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Organizational life cycle assessment of a corporate group

Bruno Notarnicola[a,*], Giuseppe Tassielli[a], Pietro A. Renzulli[a], Piero Chirulli[b]

[a] *Ionian Department of Law, Economics and Environment, University of Bari Aldo Moro, Italy*
[b] *Gruppo Finsea, Taranto, Italy*

ABSTRACT

The work illustrated in this paper is part of a project of a multisector business group aimed at defining and quantifying the environmental profile of the production activities carried out by the companies of the group during the period 2020–2021. The approach used is that of an Organisational Life Cycle Assessment (ISO 14072). The paper describes the methodological approaches and the main results. Since some of the companies of the group operate in the material recovery and self-production of electricity from renewable sources sector, thus giving rise to avoided impacts, particular attention was paid to the allocation of end-of-life situations and the separate treatment of any credits. The results highlighted environmental hotspots and enabled the companies of the organisation to undertake actions which improved the overall environmental profile.

1. Introduction

The production of services and goods inevitably has effects on the environment. Being able to evaluate such effects is paramount for the identification of hotspots and opportunities for the improvement of such production systems. An approach widely adopted for these evaluations is Life Cycle Assessment (LCA) developed to quantitatively assess the environmental impacts of goods and processes from "cradle to grave" (ISO 2006 a; b).

Even though LCA was originally developed for assessing products, the benefits of the life cycle approach may be extended to the more complex prospect of organizational assessment (UNEP 2015). At an organisational level, LCA can not only help identify environmental hotspots throughout the value chain, but it can also help track environmental performance over time, as a means to make the correct strategic decisions for the organisation, and as a means of generating information for corporate sustainability reporting.

In 2014 the ISO/TS 14072 (ISO/TS, 2014) was published. This technical specification encompasses the requirements for the application of an Organizational LCA (O-LCA). Similarly, in 2021 the EU published its latest Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of organizations (EU 2021).

The UNEP (2015) Guidance on O-LCA was published as a means to help organizations understand, quantify and communicate the environmental footprint of their activities and those of their value chain. This document includes 12 practical case studies concerning the use of organizational approaches for the environmental multi-impact assessment of organizations. Such case studies were further analysed in by Forin et al. (2019) who highlighted the need for further development of data quality assessment procedures, of region-specific LCA databases and of an O-LCA-specific software tool.

Apart from the above mentioned case studies, there are not many scientific publications concerning the application of LCA to organizations (Rimano et al., 2019). The lack of category or sector rules, which is caused by the very different nature organizations can have when compared to each other (Martinez Blanco et al.,. 2017), has slowed the widespread use of O-LCAs and its effective validation within different sectors and thus there is a need for further application and testing (Martínez-Blanco et al., 2020).

One of the earliest publications concerning O-LCAs is by Manzardo et al. (2015) which illustrates the most relevant challenges in the application of the organizational life-cycle assessment for the packaging sector. This study was then followed another (Manzardo et al., 2018a) in which an LCA and an O-LCA were applied respectively to a beverage product and the organization that produces it. The results highlight the importance of using O-LCA and LCA in conjunction, since an environmental improvement of a product system can lead to a negative effect on the overall environmental performance of the organisation generating such product.

Resta et al. (2016) developed a series of tools for the textile sector, tailored for each phase of an O-LCA, to help create management systems able to support companies in monitoring and evaluating their environmental performances. The usefulness of this decision making process was tested positively by the authors via a specific case study in which options for the reduction of the organisation's environmental impacts

* Corresponding author.
E-mail address: bruno.notarnicola@uniba.it (B. Notarnicola).

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are identified. Similar conclusions are reached by Jungbluth et al., (2016) who present their study concerning the methodology and results of the organisational LCA of canteen operations. The authors conclude that their case study indicates that calculating an organisational environmental footprint for a company in the gastronomy sector can help bring down the overall environmental impacts. Marx et al. (2020) carried out an O-LCA of a company providing services for photovoltaic and wind energy projects. Since the study regards a service-providing organisation different reference flows are considered. The results highlighted the usefulness of the study in identifying hotpots and possible solutions to improve the overall environmental performance of the organisation. The authors also conclude that there is a need for a more specific O-LCA-specific software in order to simplify the conduct of O-LCA studies.

Manzardo et al. (2018b) carried out an O-LCA of a construction company by modifying the methodological approach by analysing the system with an activity portfolio point of view in order to simplify and streamline the analysis. Furthermore, a control and influence approach was used instead of a direct and indirect concept in order to add useful information to the analysis and clearly identify actions to reduce environmental impacts.

