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METHODOLOGY AND INFORMATION AND COMMUNICATION TECHNOLOGIES TOOL TO MEASURE AND COMMUNICATE PRODUCT CIRCULARITY

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Abstract

A methodology and an Information and Communication Technologies tool tailored to companies, in particular Small and Medium Enterprises, were developed in the framework of RECiProCo project, for measuring product circularity and water use, through a simplified and easy to be applied set of indicators based on a life cycle approach, considering all the phases of product life cycle. The indicators were integrated on a free of charge web Platform to be easily managed by the company, with the possibility to make available data and information to the public, i.e. final consumers, and other companies, to stimulate the transition to circular economy goals and environmental conscious purchases. A special focus was given to the indicators that could be useful to the paper, textile and construction sectors. These sectors, very important for the Italian industry and consumer's purchases were chosen for their relevance in terms of opportunity to improve the circularity of products and efficiency in water use. The circularity and water use indicators were tested in a sample of companies that found them easy to collect and calculate. The pilot companies participated with great interest and had the opportunity to increase their awareness about the environmental data related to their products and production processes and to identify actions to improve the circularity aspects of the product analysed.
The RECiProCO web Platform can be used by companies to measure and monitor product circularity, to target improvement actions and to communicate to other stakeholders, in particular consumers, but also their customers or suppliers.

Key words: circularity indicators, consumers, water use, web platform

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1. Introduction

The transition to circular economy and sustainable development are major challenges for society in general and for organisations in particular. The European Commission has defined the frameworks for this paradigm shift with the adoption of the European Green Deal (EC Communication, 2019) for achieving the goal of climate neutrality by 2050, and the New Circular Economy Action Plan (EC Communication, 2020). The final objectives are the conservation of resources and materials value as well as the reduction of waste and residues. In order to achieve these goals, both parameters, methodologies and indicators, especially addressed to companies and territories, must be defined to measure the distance to the targets and to assess the progress resulting from the application of specific circularity strategies.

The measurement of circularity for both products and services is a crucial step in the evaluation of resource efficiency, the definition of material and energy flows, and the identification of value and

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competitiveness components in processes. Furthermore, it is an essential tool for both monitoring progress against sustainability targets and providing companies with valuable insights to implement targeted strategies with the final aim to enhance sustainability. It is only through the measurement of circularity that the achieved results, or those towards which companies and society are striving, can be communicated in a reliable and transparent manner.

Nevertheless, the assessment of circularity is a complex issue that extends beyond the mere measurement of advancements in material recycling and reuse initiatives. It also encompasses the evaluation and communication of the advantages associated with the adoption of novel business models that are geared towards the transformation from linear to circular production and consumption models. In order to facilitate this transition, new measurement metrics have to be developed. Numerous initiatives have been carried out by organisations with different methodologies and approaches, all aimed at measuring the degree of transition to circular models (Circle economy and PACE, 2020).

The landscape of available tools appears to be very heterogeneous, but main features common to the different approaches can be identified. One of the key feature is the level at which circularity should be measured: the macro level (country system), where public policy attention is focused on circularity in relation to sustainable production and consumption models applied to urban and production systems (Yuan et al., 2006); the meso level (sector/industry), such as industrial eco-parks that take advantage of shared infrastructure and exchange of materials, waste, services and energy to improve circular performance; the micro level (organisation/company), i.e., the level of companies and productions committed to improve their environmental performance by adopting sustainable production models to save raw materials, use recycled materials and apply sustainable product design; the micro level (product/asset/service/process) proposed by Saidani et al. (2017), which focuses on the circularity of products, components and materials along the entire value chain and throughout their life cycle.

Other relevant features are the measurement and evaluation methodologies, which can be qualitative or quantitative; the types of resources to be included in the evaluation method; their classification as inputs or outputs; the main objective of the measurement exercise; the validation method in which the measurement is realised (certification, written-declaration or self-declaration) (Alliance for the Circular Economy , 2021).

Numerous literature studies have proposed an analysis of tools for measuring circularity based on several factors, such as the purpose and type of tools (assessment tools or guidelines to guide strategic choices), the level of accuracy, the type of data considered for measurement and the nature of indicators (qualitative or quantitative), the scope of application (macro, meso, micro, nano) and the reports generated (Valls-Val et al. 2022).

At the European level, the document supporting circular economy policies is “A new Circular Economy Action Plan” adopted in 2020 (European Commission, 2020), which also presents a monitoring framework based on a set of indicators which can capture key aspects of circularity. New indicators on circular economy have been added to the four dimensions that identify the priority sectors and areas (production and consumption; waste management; secondary raw materials; competitiveness and innovation) towards which the plan's actions are directed, following the 2023 review (Eurostat, 2023). Specifically, new indicators to monitor material efficiency (material footprint and resource productivity) and new indicators to monitor whether EU consumption is within planetary boundaries (consumption footprint) have been implemented. Therefore, while the framework for measuring progress towards circular economy is defined at EU level (macro level), the micro level lacks an organic and standardized framework of measurement indicators (Valls-Val et al., 2023).

Various experiences to measure circularity have been developed at European and national level. An important standardisation tool applied at meso, micro and macro level is the one proposed by the Technical Committee International Standard Organisation (ISO) 323 "Circular Economy" (abbreviated as ISO/TC 323), which has been working since 2018 on the definition of a package of standards (ISO 59000 series on Circular Economy) consisting of a total of seven standards which define requirements, guidelines and supporting tools for the implementation of activities by all organizations involved, in order to maximize their contribution to sustainable development.

Moreover, the Global Reporting Initiative (GRI) through the development of GRI 306: Waste 2020 (GRI Standards, 2024) also provides a certification for companies of all sizes, sectors and geographical locations to report on waste-related impacts.

