

Article

Organizational Life Cycle Assessment of a Service Providing SME for Renewable Energy Projects (PV and Wind) in the United Kingdom

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Abstract: Companies are increasingly interested in reducing their environmental footprint. Thereby, they face the challenge of identifying and mitigating their specific impacts and hotspots and simultaneously avoid burden shifting. The organizational life cycle assessment (OLCA) method was conceived and successfully tested for the assessment of companies' potential environmental impacts. Still, the method poses methodological challenges for the application to service providing organizations. In this paper, OLCA was applied to a service providing SME in the photovoltaic and wind energy business in the United Kingdom. The environmental impact profile of the reporting organization is dominated by transport activities, including the technicians' trips to the solar farms, employee commuting, and business travels. According to the main goals of the study (gaining insights in internal operations and improving organizational procedures), recommendations to reduce travel-related impacts are provided. For existing methodological challenges like selecting the reporting flow and setting the system boundaries, innovative solutions like defining multiple reporting flows for different activities and to partly include service receiving objects in system boundaries are discussed with the aim to facilitate future applications.

Keywords: organizational life cycle assessment; service provider; supply chain management; photovoltaic; wind energy; SME

1. Introduction

Over the last years, life cycle thinking has been implemented in industry and policy. The most established tool of the life cycle family, product-related life cycle assessment (LCA) according to the ISO 14040/44 standards [1,2], provides a framework for calculating a product's potential environmental impacts "from cradle to grave". At the same time, for more and more organizations, the assessment of potential environmental impacts on a company level is getting interesting [3,4], as testified by the success of initiatives like the greenhouse gas (GHG) protocol [5]. The main driver for this development is the missing information of relevant environmental data regarding the complete portfolio of activities throughout the whole value chain for decision makers in the organization [6].

For transferring the life cycle approach from a product level to a whole company level, the organizational life cycle assessment (OLCA) was conceptualized within the framework of the UNEP/SETAC Life Cycle Initiative. Through the flagship project "LCA for organizations", a guidance document was published [4]. This presents guidelines to carry out an OLCA study with connections to existing standards and guidelines like ISO/TS 14072, ISO 14040/44, and ISO 14001. OLCA uses the life cycle perspective on organizations' activities and their value chain to compile and evaluate the in- and outputs, as well as the potential environmental impacts, and its scope was widened to social aspects be

the social organizational life cycle assessment framework (SOLCA) [7,8]. It can be used as a strategic tool for comprehensive environmental assessments to track performance over time, avoid burden shifting, inform management decisions, or as an input for supporting corporate reporting activities [9].

OLCA studies were carried out in the past within different sectors like consumer products [10–12], construction [13,14], and other industry sectors [15–17]. However, only a few service providers were assessed using multi-impact methods for organizations. Among them, the municipality Tuzla Belediyesi, two university institutes (the Faculty of Science and Technology-UPH in Indonesia [15] and Universitat Politècnica de València in Spain [18]), the canteen operator SV Group [19], and the hotel group Accor [11] were in scope for an OLCA study. These studies identified methodological challenges specific to the service sector, which might have a negative impact on the application of OLCA by service providers. Proposing solutions to these methodological challenges is expected to facilitate method application, thus encouraging environmental assessments and impact mitigation in the service sector.

The aim of this paper is to present the OLCA case study carried out by a photovoltaics (PV) and wind energy service provider. Besides adding experience to OLCA application, specific solutions to address service sector specific methodological challenges can serve as an example for future applications and spread life cycle thinking among service providing organizations.

By carrying out an OLCA study, there are several challenges that are common to different kinds of companies. Especially the classification of activities into direct, indirect upstream, and downstream activities, writing the final report, assessing the data quality, and interpreting the results were identified as the most challenging parts of an OLCA study through the 12 OLCA-road testing companies [15]. However, as outlined at an early stage of method development by Martínez-Blanco and colleagues [20], the service sector poses particular challenges at certain steps of method application.

First, a service-only portfolio poses the question of how the organization's performance can be quantified, which is necessary for establishing the reporting flow. As common measurements, such as mass, volume, or units, are not always suitable for quantifying services, different key indicators need to be explored. Choosing an appropriate reporting unit is particularly useful to track and consistently compare the organization's environmental performance over time.

Second, the service providing nature of the organization needs to be considered while setting the system boundaries. According to ISO/TS 14072, the system boundaries for a cradle-to-grave assessment should include the "[...] use stage emissions of sold products over their expected lifetime and the waste disposal and treatment of products sold by the reporting organization (in the reference period) at the end of their lives." [9]. As service providers do not sell products, and the use of a service often corresponds to its provision (at least in terms of physical inputs and outputs), a cradle-to-gate assessment is often recommended if the reporting organization is a service provider [21,22].

Third, many processes and objects can be related to but not owned by the organization as these objects are receiving the provided services. These can be, for example, facilities, assets, or legal entities. Especially in this study, there are assets that are managed and partly maintained but not owned completely or in parts by the organization. This aspect poses a further challenge regarding the classification into the system boundaries, which is known through a former OLCA study [23]. In this case, it can be analyzed how much influence the organization has on the environmental performance of these objects following the influence approach of the Guidance [4].

However, even if there is no material output like products which could have environmental impacts during the use or end of life phase, the provided services or the activities of the reporting organization might have a significant influence on further processes. For example, a company involved in planning a construction project can influence the building's environmental performance, of course within the framework set by the customer. This aspect was specifically highlighted in Manzardo et al. [13], who suggest using a two-level classification for describing the linkage between the reporting organization and indirect activities (control/influence approach).

This paper presents the OLCA study carried out by a service provider for solar farms and wind parks located in the United Kingdom. The decision of carrying out this OLCA study was taken by the managing director, interested in examining in depth their value chain and the company's environmental impacts as well as tracking the organization's performance over time. For confidentiality reasons the name of the organization and other details are not provided.

The solar farms and the wind parks are managed and partly maintained but not owned by the organization. Therefore, the influence on the environmental performance of the plants needs to be carefully analyzed in order to set the system boundary. Additionally, given the organization's service-related character, defining the reporting flow based on the product portfolio represents an additional methodologically meaningful exercise, as highlighted before.

In this paper, the report on method application focuses on the specific challenges for service providing organizations. Approaches developed by previous research are analyzed and discussed and, where necessary, additional solution pathways are developed. The structure of the study follows mainly the OLCA Guidance. The OLCA method used is presented at the beginning of Section 2 and the specific methodological choices made for the case study are explained in detail in the goal and scope and inventory phase (Sections 2.1 and 2.2). Section 3 displays the life cycle impact assessment results and addresses their interpretation. The discussion of the case results and the methodological issues emerges are addressed in Section 4. Section 5 provides a short outlook and recommendations to reduce the company's environmental impacts profile.

2. Materials and Methods

This case study is carried out following the OLCA method based on ISO/TS 14072 [9] and the Guidance on Organizational Life Cycle Assessment [4]. OLCA is defined as the "compilation and evaluation of the inputs, outputs, and potential environmental impacts of the activities associated with the organization as a whole or portion thereof adopting a life cycle perspective" [9] and aims at analyzing an organizations' value chain from raw material supply to the end-of-life of sold products by following a multi-impact approach, i.e., by including a wide range of environmental impacts in order to avoid burden shifting. The method is intended for a wide application. In fact, an organization is defined as "person or group of people that has its own functions with responsibilities, authorities, and relationships to achieve its objectives" [9] and the "concept of organization includes, but is not limited to sole trader, company, corporation, firm, enterprise, authority, partnership, charity, or institution, or part or combination thereof, whether incorporated or not, public or private" [9].

Like other LCA-based method, it is structured into four phases according to ISO 14040 [1]. The goal and scope phase provides information in the study motivation, the intended application, and the addressees of the study; it describes the system to be analyzed (reporting organization), provides quantification (reporting flow), and specifies the parts of the system to be included (system boundary). The inventory phase describes the data collection procedures and the characteristics of collected data and categorizes them into activities and activity categories following the organization's value chain (direct activities, indirect upstream activities, and indirect downstream activities). The impact assessment phase relates the input and output data collected in the inventory phase to the related environmental impacts and estimates the impact magnitude for different impact categories. Last, the interpretation phase identifies significant issues, evaluates them considering completeness, sensitivity, and consistency, identifies limitations of the study, draws conclusions, and provides recommendations.