Moreira de Camargo et al. (2019) conducted an O-LCA pilot project of a cosmetics, fragrances, and toiletry provider. The results confirmed the feasibility of such a study, and highlighted operational challenges concerning inventory data management and data quality. Similarly, in Lo-Iacono-Ferreira et al. (2017) study, which evaluated the suitability of O-LCAs for higher education institutions implementing EMAS systems, the main issue arising concerned quality and completeness of the data provided by such systems. In the study by Cucchi et al. (2022), regarding a ceramic tile manufacturer, inventory data from one plant within the organisation, collected via IT technologies on a monthly basis, in used to predict the environmental profile of the whole organisation.

Alejandrino et al. (2022) proposed a methodology to evaluate circular strategies at organizational level aimed to estimate the eco-efficiency based on environmental and economical tools, respectively O-LCA and organizational life cycle costing (O-LCC). The case studies, concerning manufacture and construction products, showed that the environmental and economic effects presented different results, although the scenarios were beneficial from the circularity perspective.

Recently, Toniolo et al. (2023), combined O-LCA and product LCA (P-LCA) to explore the environmental benefits of steel slag recovery practices; they concluded that O-LCA can assess the environmental improvements of circularity practices in the steel industry, but the reduction of the impacts is smaller compared to that estimated via P-LCA.

The work described in this paper was commissioned by a multisector business group (Finsea, 2023), consisting of fourteen different businesses. Inventory data was collected with a classic bottom-up approach from every business company within the organisation. The objective of this work is that of defining and quantifying the environmental profile of the business activities carried out within the group, during the years 2020 and 2021, according to an organisational life cycle approach. The purpose of the paper is to illustrate the results of the study and highlight O-LCA's usefulness as a tool for increasing the environmental awareness of the employees of an organisation and as a means of improving over time the environmental performance of organizations.

This paper is structured as follows section 2 briefly illustrates the structure of the organisation and then explains the methodological approach used for the study. Section 3 illustrates and discusses the main results of the study. Finally, in section 4 conclusions are drawn.

2. Methodological approach

2.1. The organisation

Since the Finsea group is composed of different businesses, the study was drawn up according to the ISO 14040 and 14044 standards and following the indications of the UNI ISO/TS 14072 Technical Specification relating to the requirements and guidelines for the assessment of the life cycle of organizations (ISO, 2014). In addition, when applicable, the UNI EN ISO 14064–1(2019), UNI Standard. Greenhouse gases - Part 1 (see section 3.1) was also taken into account.

The group, operating in the province of Taranto in southern Italy, is made up of 14 companies, belonging to various business sectors, in particular ecological and recovery services, agriculture, production of compost and fertilizers, energy, design and production of LED equipment and sustainability consultancy. Table 1 lists these companies and their respective business activities.

2.2. Goal and scope definition

The present study consists of a series of LCAs of different product/service systems, each represented by a company of the group.

For the definition of the organisation's system boundaries, as indicated in the UNI ISO/TS 14072, the consolidation method is adopted, thus including all the companies (see Table 1) over which the group has

Table 1
Companies of the Finsea group and their business activities.

Name of the Company	Business activity	2020 Business output	2021 Business output
FERTILEVA	Production of fertilizers for agricultural activities	9696 t of fertilisers	13,434 t of fertilisers
IRIGOM	Treatment of ELTs and production of secondary raw material	26,689 of RDFs	32,290 t of RDFs
NITEKO	Design and production of LED devices	27,163 lamps; 3 automatic robots	28,829 lamps: 11 automatic robots
ORTO GOURMET	Production of leaves, edible flowers and microgreens	1.95 t of microgreens	3.84 t of microgreens
PROGEVA	Composting activity for the production of agricultural soil conditioners	12,270 t of soil conditioners	12,920 t of soil conditioners
RAEECUPERA	Recovery of WEEE, components, ferrous and non-ferrous materials	1200 t of WEEE recovered	1165 t of WEEE recovered
RECSEL	Sorting and recycling of paper, cardboard, glass, cans and plastic	49,915 t of waste sorted and sent to recycling	51,146 t of waste sorted and sent to recycling
SERVECO	Environmental remediation, renewable energies, urban hygiene	Waste collected and transported: 930,402 t km; 8637 kWh wind energy produced; 831 new remediation sites;	Waste collected and transported: 1,273,696 t km; 40.579 kWh wind energy produced; 697 new remediation sites;
TERRE DI ALTAMURA	Legume production	2104 t of legumes	3179 t of legumes
PLASTEC	Brokerage company for plastic waste	4315 t of managed plastic waste	5922 t of managed plastic waste
SMOCO	Environmental consultancy and fuel marketing	Transported 24,763 t of RDF	Transported 41,156 t of RDF
DIMENSIONE 3	Design and implementation of digital tours in 3D	223 virtual tours	354 virtual tours
CONSEA	Environmental consultancy and training	1500 procedures for clients	1350 procedures for clients
TECSAM	Occupational medicine, safety, accident prevention, occupational hygiene	8411 medical consultancies; 4368 h of training	8752 medical consultancies; 10,560 h of training

executive and financial control.