When considering the tools applicable at the company level (micro level), the most tested is the one launched by the Ellen MacArthur Foundation, a private foundation established in 2009 which researches and invests in the dissemination of circular economy issues. Launched in 2020, Circulytics (Ellen MacArthur Foundation, 2020) allows companies to understand their position towards circularity. This tool evaluates quantitative and qualitative parameters by a system which considers 'enabling factors', i.e. indicators to assess the conditions that enable a company to innovate and move forward, and 'outcomes', activity-specific indicators which measure inputs and outputs of a production process. Companies will receive an overall score based on customised factors, information and comments provided by Ellen MacArthur Foundation, which can be used in investor

and customer relations, while the Foundation commits to creating "inspiring" case studies for high-scoring companies. Currently, the Foundation is moving away from data collection and individual performance assessments based on Circulytics by encouraging organisations to disclose their circular economy performance as outlined in the European Sustainability Reporting Standards (ESRS 5) (EC Delegated Regulation, 2023).

Moreover, at the micro level, it is worth mentioning for Italy the Circular Economy (CE) Client Report tool of ENEL X (https://corporate.enelx.com/en/our-commitment/sustainability/circular-economy/client-report#works), where ENEL X offers a consultancy service for companies and public administrations to design a roadmap to increase their level of circularity. The analysis is based on qualitative and quantitative data and returns a report with a detailed view of the initial level and achievable targets in terms of circular economy, with the value of a self-declaration validated by a third-party certification body. Moreover, at the Italian level, the ICMQ (Istituto di certificazione e marchio qualità per prodotti e servizi per le costruzioni) has developed a product circularity index (NCI), which provides some indicators to measure the circularity of materials, energy, water and waste of the organization (https://www.icmq.it/materiali-prodotti/certificazione-nci.php).

Nevertheless, the analysis of the already available Italian tools and indicators for circular economy measurement and monitoring, although of primary importance to guide industries towards circularity and water efficiency as well as to improve the environmental performance of their products, shows that they can be difficult to apply, they are not always available free of charge but sometimes should be purchased by companies, and could require the support of external consultants for their application and for calculation procedures.

In order to overcome this problem, and to provide an easy tool to monitor and evaluate product circularity and water use, a methodology and an Information and Communication Technologies (ICT) tool tailored to companies, in particular Small and Medium Enterprises (SMEs), for measuring product circularity and efficiency in water use, were developed by ENEA in the framework of RECiProCO project (https://www.reciproco.enea.it/), funded through an agreement between ENEA and the Italian Ministry of Economic Development for the “Development of circular economy tools and initiatives for consumers”.

The term 'product circularity' is used to describe a set of practices designed to optimise the use of resources and minimise waste throughout the production and consumption cycle of a product. This approach emphasises two key goals: sustainability and economic efficiency. RECiProCO was a wide project, which, in broad terms, aimed to support more sustainable and conscious consumers’ choices and to increase consumers, companies and citizens awareness about circular economy principles and approaches.

In particular, one of the project purposes was to carry out a feasibility study for the development of a voluntary environmental communication system for non-food and non-energy products, based on two types of indicators: a set of circularity indicators and a set of water use indicators, following a life cycle approach.

The sets of circularity and water use indicators, usable by all types of companies and products, except food and energy ones, as required by the project, are easy to be applied and referred to the product. Moreover, they were tailored to companies, in particular Small and Medium Enterprises (SMEs), to increase their awareness about circular economy principles and to support them towards the application of circular practices in their production processes, since companies, especially SMEs, could still have little knowledge or expertise about circular economy practices, methods and tools.

In addition, an ICT tool called “RECiProCO web Platform” was developed on a web platform; this tool contains the set of indicators and can be used directly and easily by companies, with the help of ENEA, if needed, to measure and monitor product circularity (self-evaluation), to target improvement actions and to communicate to other stakeholders, in particular final consumers but also their customers or suppliers. Moreover, the web platform allows companies to make available data and information to the public. Finally, a restricted number of indicators was identified for the communication to consumers through a QR code, for a more sustainable and immediate Business to Consumer communication, thus helping consumers in their purchase choices, with the final aim to boost the production of circular and water use efficient products.

The Agreement between ENEA and the Ministry of Economic Development prescribed that the set of indicators must be particularly suitable for the paper, textile and construction sectors. These sectors were chosen for their relevance in terms of opportunity to improve the circularity of products and efficiency in water use. Moreover, following the Agreement prescriptions, the indicators were tested in a sample of companies of the above-mentioned sectors, to develop the final version of the ICT tool, which was implemented on a free of charge web platform. ENEA helped companies, where necessary, to apply the set of indicators and verified the correctness and accuracy of both collected data and calculations, thus acting as a third-party reviewer.

This paper describes the methodological approach that led to the development of the set of indicators and the ICT tool; the testing phase in companies and the main results achieved; the main characteristics of the RECiProCO web platform and the description of its use by companies as well as final considerations and future developments.

2. Materials and methods

For the purpose of project activities, a preliminary survey was made on the main circularity and sustainability measurement tools, circularity indicators and environmental certifications which mainly affect the micro and nano level, i.e., applicable at the company level and at the product level, also identifying the potential that these tools, indicators and certifications have for the communication to the final consumer or for supporting companies to reduce the environmental impacts of products from an eco-design and circular economy perspective.

In the next paragraphs the methodological approach for the definition of the final sets of circularity and water use indicators and the design of the main features of the RECiProCO web Platform are described.

2.1. Development of the circularity and water use indicators

The circularity and water use indicators were developed to be used at the product level and are usable for all types of products, except for food and energy products, as required by the project; furthermore, they were identified following a life cycle approach, i.e. taking into account all phases of product life cycle, with a holistic approach. The Agreement with the Ministry of Economic Development prescribed that focus, in particular for the pilot phase, must be given to three production sectors: textiles, paper and construction.