2.1. Definition of Goal and Scope

2.1.1. Goals

To ensure the usefulness of OLCA for the reporting organization, it is recommended to preliminarily explore the expectations of the target group. A useful tool delivered by the OLCA Guidance consists in a set of general goals, which can be prioritized by the responsible management at the beginning of the

study [22]. This scheme was applied to the service provider assessed in this paper and the results are shown in Table 1.

Table 1. Prioritized goals of organizational life cycle assessment (OLCA) study according to UNEP [4] on a scale from 1 (not important) to 10 (very important).

Category.	Goal	Prio
Analytical goals	Gain insight in internal operations and value chain	9
	Identify environmental hotspots	5
	Understand risks and impact reduction opportunities	6
	Track environmental performance	8
Managerial goals	Get support for strategic decisions	3
	Improve organizational procedures	9
	Get the basis for environmental communication with stakeholders and reporting	6
	Reduce operational costs	8
	Show environmental awareness with marketing people	3
Societal goals	Reduce pressure on the environment	4
	Enhance environmental tools within stakeholders	8

To check whether the study results met initial expectations, the degree of goal achievement through the results of the OLCA study was assessed later by the management and is discussed in Section 5, together with measures to achieve the overarching managerial and societal goals.

2.1.2. Delineating the Reporting Organization

The whole service providing organization in PV and wind energy business was defined as the reporting organization.

The organization is located at two different site units in the U.K., each of them responsible for one of the two business fields, i.e., PV and wind energy. The services provided by the wind energy business include the management of the facilities by financial aspects as well as general monitoring and observing tasks. The only services on site, which are provided for the wind parks, are visual inspections by the employees. The portfolio within the PV business unit includes not only monitoring and observing tasks, but also inspections and low-voltage repair services on site carried out by the technicians' team.

A team of 17 technicians performs the maintenance and inspection services for the PV facilities. The team of 30 office employees works on trading and project business as well as in monitoring and controlling functions. The organization can be classified as a SME according to the "European User Guide to SME Definition" [24].

The reporting organization has a contractual agreement with the owner of the managed facilities, which is the basis for the provided services. Not all services needed for the operational management of the PV and wind energy facilities are provided by the reporting organization. Therefore, other third parties, which are not within the responsibility of the reporting organization, are directly commissioned by the owner. At the same time, certain third-party services are commissioned by the reporting organization on behalf of the owner. Figure 1 gives an overview of the relations between the different stakeholders.

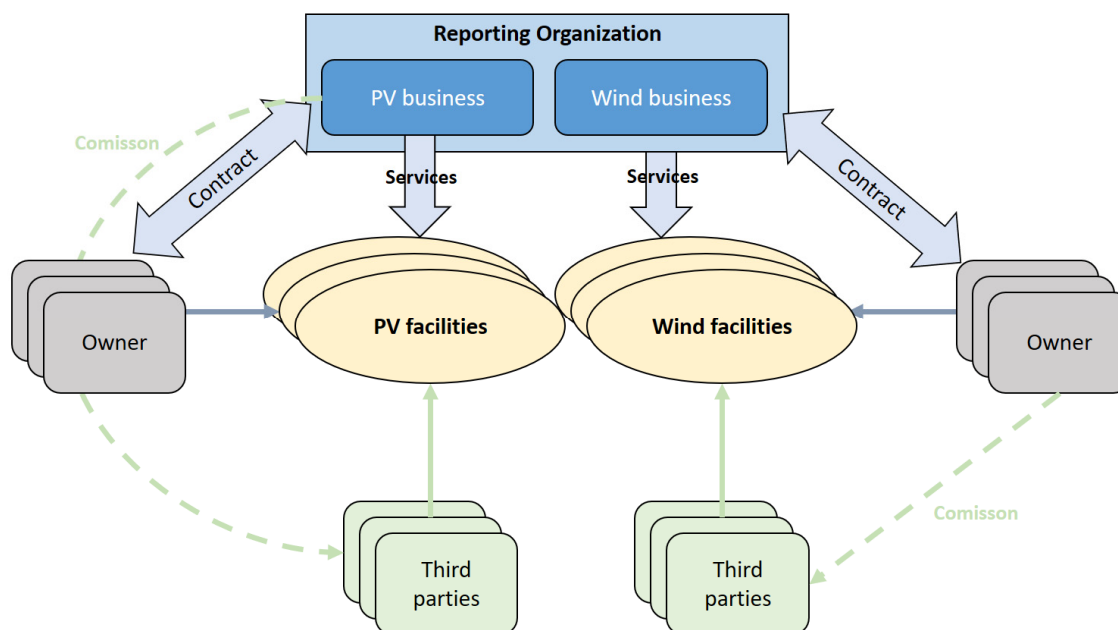


Figure 1. Schematic representation of the business field of reporting organization.

The operational control approach was chosen as consolidation method to map these relations. The reporting organization holds the full operational control of both the wind and the PV business unit, but no operational control on the third parties.

The reference period for an OLCA study is defined as the “given time period for which the organization is being studied and the environmental impacts reported” [4]. The time period chosen was the solar year 2017 because the sustainability report, which is an obligation for the whole company [25], as well as the financial data for this time frame, were the most recent ones available as the study began. The sustainability report of the reporting organization served as a data source for inventory data (see Table S1 in Supplementary Materials for details).

2.1.3. Reporting Flow

The definition of the reporting flow poses a special challenge for a service provider (see Section 1). The reporting flow is usually defined as “[...] a measure of the output of the reporting organization. It is a quantitative amount and constitutes the basis for completing the inventory of O-LCA.” [4]. As service providers often do not have any significant physical output, the reporting flow has to be defined on a different basis. The output of the reporting organization is mainly depicted as the services that are provided through the employees. Following this, the reporting flow should quantify the entire work performed. At the same time, if performance tracking is envisaged, the chosen reporting flow should serve as a normalization factor able to account for relative changes to the company’s impacts. Especially in a growing organization with quickly developing structures as the reporting organization, different changes are expected in the near future. Thus, it is not recommended to define the reporting flow following the activity portfolio of the organization (as suggested in Manzardo et al. [23]), since organizational tasks might change in the near future.

Following the recommendation of a former OLCA study [20], the turnover of the whole reference period was chosen as the reporting flow. Other options for defining the reporting flow are described in the discussion (Section 4).

2.1.4. System Boundaries

As mentioned before, setting the system boundaries poses another challenge for a service provider.

The reporting organization does not own the PV and wind energy facilities. The owner of a facility concludes a contract with the organization to transfer the monitoring and inspection tasks as well as low-voltage reparations for solar farms. Other services are outsourced to other third parties and lie within the responsibility of the owner. The reporting organization has no influence on the facility's design or construction phase as these contracts have their starting points at the start-up of the plant. In the wind business unit, some projects have their starting point earlier. However, at an early stage, the reporting organization is only involved in the financial management activities and not in the technical side of the project, thus being unable to influence the plants' environmental performance at any stage of the project.

Further, the ISO/TS 14072 standard states: "If the organization has no influence on the use stage and the end-of-life stage of its products [. . .] it can select the "cradle-to-gate" boundary where the use and end-of-life stages are excluded." [9]. Following this, the PV and wind energy facilities are excluded from the system under study. A sensitivity analysis including the facilities' production can be found in Section 3.2.

Nevertheless, there are other services in the PV business that are not provided but commissioned by the reporting organization. These third-party services are defined as relevant for the successful work of the reporting organization. Influence possibilities are also given by the explicit choice of the third party. As a result, the contractually fixed services commissioned by the reporting organization are within the system boundaries.

Additional aspects related to the electricity generation facilities are the production of spare parts and the waste generated through maintenance e.g., broken parts, cables, etc. Although within the PV business the technicians process these spare parts on site, they have no control over the purchase process and the spare parts' end of life. Therefore, this activity is not included in the system boundaries. Generated waste is excluded as the reporting organization does not own the facilities or their components.

The system boundaries are explained in detail in the next chapter for PV and wind energy business.

