP, 100 years), human toxicity potential (HTP), marine aquatic toxicity potential (MAETP), ozone layer depletion potential (ODP), photochemical oxidation potential (POCP), and terrestrial ecotoxicity potential (TETP). These impact categories are chosen because of its relevance to wastewater treatment. Another indicator, water depletion potential (WDP), is considered in this study to quantify the water resource. The water depletion potential is expressed as the total amount of water used over the life cycle.
Other	In this study, CML 2001 method (CML, 2011) is used as characterization method.
Title and authors	Environmental and economic profile of six typologies of wastewater treatment plants (Rodriguez-Garcia et al., 2011)
Type of document	Scientific article
Geographic area	Spain
Tech/practice	The objective of wastewater treatment plants (WWTPs) is to prevent pollution. In this research, the performance of 24 WWTPs has been evaluated using a streamlined LCA. The main objective of this paper is to compare the environmental and economic performance of 24 Spanish WWTPs, which derived into six typologies.
LCT applied	LCA and a bit of costing
FU and SB	A functional unit based on the volume of treated wastewater (m3) was used as the first choice for the comparison of the WWTPs (FU1). another choice for the definition of the FU should comprise the removal of both nutrients and organic matter, expressed in terms of kg PO43 eq. removed (FU2). This assessment considered the environmental impact associated with the operation of primary, secondary, and tertiary treatments (when present); final discharge of the treated effluent; as well as the sludge treatment and its final disposal.
Impact categories	Eutrophication Potential (EP) and Global Warming Potential (GWP) as environmental indicators, and operational costs as economic indicators.
Title and authors	Environmental life cycle assessment for potable water production – a case study of seawater desalination and mine-water reclamation in South Africa (Goga et al., 2019)
Type of document	Scientific article
Geographic area	South Africa
Tech/practice	Two of the methods currently considered are desalination of seawater and reuse of mine-affected water based on the use of reverse osmosis (RO) membranes. Due to their high energy consumption and associated environmental impacts, these methods have been under scrutinity and, therefore, an LCA was undertaken for both methods.
LCT applied	LCA
FU and SB	The functional unit of 1 kL of potable water was specified. System boundaries: construction, operation and decommissioning.
Impact categories	The ReCiPe Midpoint Method was used. 18 impact categories were defined: climate change, human toxicity, ionising radiation, photochemical oxidant formation, particulate matter formation, terrestrial acidification, ozone depletion, terrestrial ecotoxicity, agricultural land occupation, urban land occupation, natural land transformation, marine ecotoxicity, marine

	eutrophication, fresh water eutrophication, fresh water ecotoxicity, fossil fuel depletion, minerals depletion and fresh water depletion.
Title and authors	Life cycle assessment of decentralized greywater treatment systems with reuse at different scales in cold regions (Kobayashi et al., 2020)
Type of document	Scientific article
Geographic area	Canada
Tech/practice	A comparative life cycle assessment (LCA) of decentralized greywater management systems at different scales for a hypothetical com- munity in a cold (winter) region. To provide a comparison between nature-based and engineered greywater treatment solutions, constructed wetlands (CW) and membrane bioreactors (MBR), respectively, they were investigated at three different scales; community (3500 person equivalent [PE]), neighbourhood (350 PE) and household (a single household [up to 5 PE]). Conventional centralized wastewater treatment was also included as a business-as-usual (BAU) scenario.
LCT applied	LCA
FU and SB	The functional unit in this study was the annual treatment of greywater generated per person. Collection.
Impact categories	Global warming potential (GWP), eutrophication potential (EUP) and human health – carcinogenic potential (HHCP).
SOCIAL LIFE CYCLE ASSESSMENT	
Title and authors	Environmental and social life cycle assessment of urban water systems: The case of Mexico City (García-Sánchez and Güereca, 2019)
Type of document	Scientific article
Geographic area	Mexico City-Mexico
Tech/practice	The main goals of this study were to assess the environmental and social impacts of the water system in Mexico City using Life Cycle Assessment (LCA), identify the significant impacts and their sources, and provide a new perspective for a sustainable water system in the city.