The above-mentioned sectors were chosen for the following reasons:

- interest for the final consumer and interest in a Business to Business perspective;
- importance in relation to circularity and water use (e.g., recycled content in textile, paper and construction products; potential product recyclability at the end-of-life; high water use in the production process or during the whole life cycle; content of by-product in the main products; product made of reused materials);
- relevant regulations at national Italian level: e.g., 110% bonus for construction (IG, 2020a), new legislation for mandatory separate collection of the textile fraction in municipal waste in accordance to the Legislative Decree 116/2020 (IG, 2020b), End of Waste 188/2020 regulation for paper and cardboard (MATTM, 2020), Legislative Decree 116/2020 on packaging labelling for collection/reuse/recovery/recycling and nature of materials used (IG, 2020b).
- availability of environmental labels and certification schemes based on life cycle approach, e.g. Ecolabel, Environmental Product Declarations, other sector labels, Minimum Environmental Criteria (Criteri Ambientali Minimi – CAM) for the Italian Green Public Procurement (GPP).

The following procedure was then followed to develop the methodological framework and to define the set of circularity and water use indicators, to be included in the ICT tool (Fig. 1):

- Literature analysis of some directives, regulations and product certifications schemes to identify and analyse the circularity and water use indicators already available at national and European level, with a specific focus on the three selected sectors. The main documents examined are the following:
  - Public documents examined in the preparatory work of UNI CT (Italian Standard Body-Technical Committee) 057 "Circular Economy" related to the publication of the Italian Technical Specification UNI/TS 11820:2022 “Measuring circularity - Methods and indicators for measuring circular processes in organizations” (UNI, 2022); this document defines a set of indicators intended to evaluate, through a rating system, the level of circularity of an organisation or group of organisations.
  - Circularity criteria available in the Italian Green Public Procurement (GPP) Criteria (Criteri Ambientali Minimi – CAM) for paper (MATTM, 2013), textile (MASE, 2023) and buildings (MiTE, 2022);
  - Circularity criteria present in environmental product labels (both national and European/international), such as European Ecolabel, Environmental Product Declarations (EPD), other type I or type III environmental labels according to ISO 14020 (2022);
  - Available methodologies and tools for estimating water stress and indexes for measuring the impact of water withdrawals and consumption, related to anthropogenic activities (Vanham et al., 2018), as well as various data platforms (e.g. Aqueduct 3.0 tool, developed by Hofste et al., 2022).
- Identification of a specific number of indicators that, at first analysis, were considered significant and useful for measuring product circularity and water use. These indicators were extracted from the aforementioned standards, regulations and certification schemes, with particular reference to the public documents examined in the preparatory work of UNI CT 057 "Circular Economy" and were suitably adapted and/or modified in order to choose a set of about 30 indicators, encompassing all phases of a product's life cycle, i.e. design, procurement, production, distribution/sales, use/consumption, end-of-use. These indicators have been considered representative of circularity and water use, are suitable for all types of products, except for food and energy ones, as required by the project, and are easy to be calculated by companies on a voluntary basis (Table 1).
- Once defined the set of indicators, dedicated meetings were organised with the main national consumers association, with the support of the

Ministry of Economic Development; during these meetings the methodology and type of indicators were shown to the consumers association in order to collect feedbacks and opinions, which were very positive, and plan any possible modification or change, with the final aim to bolster a more easy application by companies and improve the understanding of each indicator and its usability by consumers.

- Elaboration of a spreadsheet addressed to companies to support them in the calculation of circularity and water use indicators during the subsequent testing phase (see also par. 2.2). This spreadsheet aims to help companies to collect and retrieve data for the calculation of the indicators and contains appropriate columns: unit of measurement, calculation procedure, value obtained.

In order to identify indicators that are relatively simple to be calculated and that require a reasonable amount of time to obtain the necessary data for calculation, the spreadsheet also demands the following information: difficulty in both finding data and in the calculation; time needed to find data for the calculation.

- Testing of the above-mentioned 30 indicators with selected companies of paper, textile and construction sectors, by means of calculation tests, carried out with the support of ENEA researchers (see par. 2.2).

- Validation of the final set of indicators: Selection of a small number of indicators for the development of a QR Code (Table 1, in bold) to be included in the ICT tool, to be affixed on products for easy understanding by final consumers, to whom this tool is mainly addressed. Similarly to the selection of the whole set of indicators, in this phase consumer's associations were consulted and their opinion were collected, in order to select the most understandable, effective and relevant indicators to be included in the QR code, which could easily use by consumers to support them during their purchase choices.

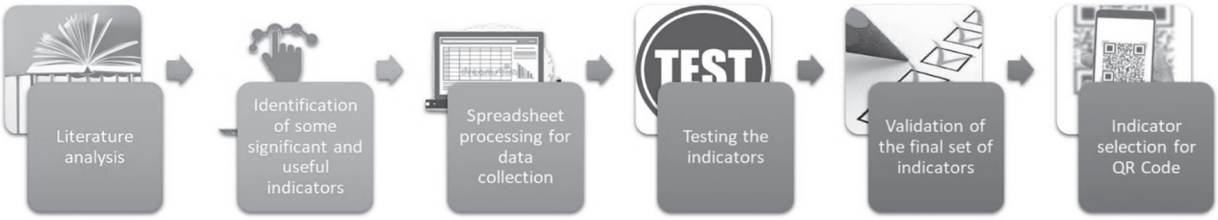

Fig. 1. Procedure adopted for the selection of indicators.