The production of all goods or services of all the group companies, within a year, represents the reporting unit of the organisation. For example, Table 2 shows the product/service portfolio of a group company which contributes to the overall reporting unit.

The system boundaries consider all indirect upstream activities (i.e. the production and transport of the raw materials used onsite), the production and dispatching of the electrical energy used onsite, the production and transport of fuels used for company activities, direct company activities, and indirect downstream activities (i.e. the management of waste deriving from company activities). For example, Fig. 1 shows the system boundaries of the of the company described in Table 2.

The foreground data was provided by the group and was collected through the use of questionnaires and interviews with company personnel. When it was not possible to gather primary data, the reference data were estimated or data from LCA databases (e.g. Ecoinvent, Wernet et al., 2016) or other bibliographic sources were used.

2.3. Allocation referred to end of life scenarios and impact assessment method

The recovery of material/energy takes place in two distinct cases for which two different methods of allocating the credits were used.

1) The first is that in which the recovery of materials/energy concerns the recovery operations that are part of the core business of the companies of the group (e.g. Irigom, which recovers tires for the production of RSF). For these cases a "0–100" approach was opted for, adopted by the ISO/TS 14067 (ISO, 2013a) standard, in order to enhance the recycling operations carried out by the companies of the group and to maximize environmental credits. Next, the environmental credit was calculated for the recycling/recovery operations (albeit sometimes partial) carried out by the companies; for each type of waste recovered, an avoided environmental impact was calculated in terms of virgin material (the production of which was avoided thanks to the recovery). This amount of avoided virgin material was quantified in three ways:
   a. In the case of material recovery for energy purposes (e.g. plastic and rubber sent to cement plants), the energy content of this material was calculated and on the basis of this, the amount of traditional fuel replaced by the recovered material was calculated.
   b. In the case of recovery of material for the production of secondary raw material (e.g. wet fraction of urban waste sent for the production of compost and fertilizers), the credit is calculated on the basis of the avoided production of the quantity of equivalent virgin product (e.g. the load avoided by the production of a virgin fertilizer with a composition equivalent to that resulting from the recovery).
   c. In the case of operations carried out which represent only a part of the recovery process aimed at the production of secondary raw material (e.g. selection of plastic waste), the quantity of avoided use of virgin material is calculated as a percentage of the mass of recovered material. This percentage is defined by comparing the market value of the selected waste with respect to the equivalent of the finished virgin material.
2) The second case is the one pertaining to the recovery of each company's waste, deriving from the company's main activities. Since for the background data the Ecoinvent database was set up with the "Allocation, cut-off by classification" method, which assigns the material production debt always to the primary user of a material and does not assign any credit to the manufacturer for the production of recyclable materials, it is clear that the basic approach used by the database for the management of multifunctionality at the end of its life is the "100–0" approach (EPD, 2013).

Table 2
Product portfolio of the company Progeva (involved in the composting activity for the production of agricultural soil conditioners).

Aspect	Details
Decription of the activity	Production of quality compost via storage and recovery and composting of urban waste, non-hazardous special waste and by-products of animal origin.
Managed products (quantity)	In 2020, Progeva produced 12,270 t of compost of which 6.816 were supplied as raw material to Fertileva (another company of the Gruppo Finsea), while 5453 were sold in bulk through Fertileva. The production of 12,270 t of compost required 79,687 t of organic waste

The impact assessment method used is the one implemented as part of the Environmental Footprint initiative, EF 3.0 method (Sala et al., 2018, Zampori and Pant, 2019).

3. Results

3.1. Main impacts

Fig. 2 shows the results of the final weighting of the potential impact assessment. The reference units are person.year, intended as the environmental impact caused by an average European citizen in a year (Benini et al., 2014).

The figure indicates that the impact categories most affected by the system, once normalized and weighted, are climate change, the consumption of fossil resources, the emission of particulate matter and the consumption of mineral resources.

In summary, the critical points of the organisation deriving from the analysis carried out are the following:

Percentage contribution, of the main impact categories, to the final weighted indicator.

— Climate change 22.5%
— Resource use - fossils 16.0%
— Particulate emission 10.6%
— Resource use - mineral and metals 9.3%

Main substances (emitted or consumed) and their contribution to the final weighted indicator.

— Carbon dioxide to air 19.5%
— Nitrogen oxides to air 15.3%
— Petroleum - use of 9.1%
— Tellurium - use of 7.4%

Percentage contribution, of the main activities, to the final weighted indicator.