2.2. Life Cycle Inventory

2.2.1. Organization Modelling and Data Acquisition

To get a comprehensive overview over the organizational structure and all relevant processes and activities of the reporting organization, the two site units in the United Kingdom were visited and several interviews were conducted with employees involved in specific activities and with management to obtain an overview of the business structure. For this purpose, a company-specific questionnaire was developed.

The aim of such interviews was twofold. First, activities were selected that were relevant for the company. As a starting point, the general activities provided by the guidance were considered [4]. Through the interviews, activities could be specified and classified into relevant and not relevant/applicable for the organization and built up an understanding over the company processes and structures. An activity performed by the reporting organization was defined relevant as soon as it has an environmental impact. Particularly for a service-providing reporting organization, it is necessary to have a deep insight into the network to select the relevant activities correctly.

Second, interviews helped analyze the day-to-day business of every organizational unit in order to identify specific activities possibly not highlighted in the guidance due to the service-specific character of the organization. As a result, all direct activities of the reporting organization as well as the upstream and downstream activities of the value chain with a potential environmental impact could be identified. The selected activities are analyzed in detail in Section 2.2.

Inventory data acquisition for the reporting organization and its supply chain required intensive work because of the missing experience in product LCA or environmental management systems (EMS). At the beginning of the study, data available in the company's CSR-Report were considered.

The report was conducted following the G4-Guidelines of the global reporting initiative (GRI) to provide a standardized disclosure of the impacts on the environment, society, and economy through the reporting organization [26]. It served as data source e.g., for purchased electricity and water used in the office buildings.

In general, the OLCA method foresees the possibility of two different data collection approaches. Inventory data can be collected top-down, i.e., company-wide, e.g., through aggregated data on purchased materials, or bottom-up, i.e., by summing up the inventory data of single products or product clusters out of the company's portfolio [4]. In this case study, a hybrid data collection approach was used for the inventory as some product LCA studies, and general data for the whole reporting organization were included. The bottom-up approach was mainly applied for capital equipment, as LCA studies were used as secondary data sources (e.g., for office furniture). The top-down approach was mainly applied for data that were company-wide available as primary data (e.g., business travels). Primary data were mainly used. The GaBi database (including the integrated ecoinvent 3.3 database) was partially used as a data source for the relevant activities of the organization if no primary data were available [27].

A complete overview on the data sources for the different activities is available in Table S1 (Supplementary Materials).

After the acquisition, the data were further processed and the organization with the related activities was modeled using the software GaBi (thinkstep).

2.2.2. Activities in PV Business

The PV key business was analyzed in the beginning to identify the direct activities of the reporting organization. Beside office work, the main activity field is the technicians' maintenance work in the PV business unit. The provided services here include several on-site operations in the low-voltage field. To identify relevant aspects of the PV maintenance work, one solar farm within the area of responsibility of the organization was visited together with one of the technicians. Such trips of the technicians to site by trucks leased or owned by the organization represent a direct activity causing among others exhaust gas emissions. The other direct activity is water consumption in the office. Due to lack of data for the PV business unit (no water bill is available because part of a general building-related service charge), the same water consumption per employee as for the wind business unit was assumed, since for the latter data were available.

The indirect upstream activities include: Storage facilities for spare parts of PV facilities, which are rented by the reporting organization; the cars and the equipment of the technicians; the purchased fuel for the technician; services needed for PV sites that are not carried out by the reporting organization but provided with a quote or commissioned. As mentioned before, the responsibility lies with the owner of the PV site. However, the third-party services commissioned by the reporting organization were analyzed to generate an insight into the upstream value chain. Landscaping and solar panel cleaning were identified as relevant services because supplier closeness is given as the reporting organization commissions these third parties by order of the facility owner.

Further upstream activities are linked to the office work: Employee commuting, business travels, purchased electricity, tap water preparation, waste and wastewater treatment, and the production of capital equipment (office equipment). The employee commuting was quantified by an email questionnaire regarding the working route and the used vehicle(s) each day. As some employees did not have usual working routes because of their frequent business travels, an average week was defined and extrapolated to the whole year. Every part of the capital equipment (including cars) is used over a longer time period than the reference time period. Therefore, a calculation method (which is required by the ISO 14072) regarding the individual lifespan and, if necessary, the life phases was applied to set the environmental impacts into a reference [9]. Examples for assumed lifespans are delivered in Table 2. The complete inventory including the assumptions and the corresponding sources can be found in Table S1 (Supplementary Materials).

Table 2. Lifespan assumptions for modeled objects.

Object	Lifespan [Years]	Source
Desk	13.0	Wolters Kluwer Deutschland GmbH, n.d.
Laptop	3.5	Hoang et al., 2009
Smartphone	3.0	Apple, 2017
Office chair	13.0	Wolters Kluwer Deutschland GmbH, n.d.
Computer display	4.0	Socolof et al., 2001
Car	18.0	Statista, 2014

As mentioned before, there is no material output at the end of the value chain of the reporting organization, therefore no indirect downstream activities were considered, as recommended in the OLCA Guidance [4].

The spare parts that were used for maintenance work at the PV sites were not considered because the reporting organization neither owns the parts nor has influence on the procurement process. Activities regarding the planning, construction, and operation of the PV facilities are excluded from the study as the reporting organization does not have any influence on these either. The maintenance activities on site by the technicians as such are not considered because no environmental impact is expected besides the end of life of broken spare parts.

A detailed figure of the relevant activities of the PV business including the defined system boundaries is shown in Figure 2. According to the color legend the data availability refers to primary and secondary data. “Insufficient data” in this context means that the data collection could neither provide enough consistent data nor a basis for useful assumptions to conduct the environmental assessment. However, the collected information regarding these activities could be used as a starting point for future data collecting processes to fill the gaps.

2.2.3. Activities in Wind Energy Business

The wind energy key business was analyzed as well to identify the direct activities of the reporting organization. Trips to site were also performed here by the employees but only visual inspections were conducted. This aspect and the water consumption in the office were classified as direct activities.

The indirect upstream activities consist of partly similar aspects as in the PV business. This includes business travels, purchased fuels, employee commuting, tap water preparation, waste and wastewater, the production of capital equipment (office equipment, personal protective equipment (PPE) and cars), and in addition, purchased gas (for heating). The employee commuting was quantified in the same way as for the PV business. Furthermore, the same calculation method and lifespan assumptions for capital equipment lifespans were applied as in the PV business.

The reporting organization performs no maintenance activities in the wind business unit. As the workers only carry out visual inspections, no further environmental impacts are expected. Every other needed service for operating and maintaining the facilities is not provided by the reporting organization and not in the system boundaries.

A detailed figure of the relevant activities for the wind energy business including the defined system boundaries is shown in Figure 3.