Table 1. Indicators of circularity and water use selected for the RECiProCO ICT tool. The indicators in bold are those selected for the communication to consumers (QR code)

Phase of the Life Cycle	***Indicator***	***Type of indicator***
Design	Is the product referable to circular design models?	Yes/No
Procurement	**Percentage of by-products and/or secondary raw materials and/or recycled material used in relation to total material resources used**	Quantitative
	Percentage of renewable raw materials used in relation to total material resources used	Quantitative
	Percentage of raw materials and secondary raw materials purchased and/or acquired from local suppliers (< 100 km) compared to total raw materials purchased and/or acquired	Quantitative
Production	Percentage of climate-changing emissions released in year n-1 compared to climate-changing emissions released in year n	Quantitative
	Percentage of renewable electricity consumed in relation to total energy consumption	Quantitative
	Percentage of renewable thermal energy consumed in relation to total energy consumption	Quantitative
	Percentage of self-produced electrical energy from renewable sources and/or recovery processes compared to total electrical energy consumed	Quantitative
	Percentage of self-generated thermal energy from renewable sources and/or recovery processes compared to total thermal energy consumed	Quantitative
	Percentage of waste sent for material recovery and/or recycling compared to total waste	Quantitative
	Percentage of by-products generated compared to total production residues	Quantitative
	Percentage of waste produced in year n-1 compared to total waste produced in year n	Quantitative
	Product-related water consumption	Quantitative
	Organisation-related water consumption (annual basis)	Quantitative
	Organisation-related water consumption (monthly basis)	Quantitative
	Percentage of water from recovery and/or recycling compared to total water consumed	Quantitative
	Quantity of wastewater discharged (annual basis)	Quantitative
	Quantity of wastewater discharged (monthly basis)	Quantitative

	Total amount of organic pollutants (total COD) in effluent before treatment (year n)/Total amount of COD in effluent before treatment (year n-1)	Quantitative
	Total amount of Total Suspended Solids (TSS) in effluent before wastewater treatment (year n)/Total amount of TSS in effluent before wastewater treatment (year n-1)	Quantitative
	Is wastewater treatment carried out at the farm or at centralised level (e.g. consortium purification plant, discharge to sewer)?	Qualitative
Distribution and sale	Percentage of primary packaging used per unit of product from renewable and/or recycled sources compared to total primary packaging used	Quantitative
Use/consumption	Is it possible to repair the product (Y/N)?	Yes/No
	Is it possible to replace its components? (Y/N)?	Yes/No
End of use	**Is it possible to regenerate the product?**	Yes/No
	Is it possible to reuse the product?	Yes/No
	Is the product disassemblable?	Yes/No
	Does the product have a suitable recycling chain?	Yes/No

2.2. The testing phase with companies

The activities of the testing phase were divided into three consecutive and closely connected phases:

- identification of companies from the three sectors by means of ENEA's contacts;
- involvement of companies by e-mails and online meetings;
- data collection and calculation of indicators.

The first step was the identification of the companies to be involved. Thanks to the communication channels established through previous experiences, such as the Italian Stakeholder Platform on the Circular Economy (ICESP), the Symbiosis Users Network (SUN) and participation in national research projects, ENEA established contacts both with the trade associations of construction, paper and textile sectors and with individual companies in order to verify their interest and willingness to share company data aimed at calculating circularity and water use indicators of their products. Eight companies, representative of the Italian production from the three sectors, participated in the testing phase: two from the paper sector, four from the textile sector and two from the construction sector.

Once the companies were identified, the ENEA working group contacted organisations representatives by e-mail and organised first operational meetings with each company, aimed at both explaining the objectives of the project, and the methodology to be adopted. During the meetings, the first step was to identify, together with the company team, the product chosen for the testing phase. Then the set of indicators to be used (organised in the above-mentioned spreadsheet, described in par. 2.1) was explained to the companies and, at the same time, there were in-depth discussions on how to carry out the data collection.

The following products were chosen by companies:

- different types of paper for the paper sector;
- jeans trousers, coated fabric made with cereals, vegetable fabric obtained from pineapple peel and fair carpet for the textile sector;
- thermal insulation material made of 100% cereals and PVC flooring for the construction sector.

In order to calculate the indicators, company data of different natures (e.g. data relating to consumption, products, waste and by-products leaving the company site etc.) and of different levels of detail were required.

Therefore, the importance of indicating the sources of the data used, as well as the procedure and any calculations made to provide the requested information, were highlighted during the discussion with the companies. In this phase companies were also asked to qualitatively evaluate the degree of difficulty encountered to obtain the data and the time needed to get the information. This phase aimed to evaluate the relevance, as well as the difficulty of application/calculation, of the complete set of indicators for the companies and their products.

According to such approach, a specific spreadsheet was produced by ENEA showing, for each indicator, the unit of measurement required, the method of calculation, calculation procedures and the final numerical values for each indicator. In addition to the value assumed by the single indicator, the following information was requested for each indicator and included in the spreadsheet:

- Value calculated/measured. The possible answer, selectable via drop-down menu was yes or no;
- Reason for non-calculation or non-measurement;
- Degree of difficulty encountered in finding the data. The possible answer, selectable via drop-down menu was: 'No difficulty', 'Medium difficulty' and 'Large difficulty';
- Time needed to find the data. The possible answer, selectable via drop-down menu was: "less than 30 minutes", "between 30 minutes and 1 hour", "more than 1 hour";
- Degree of difficulty encountered in the calculation. The possible answer, selectable via drop-down menu was: "No difficulty", "Medium difficulty" and "Large difficulty";
- Notes and sources of the data.

In order to provide a comprehensive understanding of the data collection process and the indicators calculation, some specific criteria and metrics were developed to assess the company difficulties encountered during these phases, with the final aim to increase the rigor in the testing phase (Table 2).