LCT applied	LCA- SLCA
FU and SB	The functional unit (FU) is one cubic meter (1 m3) of water for consumption. The urban water system of Mexico City consists of seven life cycle stages: water abstraction (WA), water treatment (WT), transport (T), distribution (D), use (U), sewage collection (SWC) and wastewater treatment (WWT). This study considers all the inputs and out- puts of each stage except the construction of the infrastructure and final disposal.
Impact categories	global warming (WP), ozone formation, human health (OF-HH), terrestrial acidification (TA), freshwater eutrophication (FE), freshwater ecotoxicity (FET) and human non-carcinogenic toxicity (HNCT),human rights, working conditions, health and safety, cultural heritage, governance and socioeconomic repercussions.
Title and authors	A comparative social life cycle assessment of urban domestic water reuse alternatives (Opher et al., 2018)
Type of document	Scientific article
Geographic area	Israel- The case study involves a hypothetical medium-size city of approximately 200,000 inhabitants
Tech/practice	The social benefits and impacts of four alternative approaches to urban domestic non-potable water reuse were compared: central wastewater treatment and no urban reuse, central wastewater treatment and urban reuse, semi-distributed greywater treatment and reuse, distributed greywater treatment and reuse.
LCT applied	LCA- SLCA
FU and SB	The functional unit (FU) is the supply, reclamation, and reuse of water consumed by the city for 1 year. In accordance with the goal and scope of the SLCA, system boundaries were limited to the foreground sub-systems only: potable water production and supply, WW (wastewater) and

	GW (greywater) conveyance and treatment, RW (reclaimed water, referring to either GW or WW) supply, and water reuse.
Impact categories	Water saving, equity, community engagement, local employment, urban landscape, health concerns, household expenses and convenience.
Title and authors	Addressing social aspects associated with wastewater treatment facilities (Padilla-Rivera et al., 2016)
Type of document	Scientific article
Geographic area	Mexico
Tech/practice	In wastewater treatment facilities (WWTF), technical and financial aspects have been considered a priority, while other issues, such as social aspects, have not been evaluated seriously and there is not an accepted methodology for assessing it. In this work, a methodology focused on social concerns related to WWTF is presented.
LCT applied	SLCA
FU and SB	Not disclosed
Impact categories	The methodology proposes the use of 25 indicators as a framework for measuring social performance to evaluate the progress in moving towards sustainability. Public participation, social acceptance, community engagement, sustainable behaviour, safe, healthy and secure living conditions, local employment, public commitments to sustainable issues, contribution to economic development, freedom of association, demand satisfaction,
Title and authors	Social trust, risk perception and public acceptance of recycled water: testing a social-psychological model (Ross et al., 2014)
Type of document	Scientific article
Geographic area	Toowoomba, South East Queensland, Australia
Tech/practice	Public risk perceptions and trust have been shown to be key factors in acceptance of potable reuse projects, this research developed and tested a social-psychological model of trust, risk perceptions and acceptance. Participants (*N* = 380) were surveyed a few weeks before a referendum was held in which residents voted against the controversial scheme.
LCT applied	SLCA-Consumer acceptance
FU and SB	Community, 380 participants surveyed
Impact categories	Source credibility, fair procedures, group membership, shared values, trust, risk perceptions, acceptance.
Title and authors	Socio-economic and psychological predictors of domestic greywater and rainwater collection: Evidence from Australia (Ryan et al., 2009)
Type of document	Scientific article
Geographic area	Australian Capital Territory
Tech/practice	This paper reports on an internet survey completed by 354 households residing in the Australian Capital Territory and surrounding regions. Statistical analyses examined the relationship between socio-economic and psychological variables and the likelihood of the garden being irrigated with greywater and/or rainwater.