— Transport via truck (16–32 t) 21.50%
— Medium voltage electricity production 10.45%
— Diesel combustion in agriculture 11.20%
— Transport via sea 9.26%
— Agricultural land use 9.26%
— Emissions from agriculture 5.01%
— Copper extraction 8.66%

Table 3 shows the percentage contribution of the different group companies to the overall impact of the organisation, while Fig. 3 shows the absolute vales of the eco-indicator for each company.

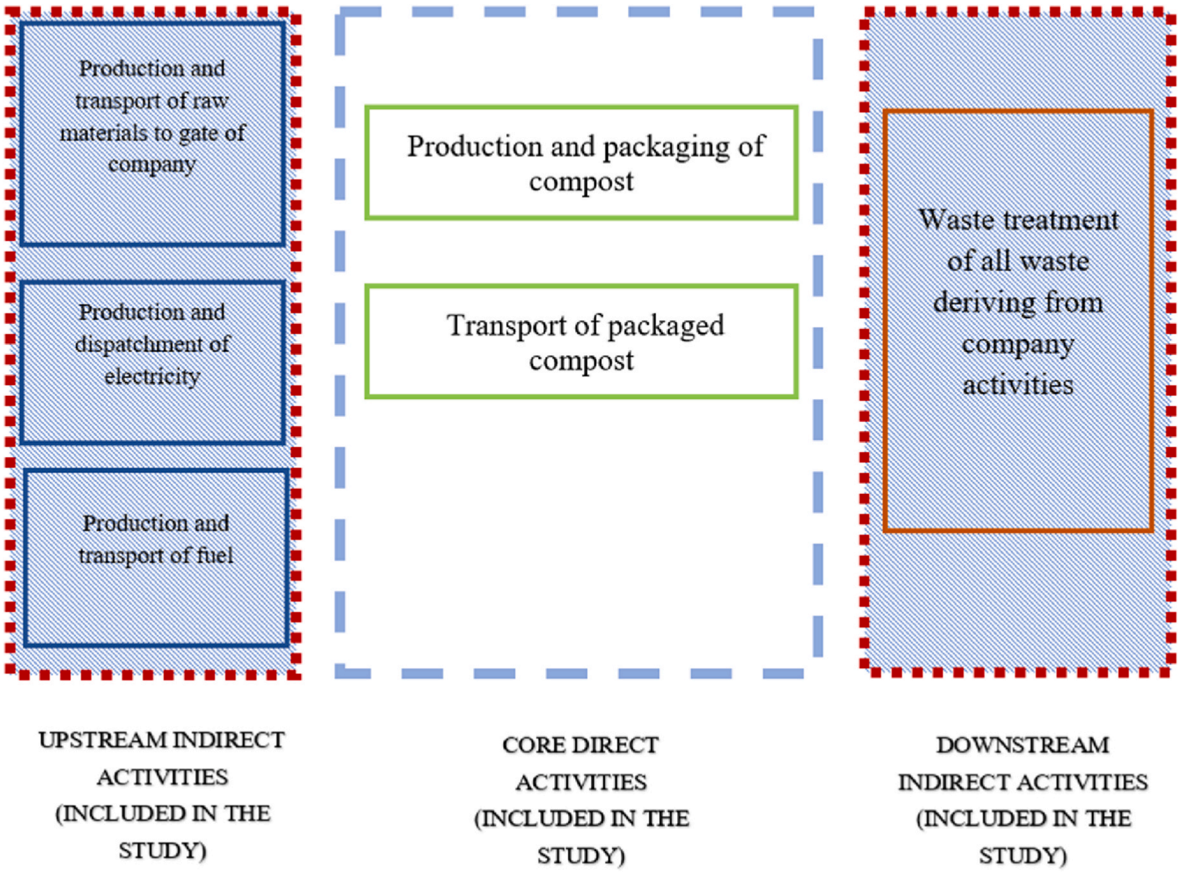

Fig. 1. System boundaries of the Progeva company (see Table 2).