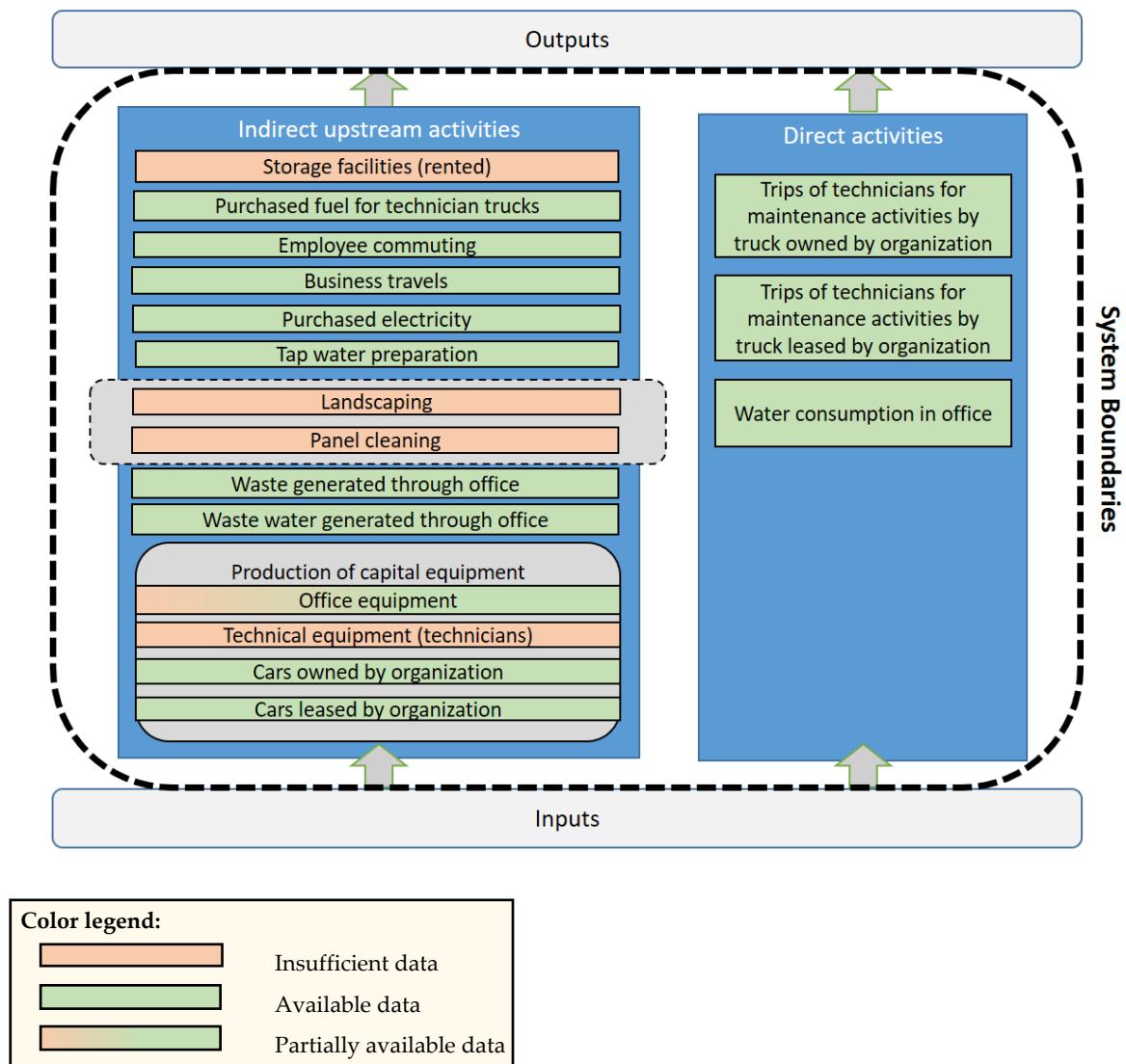


Figure 2. Activities for PV business including relevant third-party services (grey box).

The complete life cycle inventory with the detailed assumptions and the related sources can be found in Table S1 (Supplementary Materials).

Regarding the data availability and the data processing methods, there are several aspects that have to be considered to interpret the results and to set them into a reference. First of all, data could be collected for every activity that was identified as environmentally relevant. Table S1 (Supplementary Materials) provides an overview of which data could be collected for the activities and which could not, including the related assumptions. No data for a useful quantification of outputs were available for the services on site and the storages facilities for the PV business as well as for parts of the capital equipment. The waste and the water usage in the PV business is a part of a general service charge for the office rental. It was not possible to extract primary data from these. Therefore, assumptions regarding the average water consumption and the amount of waste in an office were made for both activities.

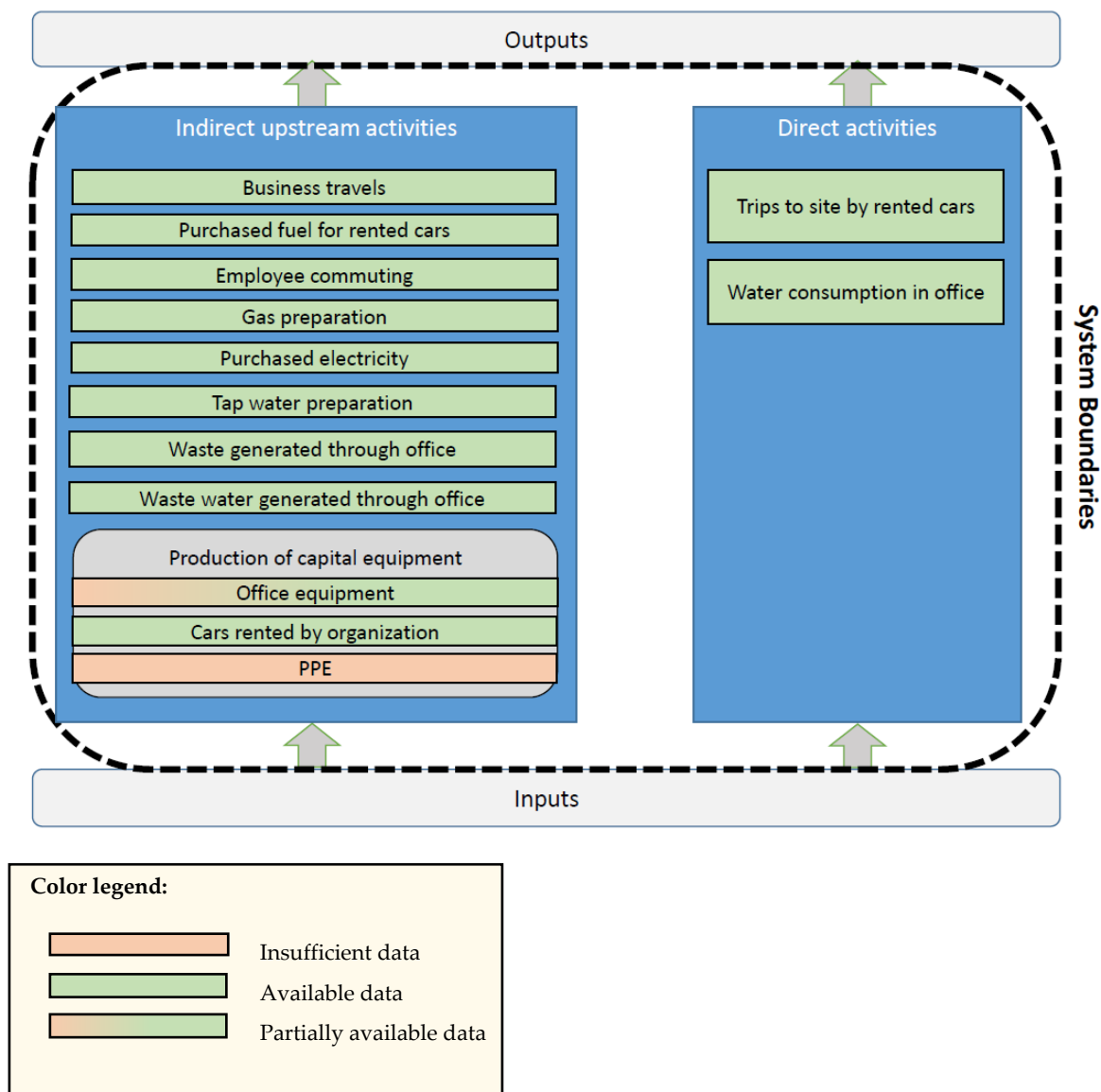


Figure 3. Activities for wind energy business.

3. Results

3.1. Life Cycle Impact Assessment and Interpretation

The software GaBi was used for the life cycle impact assessment (LCIA). The model structure was divided in the first level into the two site units, in the second level into the activity groups, and in the third level into the individual activities. This structure ensures the detailed evaluation that is needed for this study and to provide the reporting organization with site-specific data as well as general recommendations for action.

The LCIA method ReCiPe 2016 v1.1 was chosen. The ReCiPe assessment was conducted mainly through the hierarchical perspective as it is the default model of the scientific consensus [28]. Table 3 shows the used impact categories including their related unit.

Table 3. Used impact categories of life cycle impact assessment (LCIA) method ReCiPe 2016 v1.1.

Impact Category	Unit
Midpoint (H) - Climate change, incl. biogenic carbon	kg CO ₂ eq.
Midpoint (H) - Stratospheric Ozone Depletion	kg CFC-11 eq.
Midpoint (H) - Terrestrial Acidification	kg SO ₂ eq.
Midpoint (H) - Freshwater Eutrophication	kg P eq.
Midpoint (H) - Human toxicity, cancer	kg 1,4-DB eq.
Midpoint (H) - Fine Particulate Matter Formation	kg PM _{2.5} eq.
Midpoint (H) - Fossil depletion	kg oil eq.
Midpoint (H) - Ionizing Radiation	Bq C-60 eq. to air
Midpoint (H) - Land use	Annual crop eq.·y
Midpoint (H) - Terrestrial ecotoxicity	kg 1,4-DB eq.