LCT applied	Consumer acceptance
FU and SB	Not disclosed
Impact categories	Gender, age, education and income
LIFE CYCLE COSTING	
Title and authors	Economic assessment of aerated constructed treatment wetlands using whole life costing (Freeman et al., 2019)
Type of document	Scientific article
Geographic area	Not disclosed

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Tech/practice	The technologies for wastewater treatment included in this paper were saturated vertical flow (SVF) aerated wetland, a submerged aerated filter (SAF) and a rotating biological contactor (RBC).
LCT applied	Whole life cost (WLC) assessment.
FU and SB	Not disclosed
Impact categories	Not disclosed
Title and authors	Comparison of Design Alternatives Based on Lifecycle Costing: Case of an Irrigation Project in Turkey (Ökmen, 2015)
Type of document	Scientific article
Geographic area	Southern region of Turkey (Seyhan River Yedigöze İmamo˘glu Irrigation Project)
Tech/practice	The Irrigation techniques included pipe network and concrete covered open main channel of 15.812 km in comparison to a pipe network and concrete covered open main channel of 57.562 km.
LCT applied	LCC
FU and SB	FU not mentioned. Cradle to grave (from inception phase at research and development, following with stages of production, modification, transportation, introduction into inventory, construction, operation, support, maintenance, disposal, salvage revenue, and any other cost of ownership).
Impact categories	Investment costs, construction costs, annual total expense.
Other	Other considerations in the assessment included Net Present Value of the total expense, of loss of water, and during the life cycle of the project, water savings, operation easiness and required structures.
Title and authors	Environmental Life Cycle Costing and Sustainability, Insights from Pollution Abatement and Resource Recovery in Wastewater Treatment (Hall et al., 2018)
Type of document	Scientific article
Geographic area	Not disclosed
Tech/practice	The assessment considered different techniques, beginning with a waste water treatment plant with the existing technology (activated sludge with biological nutrient removal or AS-BNR); and moving into additional processes such as a)thermal hydrolysis for solid waste reduction, b)a struvite reactor for resource recovery, this later creating benefits by increasing the availability of carbon and nutrients, c) autotrophic removal using anaerobic ammonium oxidation (anammox) for further abatement of nitrogen and process efficiency.
LCT applied	ELCC
FU and SB	The FU was the treatment of 1 megaliter (ML) of wastewater and then scaled to approximately 52,000 ML/year of influent. The treatment met regulated social, environmental, and economic standards, and the scalation was performed to match the scale of the capital investment. The system boundaries established within the changes to an existing company wastewater system.
Impact categories	Income and costs for each new process as well as changes to existing treatment processes. (authors expressed it included "Changes in pollution emissions and their existing treatment costs such as the reduction in solid waste, Change in process costs for pollution abatement as an offset where the new process substitutes for existing treatment costs, and Change in existing treatment processes as a result of resource recovery processes").
Other	Social acceptance of recovered water and market access for resources created large risk for investment. Other sustainability values such as scarcity and ecological thresholds were not captured in the study. The ELCC code of practice suggests including such costs if likely in the foreseeable future; defining these values may also clarify the role of ELCC to evaluate sustainability over the life cycle.

Title and authors	Life cycle and economic assessments of engineered osmosis and osmotic dilution for desalination of Haynesville shale pit water (Coday et al., 2015)
Type of document	Scientific article
Geographic area	Haynesville basin (USA)
Tech/practice	Used technology for the treatment of Oil and gas pit water for deep well disposal entailed a) Forward osmosis (FO) b) engineered osmosis, and c)osmotic dilution.
LCT applied	LCA and LCC
FU and SB	FU: 1 bbl of pit water Scenario 1: gate-to-gate; Scenario: cradle-to-gate
Impact categories	The elements considered expenses incurred during water management (trucking and wastewater disposal), capital expenses, and yearly operation and maintenance (O&M) expenses.
Other	Authors aknowledge that although any comparison between a gate-to-gate LCI and a cradle-to-grave LCI might present an incomplete evaluation of the potential environmental impacts, thy presented this study to establish a benchmark for future comparative analyses.