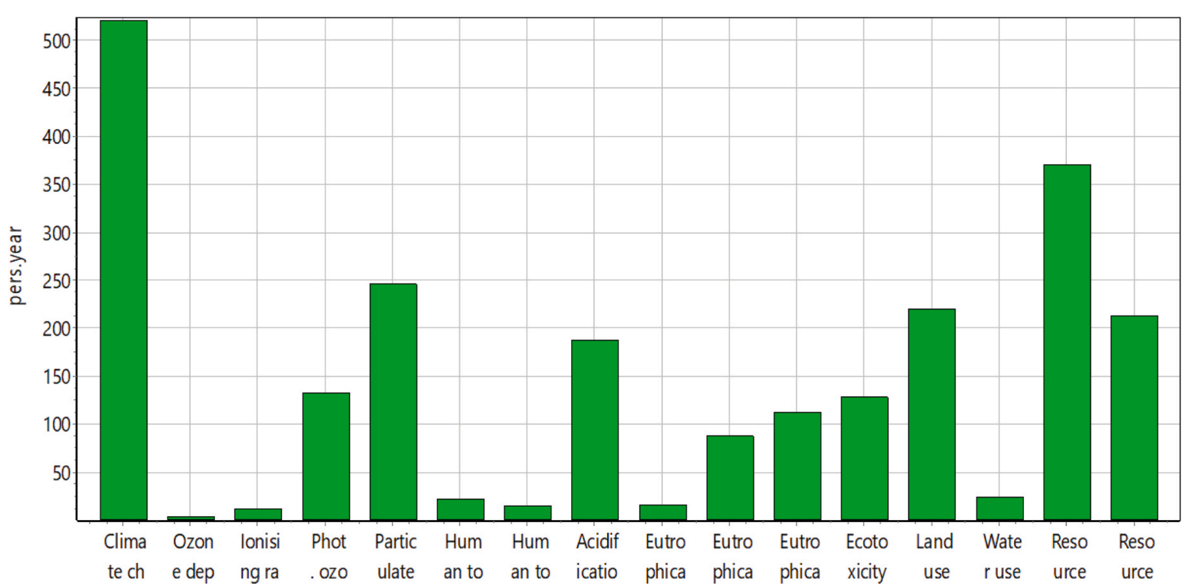

Fig. 2. Weighted results of the impact assessment of the organisation (referred to the reporting unit for the year 2021).

3.2. *Inclusion of environmental credits deriving from reuse and recycling activities*

As far as environmental credits are concerned, this study followed the approach defined by the technical report ISO/TR 14069:2013 (ISO, 2013b), according to which any avoided impacts deriving from the recovery of materials must be reported separately from all other impacts. This approach helps to better understand the differences between the results associated with the impacts and those relating to a system that also includes credits. Tables 4 and 5 show the eco-indicator values including credits for the whole group and for each single company. As can be seen from these tables the total credits slightly exceed the total debts.

Finally, the comparison between the results of the organisaton with

Table 3
Percentage contribution of the companies to the overall eco-indicator of the organisation *(referred to the reporting unit for the year 2021)*.

Company of the organisation	% contribution to overall eco-indicator
NITEKO	26,3
SMOCO	20,6
PROGEVA	15,7
TERRE DI ALTAMURA	10,9
FERTILEVA	10,6
SERVECO	6,4
RECSEL	4,1
IRIGOM	2.8
Wind energy produced by SERVECO (sold)	0,95
PLASTEC	0,73
RAEECUPERA	0,25
TECSAM	0,18
ORTO GOURMET	0,18
CONSEA	0,13
DIMENSIONE 3	0,07
PV energy produced by TECSAM (sold)	0,001
energy produced by NITEKO (sold)	0,001
Total	**100**

and without environmental credits is reported. Fig. 4 illustrates the results of the characterisation phase.

Fig. 5 shows the eco-indicator (the results are again expressed in terms of impact equivalent per person per year of the environmental debt (positive impact) and the credits (negative impact) in terms of impact categories.

3.2.1. *Comparison of the year 2020 results with those of 2021*

The O-LCA illustrated in the previous paragraphs, pertaining to the year 2021, was also carried out for the year 2020. The comparison of the results of these two years is useful for monitoring the organisation's environmental performance over time.

Fig. 6 compares the of eco-indicator values of the organisation for the years 2020 and 2021. The figures illustrate the debt (positive impact), the credits (negative impact) and the sum of these two for the two years.

Overall, the profile (debt + credits) of the organisation improved from the year 2020–2021. The environmental debt increased in 2021 due to increases in the amounts of goods produced and services provided. However, the overall credits also increased due larger amounts of recovered materials among the companies whose core business regarded waste recovery and recycling. Furthermore, an increase in production of wind and photovoltaic systems also increased the 2021 environmental credit.

Additionally, the better performance for the year 2021 was also due to better business management procedures that were stimulated by the 2020 O-LCA study. Specifically, the 2020 O-LCA indicated that a large part of the organisation's impact was due to transport and diesel consumption (see section 3.1). In 2021 more effective agricultural soil management practices (for the Terre di Altamura company) were implemented together with an increased use of electric vehicles (or better performing diesel vehicles) throughout the organisation. This caused a reduction int the debt (positive impact) of the organisation. Also, the companies that sent consistent amounts of waste to landfill in 2020, in 2021 increased the amount of recovered and recycled waste thus decreasing the amounts sent to landfill with positive effects on the overall organisation's environmental profile.

4. Conclusions

The results of the O-LCA have highlighted the usefulness of this type of study as a tool for increasing the environmental awareness of the

Table 4
Eco-indicator values including credits for the whole group and for each single company, subdivided for each impact category (including environmental credits) for the year 2021.