For confidentiality reasons, only the relative contribution of every activity group and single activity is provided in this study.

The relative contribution of the activity groups of the different businesses are displayed in Figure 4.

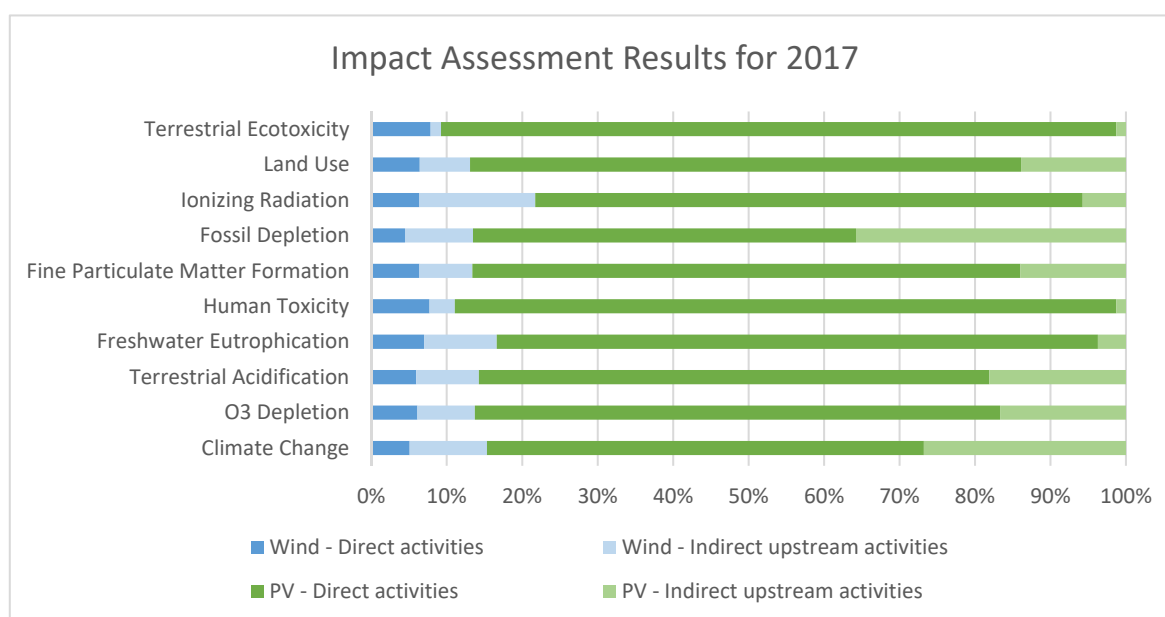


Figure 4. Impact assessment results: Relative contribution by business unit and activity category in 2017.

This business unit level was clearly dominated by the PV business, more specifically by its direct activities. It should be noted that the trips to site by technicians did have an effective impact within this activity group only (see Figure 2). In fact, technicians have their fixed operating areas around their home base but, as only 17 technicians are employed for the whole U.K., each of them has a comparatively large area of responsibility. Thus, technicians are used to driving long distances even within their own operating area. If the responsible technician is unavailable for his/her area, a colleague needs to take over, which means driving a very long distance to get to the solar farm.

This becomes evident if the results are displayed disaggregated by activity (Figure 5 for the PV business, complete impact assessment results in Tables S2–S11 in Supplementary Materials). It should be noted that the impact of the production of laptops within the production of office equipment was only available for the impact category climate change as data for other categories were not available.

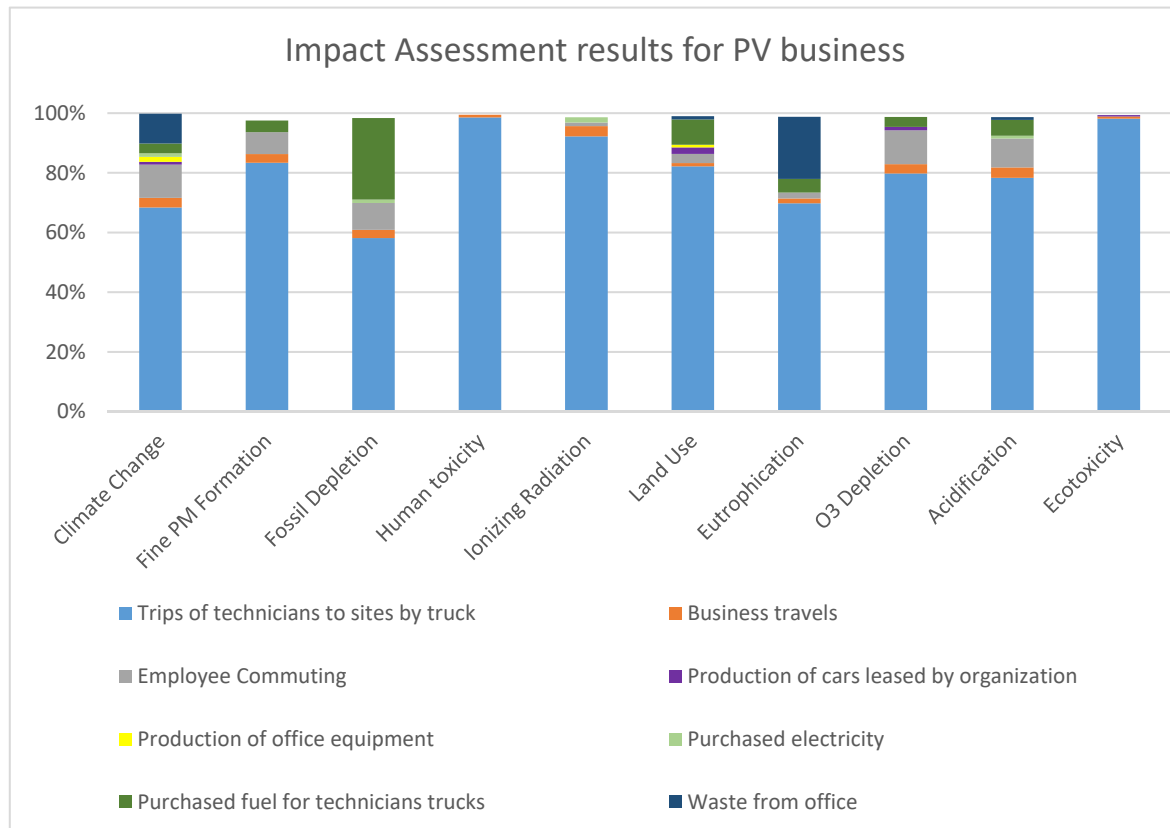


Figure 5. Impact assessment results for PV business in 2017; only activities whose contribution is larger than 1% are displayed.

As mentioned before, the dominance of the activity “trips of technicians to site by truck” in every impact category is the main result at this level. The significant tendency of human toxicity regarding the trip’s activity comes from the measurement in kilogram 1,4-DB eq. (see Table 3), which are increased during the combustion of Diesel. The impact category ecotoxicity behaved analogously through same related unit. The relatively high impact of employee commuting within the indirect activities of PV business can be explained by the isolated location of the office in the U.K., as there is no possibility of getting to the office by public transport. Commuting by foot or bike is not a viable option since no employee lives nearby. In addition, there are some commuters with long distances (more than 120 km) every day.

The impact assessment results of the wind energy business for every activity are shown in Figure 6.