Title and authors	Investigation of alternative water sources for fish farming using life cycle costing approach: A case study in North West Tasmania (Mahbub and Sharma, 2019)
Type of document	Scientific article
Geographic area	North West Tasmania (Australia)
Tech/practice	Sources of water consisted of freshwater from local rivers, groundwater, drinking water from a local water supply utility, together with other nearby irrigation schemes.
LCT applied	LCC using net present value (NPV) method. This technique combines the capital cost of infrastructure planned for providing services, the annual maintenance and the operation cost during the analysis period; as well as the replacement of components having service life less than the analysis period.
FU and SB	Not disclosed
Impact categories	Capital Cost, Operational Cost, Annual maintenance cost, Total Investment.
Title and authors	Comparative life cycle sustainability assessment of urban water reuse at various centralization scales (Opher et al., 2019)
Type of document	Scientific article
Geographic area	None (hypothetical "Model city")
Tech/practice	The study was based on a central wastewater treatment plant, a dual municipal reticulation system and a cluster scenario with rotating biological contactor (RBC) systems, followed by filtration and disinfection.
LCT applied	LCSA= LCA + LCC + SLCA
FU and SB	The functional unit (FU) is the annual supply, reclamation, and reuse of water consumed by "Model City". System boundaries included potable water production and supply, wastewater and greywater collection and treatment, and reclaimed water (RW) supply and reuse.
Impact categories	Initial costs, operation and maintenance, end-of-life costs, and total costs.
Other	Cluster level reclamation (Distributed urban water reuse), under modeled conditions, is the most sustainable option and the BAU scenario is the least sustainable.
Title and authors	Benefits of coupled green and grey infrastructure systems: Evidence based on analytic hierarchy process and life cycle costing (Xu et al., 2019)
Type of document	Scientific article
Geographic area	Nanjing, Jiangsu provice
Tech/practice	Green and grey systems
LCT applied	LCC

FU and SB	FU not mentioned System boundaries consider the design, construction, operation, and maintenance stages of coupled green and grey systems
Impact categories	Pipe material cost, Pipe laying cost, Pipe shaping cost, Excavation and backfilling cost.
Title and authors	Life cycle costs of advanced treatment techniques for wastewater reuse and resource recovery from sewage sludge (Tarpani and Azapagic, 2018)
Type of document	Scientific article
Geographic area	Not mentioned
Tech/practice	Granular activated carbon (GAC), Nanofiltration (NF), Solar photo-Fenton (SPF), Ozonation (OZO) plus sludge treatment by digestion, composting, pyrolysis and others
LCT applied	LCC
FU and SB	The advanced wastewater treatment was assessed using a FU of "treatment of 1000m3 of effluent from conventional wastewater treatment". For sludge, the FU was the "treatment of 1000 kg of thickened sludge on a dry basis". System boundaries: cradle-to-grave, comprising plant construction and operation, periodic equipment replacement, waste management and recovery of resources.
Impact categories	The LCC cost categories included capital costs, infrastructure replacement costs, fixed operating costs, variable operating costs (advanced wastewater treatment methods only), waste management costs and transport costs; minus the revenue from the sales of recovered products.
Title and authors	Life Cycle Costing of Water Treatment Plant in the Nashik City (Ambre et al., 2019)
Type of document	Scientific article
Geographic area	Nilgiri Bagh, Nashik. India
Tech/practice	Not mentioned
LCT applied	LCC
FU and SB	FU: 50MLD water treatment plant
Impact categories	Construction costs, operation and maintenance costs, equipment replacement costs, electricity costs and the disposal cost, together with Net Present Value Method. (The LCC was calculated adding initial costs, present value of replacement cost, present value of annually recurring, operating, maintenance and repair cost, present value of non-annually recurring operating, maintenance and repair cost, present value of energy costs, minus de present resale value or residual value or salvage value.)