Impact category	Person.year	%
Climate change	132.74	37.43
Ozone depletion	−9.58	−2.70
Ionising radiation	−25.53	−7.20
Photochemical ozone formation	18.94	5.34
Particulate matter	65.59	18.50
Human toxicity, non-cancer	5.47	1.54
Human toxicity, cancer	5.88	1.66
Acidification	−2.12	−0.60
Eutrophication, freshwater	−2.50	−0.71
Eutrophication, marine	36.98	10.43
Eutrophication, terrestrial	32.69	9.22
Ecotoxicity, freshwater	−38.39	−10.83
Land use	51.65	14.57
Water use	−26.83	−7.57
Resource use, fossils	−715.41	−201.76
Resource use, minerals and metals	115.84	32.67
TOTAL	**−354.59**	**−100**

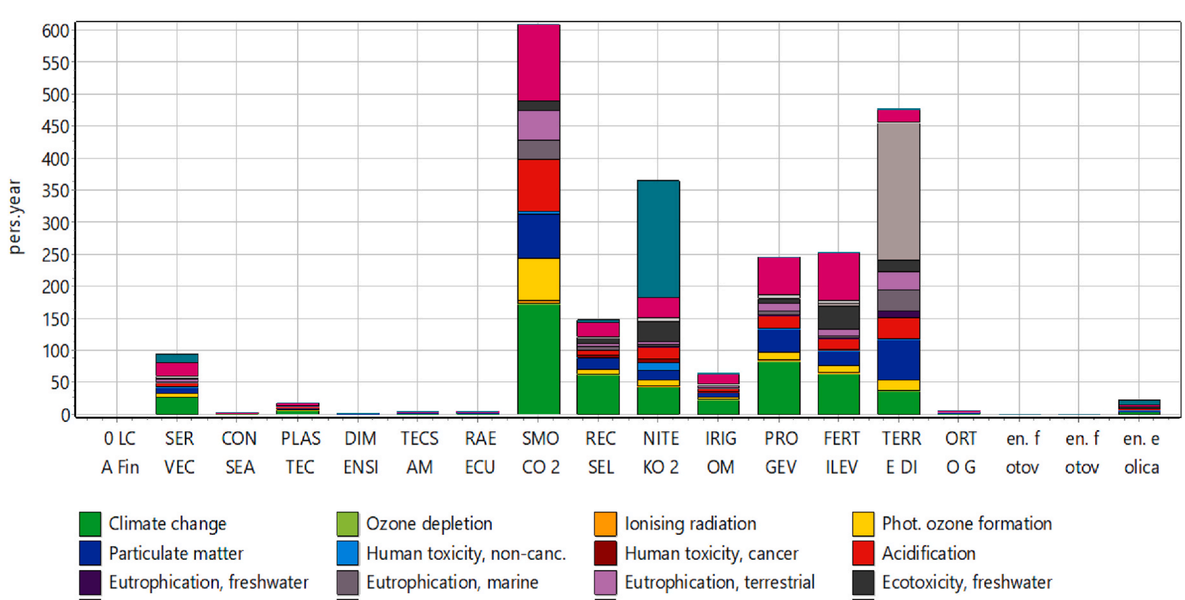

Fig. 3. Overall eco-indicator subdivided among the different companies of the organisation *(referred to the reporting unit for the year 2021)*.

Table 5
Percentage contribution of each company to the overall eco-indicator (including credits) for the year 2021.

company	Eco-indicator Person.year	% contribution
SMOCO	607.88	68.77
TERRE DI ALTAMURA	476.23	53.88
NITEKO	363.74	41.15
FERTILEVA	253.06	28.63
PROGEVA	245.80	27.81
RECSEL	147.45	16.68
SERVECO	94.09	10.64
IRIGOM	64.29	7.27
en. eolica prodotta SERVECO (venduta alla rete)	21.85	2.47
PLASTEC	16.89	1.91
ORTO GOURMET	5.80	0.66
TECSAM	4.24	0.48
RAEECUPERA	4.10	0.46
CONSEA	2.88	0.33
DIMENSIONE 3	1.50	0.17
PV energy produced TECSAM (sold)	0.03	0.00
PV energy produced NITEKO (sold)	0.02	0.00
Sub-total impacts	***2309.85***	***261.32***
PV energy produced NITEKO (avoided impact)	−0.05	−0.01
PV energy produced TECSAM (avoided impact)	−0.09	−0.01
recuperated products RAEECUPERA	−98.66	−11.16
wind energy produced SERVECO (avoided impact)	−195.71	−22.14
recuperated products PROGEVA	−297.61	−33.67
recuperated products RECSEL	−673.29	−76.17
recuperated products IRIGOM	−1928.38	−218.16
Sub-total credits	−3193.78	−361.32
Total	***−883.93***	***−100.00***

organisation's employees and improving the environmental performance of organizations. In particular, in this paper the O-LCA approach was applied to a corporate group which is made up by fourteen companies operating in the fields of ecological and recovery services, agriculture, production of compost and fertilizers, energy, design and production of LED equipment and sustainability consultancy.