Table 2. Criteria and metrics for the definition of the different degrees of difficulty during data collection and indicators calculation

Type of difficulty	***Degree of difficulty***	***Definitions***
Data collection	None	Data are fully available in company management/accounting systems and can be retrieved easily and without any specific internal/external expertise
	Medium	Data are partially available in company management/accounting systems and can be retrieved with some specific operations /internal expertise/external expertise
	Large	Data are not available in company management/accounting systems and have to be searched by hand in bills/invoices/registers or only with the help of specific internal/external expertise
Calculation	None	All indicators are calculated by companies on their own in relation to the chosen product, without the need of any external help/expertise
	Medium	Some indicators are calculated directly by companies on their own in relation to the chosen product, whereas external help/expertise is needed to calculate the remaining indicators
	Large	Indicators are calculated only with the help of external expertise, which is needed to relate the collected data to the product (e.g. data are referred only to the whole company and the company needs help to relate them to the product)

Following this preliminary activity, which was carried out in the same way for each company ("formal" involvement via email and subsequent remote preliminary meeting), the work proceeded with each company in different ways, with different timing and critical issues, which were solved step by step by a joint cooperation between ENEA and the involved companies. Table 3 shows some of the problems encountered and the solutions proposed and implemented to overcome them.

2.3. Design of the ICT tool: the RECiProCO Platform

The RECiProCO Platform, developed by ENEA with the support of LASER ROMAE S.r.l, is an ICT tool which allows companies to publish, retrieve, measure and evaluate the circularity and water use indicators of their products, together with their relevant characteristics. The set of indicators contained in the Platform is that identified in the previous phases of the project. The Platform is a web application aimed at the acquisition, normalization and visualization of data relating to the circularity of products, to support companies in identifying areas of environmental improvement. The Platform is accessible through any web browser at the following link: https://simulatore.reciproco.enea.it/#/home; it is available in Italian, but a translation in English language will be evaluated in the next future.

The Platform architecture foresees two types of roles, supported by specific profiling mechanisms for The customisation of specific functions. The predefined roles are: company employees/managers and Platform administrator (ENEA).

The employees/managers of a company, upon first login, can register and associate the user with their company. Moreover, they can insert products and circularity indicators by filling in guided questionnaires. ENEA, as the administrator, verifies and validates the data entered by companies, checking for any errors and requesting companies to correct them and enter any missing information.

The administrators have access to the lists of companies, products and circularity indicators included in the Platform and can search and export data. Moreover, the Platform implements a customized dashboard to display aggregate data in terms of products and indicators.

The Platform architecture is multi-layer, the various functions are logically separated, and are therefore divided into layers or engines. Each engine plays a specific role within the Platform architecture.

With reference to the architecture model, the engines are defined as follows:

- AuthEngine: Engine in charge of the authentication, logout and information retrieval functions of the current user;
- CryptoEngine: Engine that carries out entity encryption / decryption operations. It allows the encryption/decryption of a generic object or a file via the application's secret key or via a key passed as input. Its purpose is to encrypt the reporting entity and the files uploaded as "to be encrypted". Only one active CryptoEngine can be used at a time;

Table 3. Data collection critical issues

Critical issues emerged during the test phase	***Identified solution***
Difficulty in obtaining data for foreign suppliers of raw materials	Data collection focused on national suppliers
Difficulty in definition of the "upstream" system boundaries	Boundaries set starting from the supply of a secondary raw material input to company processes
Procurement of raw materials information from national retailers who refer to foreign producers	Procurement referred to the dealer present in the national territory
Inability to provide complete data on multiple years	Indicators based on data relating to several years not calculated
Presence on the national territory of sales offices, but production processes located abroad	Use of environmental labelling (for example EPD) for the (partial) evaluation of indicators

- LoggingEngine: Engine which carries out "logging" operations of the application. There are 5 "classic" log levels (DEBUG, INFO, WARN, ERROR and CRITICAL) and in its basic version it saves logs on the filesystem. There must be at least one active LoggingEngine; the Platform can manage multiple LoggingEngines (e.g. N on filesystem and remote M);
- MetricsEngine: Engine which calculates Platform statistics and supports different types of extraction (.XLS, .CSV, etc.). In its basic version it saves statistics on the application's internal database and allows export in .XLS and .CSV format. Only one MetricsEngine is active at a time;
- StorageEngine: Engine that saves information relating to files, questionnaires and notification templates. In its basic version it saves this information on the filesystem. There must be at least one active StorageEngine; the Platform can manage multiple StorageEngines (e.g. 1 on filesystem, 1 on MongoDB). There is a background job that synchronizes between all active StorageEngines. The data format used is JSON;
- WorkflowEngine: Engine which perform the workflow of the phase transaction states. It allows the creation or removal of associations between two states, the start of a new process or its finalisation. In its basic version the workflow is saved on a database external to the application.

The Platform implements the entire treatment process, which involves, through complete automation of the workflow, the acquisition of data useful for calculating the indicators, the normalisation, processing, storage and visualisation.

Once the products and data useful for calculating the indicators have been entered, the Platform guides users through the transition of states, up to validation and publication. A selection of data relating to products and indicators can be inserted into a QR-Code. Finally, the Platform allows companies to calculate the level of circularity of the products inserted, for each life cycle stage, according to an algorithm which calculates an average value, expressed as a percentage, obtained from the ratio between the sum of all indicators in each stage and the total number of indicators available in that stage.

3. Results and discussion

3.1. Results of the testing phase with companies

The testing phase of circularity and water use indicators at company's product level proceeded with a constant and close cooperation with ENEA, which provided continuous support to the organisations in order to collect the data and to calculate the indicators in the most appropriate way, to guarantee their completeness and correctness, to verify the data sources robustness and finally to ensure an adequate understanding of the calculation or estimation procedures adopted.