Title and authors	Holistic analysis of urban water systems in the Greater Cincinnati region: (2) resource use profiles by emergy accounting approach (Arden et al., 2019)
Type of document	Scientific article
Geographic area	Cincinnati, Ohio USA
Tech/practice	Water sourced from the Ohio River is pumped to the plant and delivered to consumers. Techniques include coagulation with aluminum sulfate and gravity settling, sand filtration, filtration and granular activated carbon (GAC). There are also adjustments of pH, disinfection and fluorination. Wastewater processes include a screening for large and settle-able debris, primary sedimentation, an aerobic activated sludge process, secondary clarifiers, and disinfection prior to discharge. Sludge from primary and secondary treatment goes through a thickening, dewatering and incineration operation before disposing the ashes in a landfill.
LCT applied	LCC is used with LCA to compliment Emergy analysis
FU and SB	The FU is 1m3 of potable water and 1m3 of combined wastewater. System boundaries entail processes in the source water acquisition, water treatment train, and distribution network to the consumer for the supply plant. The wastewater treatment operations considered sewer collection network, treatment train, effluent discharge, and sludge disposal.
Impact categories	Plant inputs, plant infrastructure, collection/distribution, collection/distribution infrastructure. L

Title and authors	Fit-for-purpose wastewater treatment: Testing to implementation of decision support tool (II) (Chhipi-Shrestha et al., 2017)
Type of document	Scientific article
Geographic area	Okanagan Valley, Canada
Tech/practice	Gravity collection system for sourcing. Raw wastewater treatment alternatives under evaluation included screening and sedimentation, secondary treatments as a membrane bioreactor, biological nutrient removal, trickling filtres, coagulation and flocculation, micro-depth-suface filtrations, ultrafiltration, electrodyalisis, reverse osmosis, activated carbon and desinfections of different types.
LCT applied	LCC
FU and SB	FU: m3 of water. System boundaries, although not explicitely mentioned entail sourcing, delivery, wastewater treatment and reuse
Impact categories	Cost categories included capital, operation and maintenance cost of treatment units. LCC is estimated as Net Present Value (NPV)
Title and authors	Establishment of an Inventory for the Life Cycle Cost (LCC) Analysis of a Water Supply System (Lee et al., 2017)
Type of document	Scientific article
Geographic area	Different areas from South Korea
Tech/practice	Fast filtration method
LCT applied	LCC
FU and SB	Not disclosed
Impact categories	Inventory construction for LCC studies in water supply systems shall include Water Conveyance facility, Water Transmission facility, Water Distribution facility and Water Supply facility.
Title and authors	Environmental and economic performance evaluation of municipal wastewater treatment plants in India: a life cycle approach (Kamble et al., 2019)
Type of document	Scientific article
Geographic area	India
Tech/practice	Sequencing batch reactor (SBR), membrane bioreactor (MBR), moving bed biofilm reactor (MBBR), activated sludge process (ASP), soil biotechnology (SBT) and aerated lagoons (AL)
LCT applied	LCA and LCC, using the Present Worth (PW) method for the LCC.
FU and SB	The selected FU was 1 m3 of treated wastewater. System boundaries were defined for the operational stage of the plants since construction and demolition phases are considered as negligible impacts according to other studies. Therefore, this case considered unit processes related to wastewater treatment, sludge treatment, sludge disposal and transportation to a landfill site.
Impact categories	Capital Cost, Operation and Maintenance Cost.
Title and authors	Is SCENA a good approach for side-stream integrated treatment from an environmental and economic point of view? (Longo et al., 2017)
Type of document	Scientific article
Geographic area	Treviso, Northern Italy
Tech/practice	Short Cut Enhanced Nutrient Abatement (SCENA) on the side-stream treatment of a municipal wastewater treatment plant, and alternative scenarios with SCENA together with other technologies or practices including Sequencing batch fermentation reactor (SBFR), Short Cut Enhanced Nutrient Abatement (SCENA), Short-cut sequencing batch reactor (scSBR), and Sludge dynamic thickening (SDT).