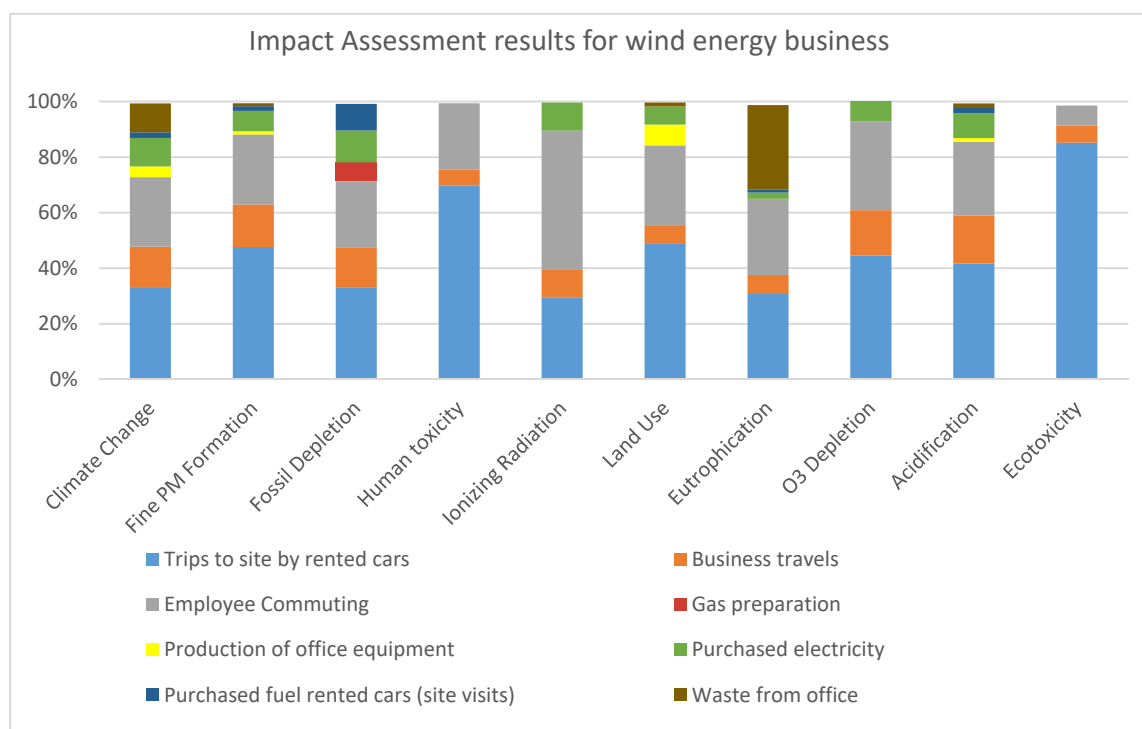


Figure 6. Impact assessment results for wind energy business in 2017; only activities whose contribution is larger than 1% are displayed.

The trips to site by rented cars also had a high impact in every category, but as the employees do not provide maintenance services as in the PV business, the frequency of the trips as well as the total distances and their impacts were lower than in the PV business. The impact categories human toxicity and ecotoxicity were mostly determined through the trips to site activity following the same argumentation as above.

The relatively high impact by employee commuting can be explained through the commuting behavior. As mentioned before, there are some cases in which the employees have to drive long distances to the sites every day. Together with the business travels, the transport activities in general had a significant impact in every impact category.

Furthermore, an analysis was performed with the different ReCiPe perspectives egalitarian (long-term perspective and all impact pathways) and individualist (short-term perspective and only undisputed pathways) [28]. These results for the other perspectives can be found in Table S12–S17 in Supplementary Materials. Although a percentage shift takes place, the dominating hotspot (trips of technicians to site) represents more than 50% of the total contribution to every impact category in every scenario.

In summary, the hotspots of the whole environmental performance of the reporting organization in 2017 were posed by the trips to site and the transport-related activities, which includes business travels and employee commuting in PV as well as in the wind energy business.

Given the relevance of transport activities, transport-related inventory data were analyzed in depth. A specific data divergence was found within the direct PV activity “trips of technicians by truck”. The used GaBi data record “transport, passenger car, large size, diesel, EURO 5” includes CO₂ emissions of 0.357 kg per km. As a comparison, average CO₂ emission factors were calculated (see Table S1, Supplementary Materials) for every type of car used in the PV business. The resulting value was 0.18642 kg CO₂ per km. Though the difference might be due to the divergence between catalogue values and real-life conditions, a sensitivity analysis was performed. With the GaBi data record of 0.357 kg CO₂ emission per km, the trips of the technicians resulted in almost 69% of the total contribution for impact category climate change of PV business whereas the model with the calculated

CO₂ emission value of 0.18642 kg per km resulted in 41% of total contribution. The detailed results are displayed in Table S19 in Supplementary Materials.

Activities whose contribution was below 1% in all impact categories were tap water preparation (PV and wind) and production of cars owned by the organization (PV). These activities are not further considered in the following section.

3.2. Beyond the System Boundaries

So far, the PV and wind facilities are excluded from the system boundary because of the missing influence by the reporting organization. However, when it comes to a service provider, options to include the service receiving objects in the analysis can be analyzed individually. The rationale behind this is that the activities of the reporting organization linked to objects outside of the system boundaries would not be performed if the object as such (and the associated environmental impacts) did not exist. In other words, although the reporting organization has no influence on the environmental performance of the facilities, the latter might be included because their existence represents the condition under which the reporting organization's activities take place. An exemplary analysis within this OLCA case study was carried out by including PV and wind energy facilities for the impact category climate change. It was assumed that a wind plant produces 0.0072 kg CO₂ eq. [29] and a PV system 0.053 kg CO₂ eq. per kWh [30] through their whole life cycle without considering their own energy production. With average full load hours of 1,760 [31] and 928 [32] per year, the emissions of kg CO₂ eq. were calculated and added to the OLCA impact assessment results for the impact category climate change. The results are shown in Figure 7. It can be seen that the facilities dominated the overall climate change impacts.

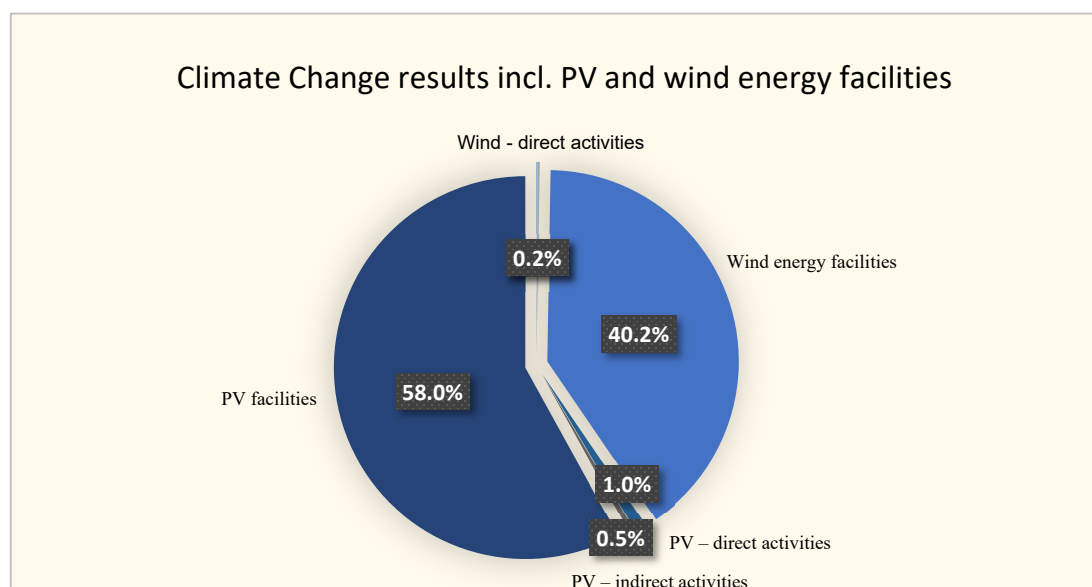


Figure 7. Cumulative contribution of the reporting organization to climate change [kg CO₂ eq.] including wind and PV facilities (ReCiPe hierarchical perspective).

This brief exercise raises the question whether and to what extent facility life cycle impacts should be included in the service provider's system boundary. As the focus of the OLCA study lies in the environmental analysis of the reporting organization, it seems advisable to allocate only a limited share of the facilities' environmental impacts to the service provider or include them in a sensitivity analysis as demonstrated in this paper.

The detailed results of the assessment including the PV and wind energy facilities are shown in Table S12 in Supplementary Materials.

4. Discussion

The identified challenges for carrying out an OLCA study for a service provider as well as general OLCA challenges are addressed in the following and some solution options are presented.