The companies joined the project with great interest and good cooperation with ENEA and most of them found few or modest difficulties in compiling the file containing the indicators; the average time required for finding the data and for calculation of indicators was 1 hour maximum. All data collected by the companies and included in the indicator tables (one table for each company/product) were reviewed and approved by ENEA, which acted as third-party verifier; in case of errors or lack of detailed information, companies were asked to review the data and calculations and correct the errors. In particular, ENEA applied specific verification procedures to verify if the data used were corrected, with the aim to ensure data reliability and accuracy. More in detail, ENEA checked data sources, how they have been searched and retrieved within company's administrative or technical departments (e.g. from excel spreadsheets); moreover, ENEA verified the bills and invoices used, when needed, for each indicator, as well as the calculation procedures, checking if allocation procedures were needed to relate the data to the chosen product and finally if the calculation was correct or if it needed revision or adjustments. Figure 2 collects the feedback obtained from the eight companies that participated in the testing phase. All the eight companies completed the spreadsheet with their data, their calculations and the final indicators values. The elaboration of the data collected in the spreadsheets showed that most companies (81%-91%) had very low difficulties in collecting data and calculating the indicators, while some of them (7-18%) had medium difficulties (Fig. 2). Only 2% of companies had high difficulties (see Table 2 for difficulties criteria). Examples of difficulties, defined by Table 2, include the need to search data in bills and invoices because the company did not have a specific accounting system for the type of environmental data needed to calculate the indicators, or the help provided by ENEA to the company in order to perform allocation procedures needed to calculate, for instance, the amount of energy consumption of the chosen product, in case the company had only the energy consumption of the whole factory (i.e. not related to the product).

As regards the time necessary to collect the data for the calculation of the indicators, it turned out that a large part of the information was collected in less than 30 minutes (87%), a small part (12%) between 30 minutes and 1 hour and only 1% of the data took more than an hour.

3.2. The final set of circularity and water use indicators and the RECiProCO web platform

The results of the testing phase of the set of indicators and the spreadsheet for data collection and indicators calculation confirmed the validity and feasibility of the set of indicators previously identified (Table 1) which also met the requirements of:

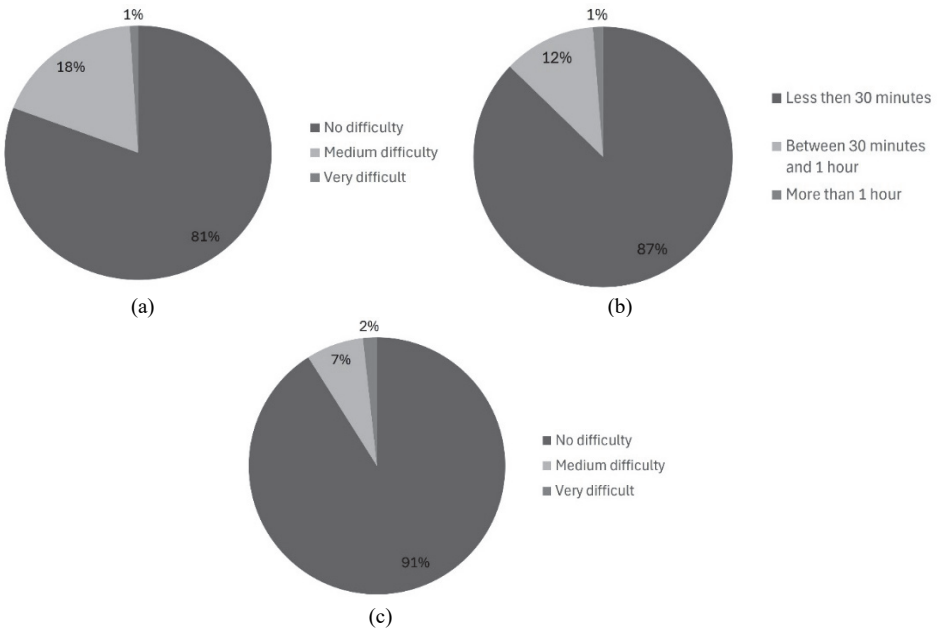

Fig. 2. Results from the testing phase regarding the data collection and indicators calculation: (a) difficulty in data collection, (b) data collection time, (c) difficulty in indicators calculation

- significance from the point of view of circularity and water use;
- suitability for measuring the circularity and water use of a product and for their use in the RECiProCo web Platform (which contains the whole set of indicators);
- simplicity and rapidity of retrieval and calculation by organisations.

The testing phase led to the definition of the final set of indicators (28) reported in Table 1, which are related to all the life cycle phases: design, procurement production, distribution and sales, use/consumption and end of use.

Within the set of indicators previously defined, a restricted number (11) were identified as clearly understandable to the consumer, to be used for consultation through the QR code available in the RECiProCO web Platform (Table 1, in bold) (see also par. 3.3).

The RECiProCO Platform was finalized as well, according to the final sets of indicators reported in Table 1 and made it available on line and free of charge for companies.

The Platform was presented and explained during some dissemination events, which included dedicated workshops with the Ministry of Economic Development and the project final event, with the participation of a wide public, such as companies, consumer's associations, research institutions and citizens.

3.3. Description of RECiProCO Platform

In order to register to the Platform, a company must connect to https://simulatore.reciproco.enea.it/#/home and proceed with the registration, creating a username and a password, by selecting "Sign in", on the top right corner of the page.

After having registered, the company can enter the Platform with their username and password. At this point, the company dashboard is divided in two main parts (Fig. 3):

- a navigator at the top
- a consultation section at the bottom

In the left part of the top navigator the company can create/consult their contents and private pages. In the lower part of the page, the company can view the selected section.

Upon first login, the company must fill in the fields of the contact data (of the company and of the person fulfilling the questionnaire), the ATECO code, the name of the product they want to analyse.

ENEA will then proceed with the validation of the request and will authorize the company to access the Platform's functions.