LCT applied	LCA and LCC (Net Present Value)
FU and SB	FU was 1 kg PO3-4 eq. removed, defined as the reduction of eutrophication.

	System boundaries entailed the treatment plant operation with all its associated background processes, effluent discharge and direct gaseous emissions. The construction phase accounted only data from SCENA. Upstream-wastewater collection and transportation were not included.
Impact categories	Cost were categorized in capital cost (construction, mechanical instrument and consulting costs), and operating costs (the electricity, chemical consumptions, sludge disposal and staff costs). The different scenarios were presented and compared through the Net present value (NPV) indicator.
Title and authors	Benchmarking wastewater treatment plants under an eco-efficiency perspective (Lorenzo-Toja et al., 2016)
Type of document	Scientific article
Geographic area	Spain
Tech/practice	Primary treatments in some of the assessed wastewater treatment plants consisted of Physico-chemical and Primary settling. Secondary treatments consisted of SB and AB reactors, (S.B)*, B. Reactor (A.B), Nutrient removals and Secondary settling. Finally, the sludge line consisted of Thickening, Anaerobic digestion and/or Dewatering.
LCT applied	LCA and LCC
FU and SB	FU was 1 cubic meter of wastewater treated by a Spanish Wastewater treatment plant in 2011. System boundaries excluded the construction phase and comprised only the operational phase, the sludge management and the final disposal.
Impact categories	Cost categories expressed mostly operational and maintenance costs of the described stages in the system boundaries, resulting from materials, chemicals, energy, personnel, waste, fees, maintenance and lab analysis.
Title and authors	Economic and environmental sustainability of submerged anaerobic MBR-based (AnMBR-based) technology as compared to aerobic-based technologies for moderate-/high-loaded urban wastewater treatment (Pretel et al., 2016)
Type of document	Scientific article
Geographic area	Treatment schemes evaluated under the premise they'd meet European discharge quality standards
Tech/practice	Anaerobic membrane bioreactors (AnMBRs) compared to Aerobic-based technologies for moderate-/ high-loaded urban wastewater (UWW) treatment
LCT applied	LCA and LCC
FU and SB	The FU was the volume of treated wastewater (m3). System boundaries went from cradle to grave (construction, operation and demolition phases). Pre-treatment, disposal, emissions and use of sludge were included.
Impact categories	Capital cost, and operating and maintenance costs
Title and authors	Life Cycle Costing Assessment-Based Approach for Selection of Wastewater Treatment Units (Rawal and Duggal, 2016)
Type of document	Scientific article
Geographic area	Kalyani, West Bangal, India.
Tech/practice	Trickling filter system, Waste stabilization pond, and Activated sludge process
LCT applied	LCCA (Life Cycle Costing Analysis also mentioned as a multi-criteria decision analysis approach)
FU and SB	The FU was defined as the water treated by a 2MLD plant of municipal wastewater in a semi-urban locality
Impact categories	Capital investment, capital replacement, residual value, electricity, operation and maintenance, revenue earned, presented in Net Present Value.
Title and authors	Assessment of the reliability-cost efficiency of the pumping subsystems at water treatment plant (Zimoch and Szymik-Gralewska, 2016)
Type of document	Scientific article

Geographic area	Silesian, Norther Poland.
Tech/practice	Gravity and pump systems for water sourcing, followed by pre-ozonation, coagulation (with aluminium sulphate), sedimentation and filtration, ozonation subsystem, active carbon filtration and disinfection with chlorine.
LCT applied	LCC (Also reliability-cost efficiency analysis)
FU and SB	System boundaries: from cradle to grave (design phase [construction phase, usage and disposal phase)
Impact categories	Cost categories considered those costs from the design phase, construction phase, usage phase and disposal phase.