First, setting the system boundary is a general challenge for carrying out an OLCA study but requires particular attention if the reporting organization is a service provider. In the case study presented in this paper, especially the service receiving objects PV and wind energy facilities and the linked third-party services, were identified as critical aspects. The decision to include third-party services in the system boundaries and exclude the service receiving objects is based on the consideration that, while the former can be influenced by the reporting organization (which chooses them), the latter (and their environmental performance) do not depend on the reporting organization. However, it should be acknowledged that this issue might be also considered differently. Following the argument that the PV and wind facilities build the basis of the whole work of the reporting organization (as there would be no services without these facilities), their inclusion in the system boundaries might be justified. The consequences of this choice for the results is exemplarily shown in Section 3.2. The fact that impact assessment results might, like in this case, be dominated by the service receiving entity suggests that the latter's impacts should be, if included, only partly allocated to the service provider. A viable option might be allocating the burden according to the facility-related revenues of the companies involved. Further, it may be taken into account that the facilities are generating electricity during their use phase if the whole life cycles of the PV and wind facilities are considered within the system boundaries. In both studies that are used for the amount of CO₂ eq. [29,30], the produced electricity lies outside of the system boundaries so that no emission savings were offset through their life cycle.

The other way around, it has to be considered which activities related to service receiving objects can be included if these objects are not within the system boundaries. In general, the facility-related services such as landscaping and panel cleaning may have to be excluded from the system boundaries because they are directly related to the facility. However, in this specific case study, the third-party companies that provide these services are commissioned by the reporting organization according to a specific contract with the service receiving organization. Therefore, the reporting organization does have an influence on such activities, which consists in the choice of the third party. As data for panel cleaning and landscaping were not available, the contribution of these activities to the total environmental impacts of the reporting organization could not be analyzed.

The second specific challenge for a service provider regards the reporting flow and results from the missing physical output of the reporting organization. Usually, the reporting flow is defined by the product output within the reference time period [15]. For organizations, whose portfolio is not represented by material products, it is recommended to use economic values or the number of employees to measure the volume of the organization [20]. The reporting flow in this study was defined through the total turnover within the reference time period. As mentioned before, this is an aspect that approximately reflects the non-physical output of the organization through the work of the employees. This follows the rationale that achieving a higher turnover implies a higher amount of work through the employees, which in turn results in higher environmental impacts through more technicians' trips and more office employees (with the related commuting, business trips, office equipment, and water and electricity consumption). Especially for the organization's performance tracking, it is important to set these environmental impacts in relation to turnover (as a proxy for employees' activities). The value obtained serves as a basis for performance tracking if the assessment is repeated for later reference periods. Possible alternative measures for the reporting flow are the amount and sizes of the projects or the working hours of the employees. As no exact capturing tool for working hours was implemented in 2017, this reference flow was not suitable for this OLCA study. Using the number of projects or the total project capacity as reporting flow would have been possible, but it carries the risk of a wrong assignment. At a first glance, the argumentation of the correlation might appear the same as before (more or larger projects equals higher workload equals higher impacts). Nevertheless, especially in the wind energy business, the size of a project (e.g., in Mega Watt) is not a good indicator for the workload

on the side of the reporting organization as they are not responsible for technical maintenance or other services that are strongly related to the facility size.

Also, by using the total turnover as reporting flow, a wrong assignment could be a risk if the reporting organization receives financial benefits besides the payment for service providing (e.g., capital contribution by shareholders). In this case, the assumption that increasing turnover means increasing working activities and thus higher environmental impacts would not necessarily hold, thus endangering a meaningful comparability across time, which is the basis for performance tracking.

Given the drawbacks mentioned so far, alternative reporting flow definitions are suggested.

First, it can be helpful to define a kind of a complex unit as reporting flow. An example for this could be the total turnover [monetary currency] multiplied by headcounts [number]. This limits the mentioned wrong assignment of an increasing turnover by financial benefits besides the payment for service providing to a higher workload of the reporting organization as the headcounts would not rise in the same way. This complex unit provides an indicator through which a one-sided increase that does not necessarily correlate with the environmental impacts can be discovered.

Second, a definition of multiple reporting flows according to the activity group could be useful. Usually, a reporting flow is defined through the quantity of products produced or sold [15]. This is a good value to quantify the indirect downstream activities in general but is not necessarily an appropriate proxy for other activities' environmental performance. The idea is that direct, indirect upstream, and indirect downstream activities get individual reporting flows, which quantify their outputs separately. This would provide a more specific quantification for the different activity groups as one reporting flow for the whole OLCA study. In this case study, the only direct activity that influenced several environmental impact categories is the trips of technicians to site. This can be quantified by distances driven by the technicians. The indirect upstream activities are mostly related to employees' activities and can be quantified by headcounts. As there are no relevant indirect downstream activities, this aspect is not applicable here. As mentioned before, a useful reporting flow for indirect downstream activities could be the amount of sold products or a quantification of services, if applicable. A single-score indicator for the whole company can be created by combining the different reporting flows into one complex unit again. Figure 8 gives an overview over the delineated reporting flow structure.

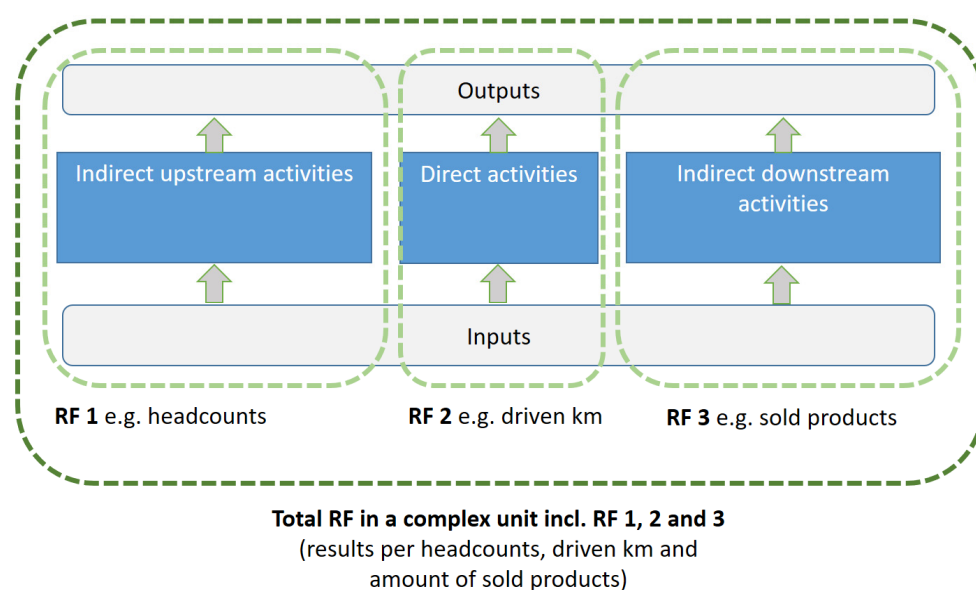


Figure 8. Definition example of multiple reporting flows including one total reference flow (RF) in a complex unit.

Processing the activity groups separately with different reporting flows can have several advantages. First, it can be easier to define the reporting flows as the separate activity groups

could be represented specifically through different aspects. This can be relevant as the definition of the reporting flow poses a general challenge by carrying out an OLCA study [15]. Second, the environmental performance tracking could be provided more in detail as the data from different reference time periods could be compared at an activity group level with a specific quantification. This provides in-depth information on which part of the supply chain witnesses a change in their environmental performance regarding with reference to their own reporting flow. As a result, the organization–internal variables relationship could be revealed.

As known from past studies [22], one challenge for every organization is that no OLCA-specific software is available. This challenge was tackled by the road-testing organizations by using product LCA specific software products such as GaBi or SimaPro, or Excel-based models [15]. To carry out the life cycle impact assessment in this study, the software GaBi was used. As this is technically a software to carry out product LCA, the system modelling procedures were adapted to carry out an OLCA. For product LCA, it is useful and necessary to model the processes as intertwined as possible to give an overview over the whole life cycle. For OLCA, it is necessary to give the data an identifier that allows assigning each elementary flow to the related activity, in order to evaluate the impact assessment results with the corresponding disaggregation level. This was applied to the model structure in this study, which includes three layers (the two business fields, the different activity groups, and the activities). The GaBi model structure was chosen to break down the environmental impacts on a business unit level, which was interesting for the reporting organization, and to provide a specific hotspot analysis on an activity level. Many datasets from the GaBi database include direct as well as indirect activities in just one data record. For example, driving a car includes the output of exhaust gases, which here is a direct activity, as well as the outputs generated by the car production, which here is an indirect upstream activity. Therefore, not every data record from the database could be used and some data records had to be modified and divided into two different data records to assign each output to the related activity.