At this point the company can create a new product sheet: to create a new Content, the company must click on the "Contents" button in the navigation bar at the top left of the homepage, then click "Dynamic Contents" and then on the "Add Content" button (Fig. 4). In the New content section (Fig. 5), the company has to click on "Form nuovo prodotto" and fill in the "Content title" with the name of the product.

After that, the company has to fill in the data about each circularity indicator with quantitative information (either a percentage or an absolute value) or with qualitative information; the indicators are divided in the following sections, representing the stages of product life cycle:

- product description;
- design;
- procurement;
- production;
- distribution/sales;

- use/consumption;
- end-of-use.

Finally, the company has to decide whether authorize the public access to their indicators or not. In fact, a company could decide to compare the results of its indicators for a certain product with those of a similar product produced by another company, thus boosting the improvement of company's circularity performance.

ENEA will then proceed with the validation of the data provided by the company through the Platform and will authorise the publication of the questionnaire on the Platform. At the end of this process, the company can see on the Private Pages menu, the level of circularity of its product (Fig. 6) and the one of other companies products available in the Platform, according to an algorithm which calculates an average value obtained from the ratio between the sum of all indicators in each life cycle stage and the total number of indicators available in that stage.

In the Private Pages menu the company can also see the QR code associated with its product (Fig. 7) and can use its for dissemination purposes towards other companies and also final consumers. A user guideline and training material will be soon available to support the correct fulfilment of all sections, with the goal to make the company autonomous in the quantification of the indicators.

Fig. 3. Dashboard of the Platform for the user: contents and private pages (on the top) and the selected section

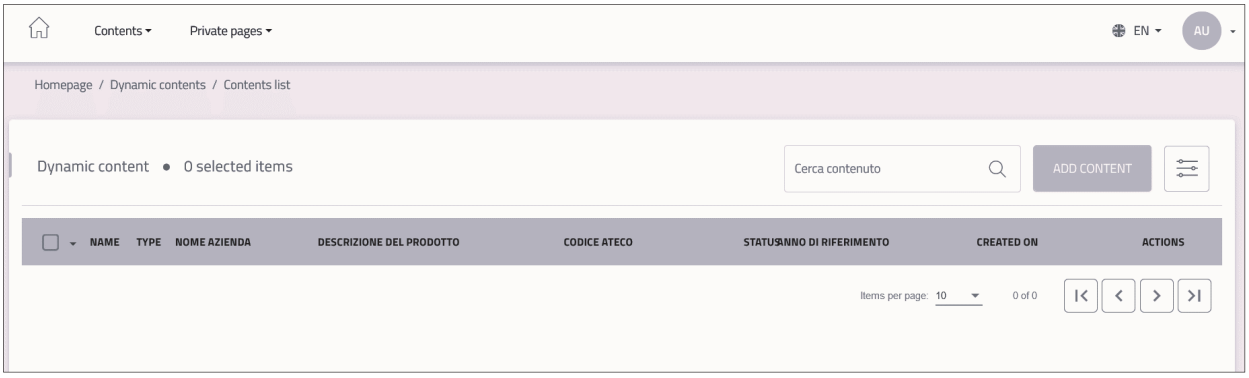

Fig. 4. Page of the Platform where a company can create and add a new content

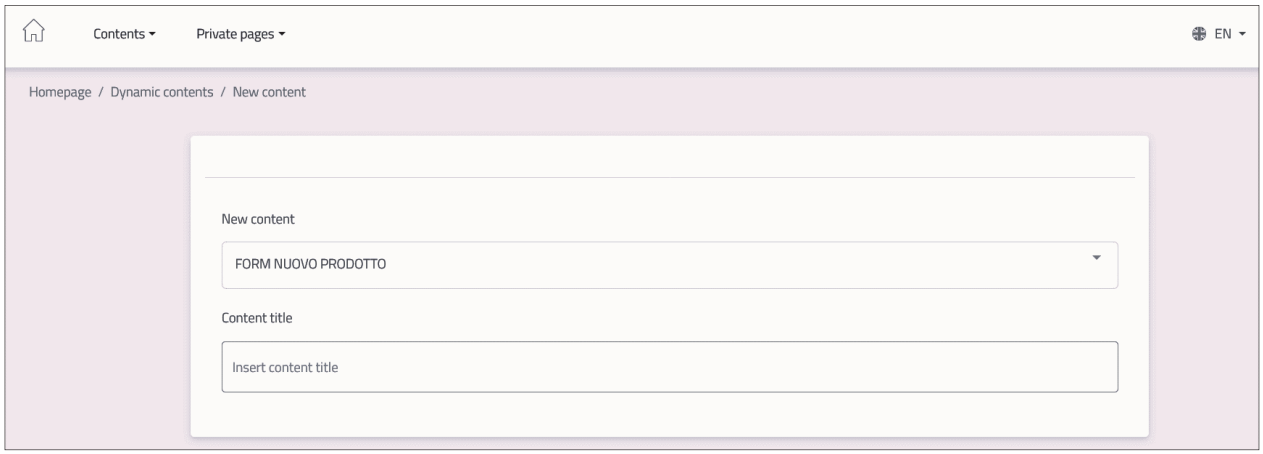

Fig. 5. Page of the Platform where a company can add a new product and its circularity and water use indicators

PRODUCT	AGENCY	LEVEL OF CIRCULARITY	DESIGN	PROVISIONING	PRODUCTION	DISTRIBUTION/ SALE	USE/ CONSUMPTION	END OF USE
testiera nera di plastica dura	–	79.41 %	100 %	80 %	64.29 %	60 %	100 %	75 %
product 1	–	23.53 %	100 %	0 %	0 %	100 %	0 %	50 %
product 2	–	25.88 %	100 %	46.67 %	14.29 %	0 %	0 %	25 %
product 3	–	17.65 %	100 %	33.33 %	0 %	0 %	0 %	25 %