The application of the O-LCA approach to the corporate group allowed all the analytical and managerial objectives (specified in the UNEP O-LCA Guide), that can be achieved at an organisational level, to be accomplished. In particular.

— Gain insight into internal operations and the value chain: the O-LCA helped the corporate group to better understand the relationships between the activities and processes involved in the entire value chain and the environmental impact of its product/service portfolio.

— Identify environmental hot spots: the corporate group is now aware of its hot spots both at a group level and at a level of individual companies and/or products/services and is able to investigate certain environmental criticalities with more precise data collection or with more accurate LCA product/service details.

— Understand risks and impact reduction opportunities: the group now has a greater clarity of the areas that present environmental risks and of those where there is potential for impact mitigation and greater resource efficiency both within the company boundaries and upstream or downstream. Similarly, the group is more aware of the trade-offs between one impact and another and of the possibilities of mitigating them.

— Track environmental performance: the application of the O-LCA approach tool for two consecutive years highlighted hotspots during such period in the same way that can be done for business budgets, enabling the companies of the organization to undertake actions which improved the overall environmental profile.

— Support strategic decision making: the corporate group has become aware of the hotspots and has decided to mitigate them, for example by decreasing the quantity of waste directed to disposal and increasing the recovery of material and energy.

— Reduce operational costs: certain actions that have been implemented, such as the one described above, have made it possible to reduce operating costs.

— Establish a basis for environmental communication with stakeholders and reporting: the results of the O-LCA were published in a company report thanks to which greater communication was established between the companies of the group and its stakeholders.

— Show environmental awareness with marketing purposes: the application of O-LCA has given the corporate Group a possibility to show its commitment to better understand, thanks to scientific tools, its real impact on the environment and the actions for its mitigation. The management of the group intends to use the results of this work to start a virtuous spiral of continuous improvement of the environmental performance of the individual companies of the group, which from one year to the next will compete from an environmental point of view.

The study highlighted some challenges dependent on the fact that the analysis concerns a corporate group and not to a single company. In particular, the product portfolio considered is very broad and this generates the need for an inventory which is very costly and time

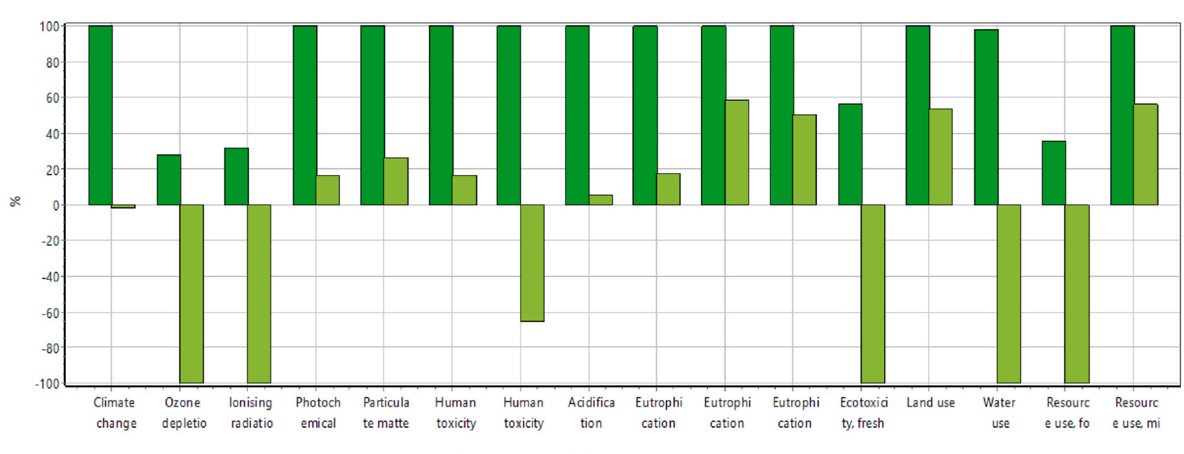

Fig. 4. Percentage contribution of the various impact categories: results with and without environmental credits (year 2021).