Title and authors	Environmental Life Cycle Costing (Hunkeler et al., 2008)
Type of document	Book
Geographic area	Not disclosed
Tech/practice	Not disclosed
LCT applied	E-LCC
FU and SB	Various FU can apply depending on the goal and scope the costing exercise, keeping consistency with the LCA FU and system boundaries. This later can be from cradle-to-grave, and cradle-to-gate.
Impact categories	Categories related to costs and revenues can be included. Authors recommend defining the cost bearer(s) as different upstream and downstream costs could be included. According to summaries from De Menna, et al (2016) based on this guidelines, discounting of results is inconsistent and not recommended with the steady-state environmental LCC, while discounted cash flows for money flows occurring at different times within 1 product life cycle is commonly applied. It is suggested to conduct a sensitivity analysis for different discounting rates. Depending on the nature of the LCC (Common, environmental or societal) there should be specific observations regarding external costs and the avoidance of double accounting with the LCA.
COST-BENEFIT ANALYSIS	
Title and authors	Cost-benefit analysis of wastewater reuse in Puglia, Southern Italia (Arborea et al., 2017)
Type of document	Scientific article
Geographic area	Puglia región, Italia
CBA appplied	Financial CBA
Water reuse scale, sources and uses	Region scale of Puglia – All WWTP Agricuture irrigation
Economic homogenization methods	Value transfer for Monitoring and control costs Hedonic prices for economic value of irrigation Avoided costs for economic value of groundwater increased quality (salinity)
Other	Only the costs at WWTP are considered (no storage or irrigation costs) Study carry out at regional scale, no site-specific
Title and authors	Reusing wastewater to cope with water scarcity: Economic, social and environmental considerations for decision making (Garcia and Pargament, 2015)
Type of document	Scientific article
Geographic area	Israel – City of Tel-Avis
Tech/practice	Economic social CBA with Monte-Carlo Analysis
Water reuse scale, sources and uses	Indirect water reuse for 2 WWTP Uses: agriculture and park irrigation
Economic homogenization methods	Transfer value for fertilization and social impacts Replacement costs for environmental impacts Avoided costs
Other	Comparison of 2 discounts rates: 3,5% and 5,5%

Title and authors	Cost–benefit analysis of water-reuse projects for environmental purposes: a case study for Spanish wastewater treatment plants (Molinos-Senante et al., 2011)
Type of document	Scientific article
Geographic area	Valencia región, Spain
Tech/practice	Economic social CBA
Water reuse scale, sources and uses	13 homogenous WWTP Agricultural irrigation
Economic homogenization methods	Shadow price to assess environmental benefits: directional distance function method
Other	Directional distance function method seems no time consuming compared to contingent methods
Title and authors	Assessing the economic viability of alternative water resources in water-scarce regions : Combining economic valuation, cost-benefit analysis and discounting (Birol et al., 2010)
Type of document	Scientific article
Geographic area	Limassol region, Cyprus
Tech/practice	Economic social CBA
Water reuse scale, sources and uses	Limassol WWTP with indirect reuse (recharge of aquifer) for agricultural irrigation
Economic homogenization methods	Stated preference method to quantify and to monetize environmental and social impacts
Other	Comparison of constant discount rate (3,5% and 6%) and decreasing discount rates more adapted to long-term environmental benefits Focus groups discussions to identify the groups of stakeholders impacted and the benefits they will derive
Title and authors	Socio-Economic Interest of Treated Wastewater Reuse in Agricultural Irrigation and Indirect Potable Water Reuse: Clermont-Ferrand and Cannes Case Studies' Cost–Benefit Analysis (Declercq et al., 2017)
Type of document	Technical document
Geographic area	France: 3 case studies (Sainte Maxime, Clermont-Ferrand and Rhuys Kerver)
Tech/practice	Economic and financial analysis
Water reuse scale, sources and uses	Site-specific analysis Sainte Maxime: golf course irrigation Clermont-Ferrand: agriculture irrigation Rhuys Kerver: golf course irrigation
Economic homogenization methods	Prices-Costs methods: avoided costs, replacement costs Revealed preference methods
Other	Only in French No contingent method because time-consuming