Fig. 6. Level of circularity for company's product and for any other product available in the Platform (also from other companies)

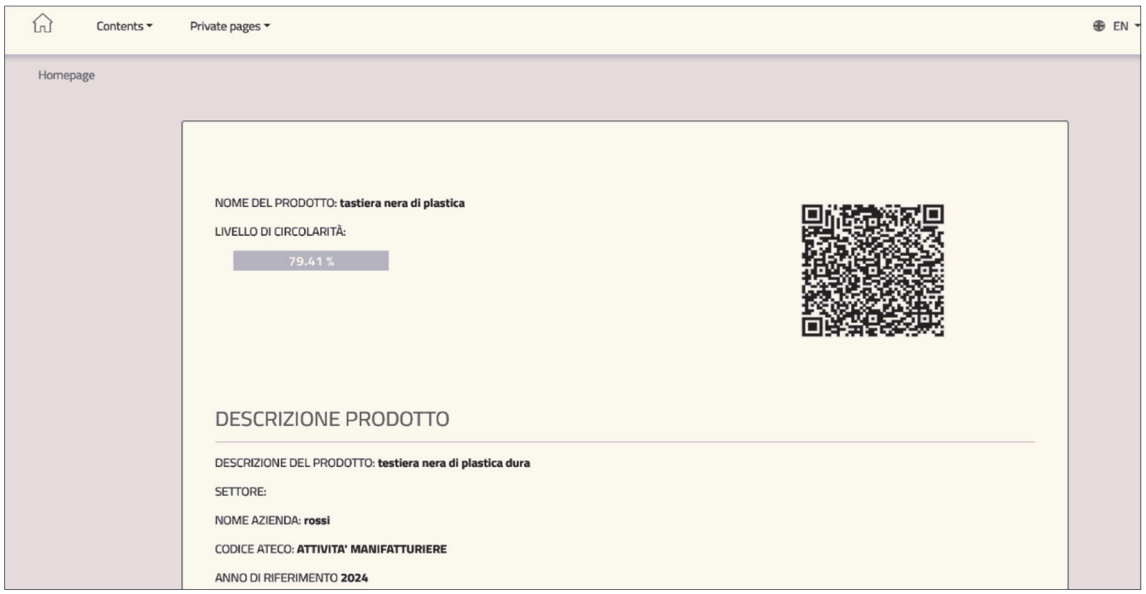

Fig. 7. Example of QR code of a company's product

4. Conclusions

The activities carried out in the framework of RECiProCo project led to the final identification, on the basis of a life cycle approach, of a set of 28 indicators of circularity and water use, which are significant, easy and quick to be calculated. The set of indicators can be used by organisations, also without the need of external support, to measure and monitor over time the circularity and water use of their products and to communicate them to other companies (for example customers and/or suppliers) in a Business to Business approach. Furthermore, 11 of these indicators were chosen for communication to final consumers, because they were considered to be clearly understandable by non-expert's buyers, who can use the QR code information as support and guidance for responsible and environmentally conscious purchases.

Moreover, a free of charge web Platform was developed, addressed to companies, especially to SMEs, aimed at the acquisition, normalization and visualization of data relating to the circularity and water use of products. The Platform contains the whole set of indicators developed in the project and can be used directly by organisations to calculate the level of circularity of their products, to identify areas of potential environmental improvement and to communicate their environmental commitment towards circular economy goals to final consumers and to other companies.

The set of indicators was developed by means of open consultations with several national consumer's association, which provided useful feedbacks, and suggested modifications, in order to boost a more easy application by companies and improve the clarity of each indicator and its usability and effectiveness by consumers.

The companies involved in the testing phase were grateful to ENEA for having been involved in the project and participated with great interest; the calculation of the indicators allowed them to become more conscious about the environmental data related to their products and production processes, and was a first step towards the management and monitoring of

these type of data, especially for companies, mainly SMEs, which did not have any previous expertise or little knowledge in the field of circular economy.

The Platform is now in its launching phase and a supporting guideline for users will be available and published soon on the Platform, with the possibility to develop further training materials, such for example videos or power point presentation on circular economy, environmental sustainability and efficiency in water use concepts.

The Platform was presented and explained during some dissemination events, such as the project final workshop, with companies, consumer's associations and research institutions.

At the moment, some new companies have already registered to the Platform, tried its functions and are evaluating how to use it within other projects in collaboration with ENEA. Moreover, in order to boost a broader use and knowledge, the Platform will be explained and disseminated in further communication events with the cooperation of consumer's associations and different type of companies.

In particular, specific dissemination action plans and capitalisation activities of the Platform, including its possible improvements, could be planned by ENEA with the collaboration of either national consumer's association or the Italian Circular Economy Stakeholder Platform (ICESP), addressed to both industries, consumers associations and citizens could be organised. These dissemination activities will enable ENEA to gather new important feedbacks from consumers about their understanding of the set of indicators, their effectiveness to support sustainable and circular purchasing choices and finally to obtain any suggestions for possible improvements or modifications to the set of indicators.

Moreover, further tests of the Platform will be performed in other companies, also in the framework of national or European projects about circular economy indicators and sustainability assessment to which ENEA participates. The outcomes from this larger sample of companies will lead to more comprehensive and robust considerations about the actual effectiveness of the set of indicators and the Platform.

In addition, possible improvements and extension of both the methodology and the Platform to other types of products and industrial sectors could be designed and implemented, by the adaptation and integration of the indicators already available, also on the basis of sector specific characteristics and peculiarities as well as on the basis of the results of the new testing phases.

Finally, within this further developments and tests of the Platform, a specific verification procedure will be developed, with dedicated guideline and rules, which could be applied also by external reviewers.

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