Finally, the lack of general and specific inventory data emerged in this case study. Product LCA case studies for some typical office equipment, technical equipment, and personal protective equipment are currently not available and could be relevant also for future (OLCA) case studies, since there are many equipment overlaps e.g., in office-dominated organizations. Additionally, for the reporting organization, no data were available for the services on site for the PV business and the third parties of the managed facilities. Moreover, as the waste treatment and water consumption were part of a general service charge in the PV business office, no data were available, and several assumptions were made here. The amount of total waste may be too high as it was assumed that the waste containers were full at any time when it was collected. As no assumptions on the treatment could be made, a general collecting and waste treatment data record for household waste was used in GaBi. To improve the accuracy of the waste treatment data, an analysis should be done regarding the exact treatment of the different waste types within the local processes. Furthermore, the landlord should be contacted for water consumption data.

There are some aspects that have to be considered for future versions of an OLCA study and for tracking the environmental performance of the reporting organization. According to ISO 14072, the time period over which the capital equipment is used was taken into account through the calculation of the LCI [9]. The assumptions should be used again through future OLCA studies to ensure consistent performance tracking. Also, several changes within the key data for 2018 need to be considered. As the organization is witnessing an increase in customers and orders, the size has been enlarged. This results in higher headcounts and an additional office in the wind business unit. Also, the amount of the capital equipment like vehicles and office equipment has increased and several items are completely new. Further, the activities for PV sites have changed as third parties were commissioned in addition for thermography maintenance by drones. Furthermore, the capital equipment should be assessed with the same data basis or even improved by integrating more product LCAs.

5. Conclusions and Outlook

The OLCA study of a service provider for renewable energy projects (PV and wind) was carried out for the two related locations in the United Kingdom. Through the impact assessment, the hotspots trips of technicians by truck, and the employee commuting within the PV business unit as well as the trips to site, the employee commuting and the business travels for the wind business unit were identified.

Organizational, technical, and personnel measures are possible to reduce the environmental impact through the trips to PV or wind sites. As an organizational measure, it could be useful to optimize the transport, e.g., to revise the areas of responsibility of the technicians and thereby reduce the radiuses of the operation areas and the distances the technicians have to drive. A second organizational measure could be to engage more technicians to improve the geographical covering, but this is also a financial decision that has to be evaluated. If it is not possible to reduce the impact of the trips through this, the organizational process of the coordination of the technicians could be improved by a software solution that allows a better overview over the individual location of the technicians and the sites. The technical measures are related to the vehicles as such, e.g., buy/lease vehicles with better environmental performance. Especially the trucks leased by the organization could be exchanged during the existent six-month leasing cycles. Even personnel measures like informing the technicians about their environmental impact and instructions to reduce the emissions while driving could have a high effect.

Also, for reducing the environmental impacts through employee commuting and business travels, informing and instructing the workers could help to raise awareness. Further, carpooling or car sharing could take place, and more meetings could be planned and executed online via software solutions. Working in home office is already implemented and could be extended especially for the commuters with long distances.

The prioritized goals of Table 1 were reviewed by the management at the end of the study to verify the benefits of OLCA. The feedback can be found in Table 4 with a rating of goal achievement. The frame of the rating is 1–10 whereby 1 means expectations are not fulfilled and 10 means completely fulfilled. It should be noted that the hotspots of this OLCA study regarding the transport activities were already targeted as improvable before from a financial perspective within the reporting organization. Therefore, the goals of getting support for strategic decisions as well as the improvement of the organizational procedures were rated comparatively low. Tracking the environmental performance of the organization is also rated comparatively low. This could be a result of the missing internal knowledge to carry out a future OLCA study by themselves. Therefore, the demand for support for a next OLCA study is still existent.

Table 4. Feedback of goal achievement.

Category	Goal	Level of Achievement
Analytical goals	Gain insight in internal operations and value chain	9
	Identify environmental hotspots	8
	Understand risks and impact reduction opportunities	7
	Track environmental performance	5
Managerial goals	Get support for strategic decisions	5
	Improve organizational procedures	6
	Get the basis for environmental communication with stakeholders and reporting	7
	Reduce operational costs	8
Societal goals	Show environmental awareness with marketing people	7
	Reduce pressure on the environment	4
	Enhance environmental tools within stakeholders	8

From a methodological perspective, an OLCA study according to ISO 14072 and the Guidance on OLCA poses several challenges for a service provider from a methodological point of view. Defining a single reporting flow for service providing organizations bares the risk of distorting the results if performance tracking over time is envisaged. The multiple reporting flow approach proposed in this paper tackles this challenge by increasing the transparency of representative parameters for different activity groups and provides the possibility for the organization to subdivide their activities and assign them an appropriate parameter.

Especially the process of setting system boundaries for service provider should be conducted carefully, as the reporting organization might have an impact on the service receiving objects. Therefore, the influence of the reporting organization on the environmental performance of these objects should be analyzed.

A more general challenge is posed by the lack of an OLCA-specific software solution. Although a workaround is possible, for example by using the Gabi database, an OLCA-specific tool would simplify the conduct of OLCA studies. The WELLE tool for the calculation of an organizational water footprint shows first efforts in this direction [33].

Last, OLCA's scope, though wide, is limited. It only includes the environmental impacts of the organization under study, thus leaving the social and economic aspects of sustainability unconsidered. These are accounted for in other emerging methods that can complement OLCA's results. First, the SOLCA (social organizational life cycle assessment) framework builds on the OLCA scoping phase and allows adding a social inventory and detecting social hotspots along the organization's supply chain. Second, financial aspects can be accounted for, e.g., by applying sector-specific tools. A valid example for the renewables sector is offered by the RETScreen clean energy management software [34], that offers numerical analysis among others on energy generation and efficiency, prices, and financial variability for renewable-energy and energy-efficient technologies, based on satellite parameters. Complementing OLCA results by findings provided by additional tools like SOLCA and RETScreen can contribute to holistically address the triple bottom line of sustainability.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2071-1050/12/11/4475/s1>, Table S1: Complete life cycle inventory for the PV and the wind energy business, categorized by activity group and activity. Assumptions and data sources are made transparent to ensure replicability, Table S2: Life cycle impact assessment: Cumulative contribution to the impact category Global Warming Potential (GWP), Table S3: Life cycle impact assessment: Cumulative contribution to the impact category Stratospheric Ozone Depletion, Table S4: Life cycle impact assessment: Cumulative contribution to the impact category Terrestrial Acidification, Table S5: Life cycle impact assessment: Cumulative contribution to the impact category Freshwater Eutrophication, Table S6: Life cycle impact assessment: Cumulative contribution to the impact category Human Toxicity, cancer, Table S7: Life cycle impact assessment: Cumulative contribution to the impact category Fine Particulate Matter Formation, Table S8: Life cycle impact assessment: Cumulative contribution to the impact category Fossil depletion, Table S9: Life cycle impact assessment: Cumulative contribution to the impact category Ionizing Radiation, Table S10: Life cycle impact assessment: Cumulative contribution to the impact category Land use, Table S11: Life cycle impact assessment: Cumulative contribution to the impact category Terrestrial ecotoxicity, Table S12: LCIA Climate change, incl biogenic carbon, egalitarian perspective, Table S13: LCIA Climate change, incl biogenic carbon, individualist perspective, Table S14: LCIA Stratospheric Ozone Depletion, egalitarian perspective, Table S15: LCIA Stratospheric Ozone Depletion, individualist perspective, Table S16: Terrestrial Acidification, egalitarian perspective, Table S17: LCIA Terrestrial Acidification, individualist perspective, Table S18: Climate change, incl. biogenic carbon, incl. facilities, Table S19: LCIA Climate change, incl. biogenic carbon, with calculated CO₂ emission of trucks.

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