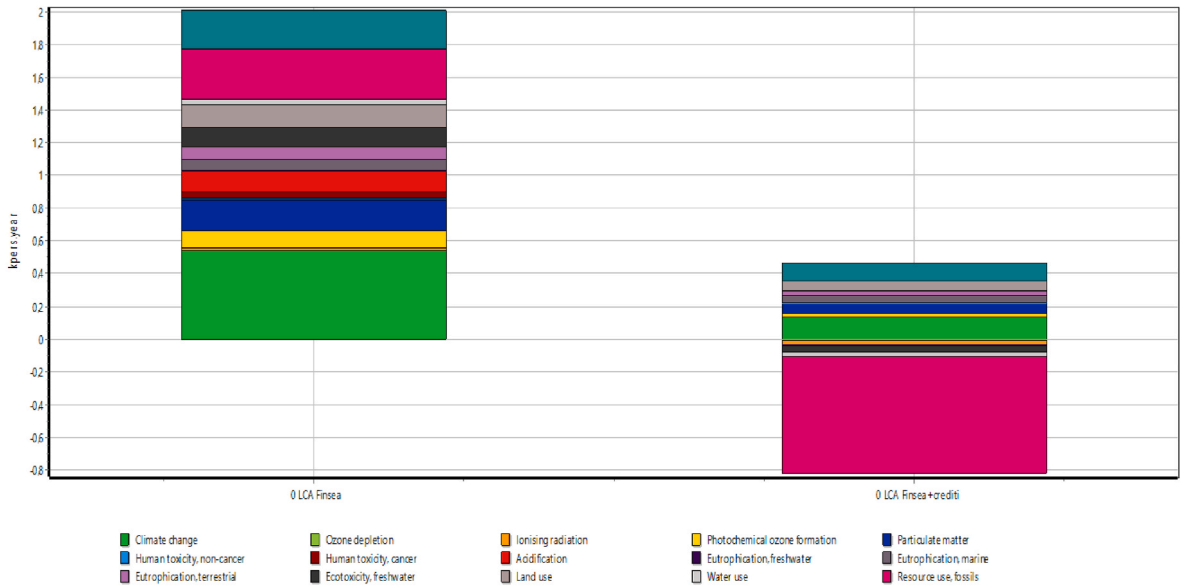

Fig. 5. Eco-indicator of the organisation with and without environmental credits (with indication of the various impact categories; year 2021).

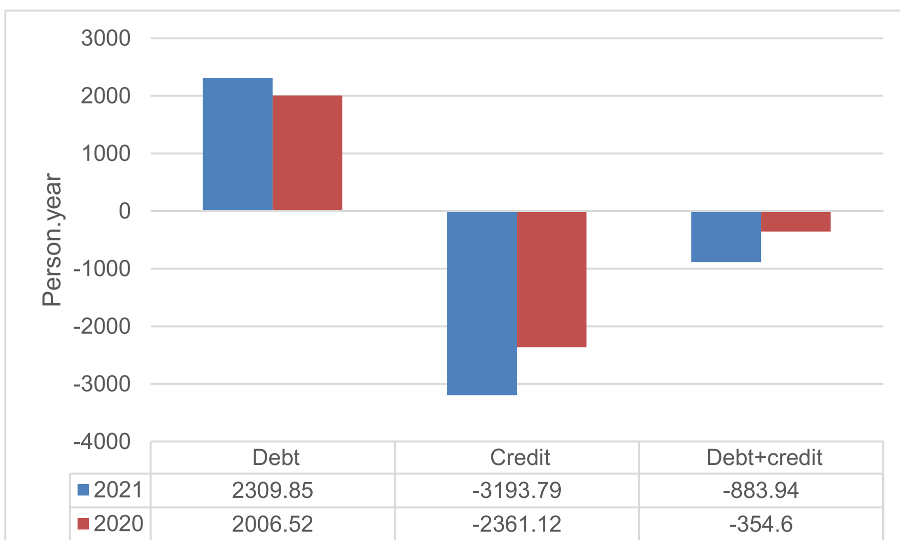

Fig. 6. Comparison of Eco-indicator values (Debt, Credit and Debt + Credit) of the organisation for the year 2020 and 2021.

consuming. This requires a trade-off between a very complex bottom-up process-based analysis, i.e. the O-LCA applied to a corporate group, and the need to be time and cost efficient. Future work could entail considering an activity portfolio instead of product portfolio (Manzardo et al., 2018b). This different approach would simplify the inventory setup and the analysis and would nonetheless allow the identification of the hot-spots of the group's activities. However, this approach is easily adaptable to a company dealing with one only activity (e.g. construction), but it is much less so in the case of a corporate group, like the one analysed in this study, which includes productions concerning various sectors ranging from agriculture, robotics, as well as the end-of-life recovery of material from industrial activities. Furthermore, the analysis applied to a group, characterized by heterogeneous group activities, implies comparing the results of companies with a large environmental impact (e.g. long-distance transport activities or agricultural activities) with others that have very limited impacts (e.g. consultancy activities). A future re-implementation of the study could entail the aggregation of companies with similar activities into clusters which would make it possible to obtain more easily comparable results, even if this would imply losing the specificity of the results of individual companies. Finally, carrying out the study with several reporting units, for example the turnover of the entire corporate and of the individual companies, could also help to obtain more easily comparable results.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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