



# Hierarchization of social impact subcategories: towards a systematic approach for enhanced stakeholders' representativeness

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## Abstract

**Purpose** Social life cycle assessment (S-LCA) aims to assess the potential social impacts related to stakeholders over the life cycle of a product or service. For legitimacy and meaningful results, direct consultation of stakeholders ranks among the most recommended approaches. This paper aims to provide the methodological basis for S-LCA to target potential impacts and to support decision-making using this kind of participatory approaches. In particular, the work aims to address some of the limitations of the systematization of stakeholders' consultation. An approach to facilitate and speed up the access to stakeholders and the construction of respondent panels is proposed. Then, representativeness of the collected answers is verified using a statistical data treatment. The method is applied to hierarchize social impact subcategories in the offshore wind energy sector, a huge up-coming sector in France. This emerging sector raises a number of socio-economic issues that can be related to the development of a new industrial sector and its coexistence with local communities.

**Methodology** Based on the participatory approach principle, the hierarchization of social impact subcategories is carried out by stakeholders. The developed methodology includes 5 steps. In step 1, the social impact subcategories from the UNEP in Guidelines for Social Life Cycle Assessment of Products and Organizations 2020 (2020) list are adapted to the sectoral context. In step 2, the hierarchization criteria are defined. Instead of using a ranking based on an importance criterion, hierarchization is based on two quantitative criteria to target impact subcategories that are both important and perceived as potentially problematic. In step 3, the stakeholders and a sampling approach are defined. Then, in step 4, an online survey consultation methodology is used and improved for the selection of qualitative variables. Finally, in step 5, the methodology specifies the data treatment protocol. The data treatment protocol in this fifth step aims at addressing the issue of the representativeness and relevance of the responses obtained from surveys. Indeed, hierarchization approaches based on consultations typically consider responses at the aggregated level of the stakeholder category. However, it is likely that different stakeholder profiles of respondents within a large heterogeneous stakeholder category influence the perception of social impact subcategories. To verify this point, it is necessary to look at a disaggregated scale of stakeholder sub-groups. This potential bias led to the need to adjust the survey responses.

**Results and discussion** Large-scale sampling allowed us to collect 82 responses from value chain actors and 50 responses from local community with a respective response rate of 13% and 16%. Firstly, hierarchization of social impact subcategories was possible at the level of the whole aggregated stakeholder category. Then the disaggregated level was considered. To do so, qualitative data in the surveys allowed different profiles within a stakeholder group of the panel to be identified. Then, chi-squared tests on a representative variable were conducted and an adjustment of the responses and, therefore, on the resulting hierarchical order of social impact subcategories was applied. The study of the disaggregated responses led to the identification of a significant dispersion of the responses and the influence of certain variables of the respondents on their perception of social impacts.

**Conclusions** Participatory approaches were found to be useful to legitimate the selection of impact subcategories when applying S-LCA. However, considering aggregated hierarchization results at the whole stakeholder category level may mask some polarized opinions within the same stakeholder category. An adjusted hierarchization can serve to enhance the representativeness of the consulted stakeholders' perceptions. It would be good practice for the practitioner to highlight the

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limitations and possible biases. For this, one recommendation is to provide transparency on the dispersion of responses and disaggregated information on the stakeholder panels involved. With the proposed method, it was possible to both adjust the hierarchization results and express the residual uncertainty for the sake of transparency. The proposed method is designed to be transferable to any sector where stakeholders are assembled in sectoral clusters. We were able to access many stakeholders with different profiles. This broad sampling supports a holistic view of the social impact subcategories. The hierarchization results allow the practitioner to target a priority order to address the impacts subcategories for next S-LCA steps and to specify the chosen scope of the study.

**Keywords** S-LCA · Renewable energy · Social impact subcategories · Stakeholders' perspective · Representativeness · Participatory approach

## 1 Introduction

In the context of the energy transition, the installed capacity of offshore wind power is projected to increase significantly over the next decades, reaching up to 2000 GW by 2050 (IRENA 2021). Despite the widely accepted need to transition to renewable energies such as wind power having, in principle low environmental impacts, the installation of these new plants may also involve socio-political and economic consequences, both at local and global level, that should be accounted for (Jollivet 2013). Because private and public decision-makers must anticipate the impacts and changes these technologies will generate, a current challenge resides in defining impacts in a synthetic and measurable format. Such a framework should lead to a more objective consideration of social impacts. It is particularly necessary to address this challenge in the case of emerging technologies for which there is still a lack of experience of the potential social impacts. In the context of offshore wind power, which is still at early stages of development in some countries, social life cycle assessment (S-LCA) can be seen as a tool to gather information to help negotiate with the different stakeholders. Thus, S-LCA can, for example, contribute to the overall reflection, facilitate monitoring of impacts, and adjust practices of industrial developers.

Despite the relevance of S-LCA, its application requires numerous social impact subcategories for diverse stakeholders to be evaluated. From a S-LCA practitioners' perspective, a broad scope suggests substantial deployment of time and resources. It is necessary to define the system's limits, as a complete assessment would take an infinite amount of time (Grießhammer et al. 2006). It implies the identification of relevant social impacts subcategories that ensure both the holistic nature of LCA and stakeholders' perspectives, while maintaining a reasonable number of indicators to be evaluated (Yu and Halog 2015).

A challenge lies in ensuring that the definition of the goal and scope reflects stakeholders' values, makes sense, and leads to legitimate outcomes (Mathe 2014; Sureau et al. 2018). Generally, studies rely exclusively on literature

reviews to identify the impact subcategories to be addressed. To the best of our knowledge, hierarchization of the social impact subcategories is often briefly justified in current S-LCA studies.

To cover the scope of social impact subcategories in a more holistic way, bottom-up approaches can be relevant if not necessary. Participatory approaches have been explored to increase the legitimacy of social impact subcategory prioritization by addressing stakeholders directly (Feschet 2014; Mathe 2014) (Bouillass, et al. 2021). The relevance of stakeholders' roles in the frame of a social impact assessment has been emphasized since the first feedback from S-LCA studies (Benoît-Norris et al. 2011). Indeed, to ensure quality, social impact subcategory selection should be subject to consensus among all stakeholders (Garrabé et al. 2014). For example, Mathe (2014) notes that a participatory approach can be used to make the UNEP social impact subcategories list more meaningful and rank these subcategories according to a stakeholder perspective. It is also expected that stakeholders can provide local knowledge about the system. Therefore, including them in S-LCA may allow the diversity of social representations of a given territory to be considered (Jouini et al. 2019).

The listing of social concerns arising from participatory approaches can result, however, in a very broad scope. Furthermore, the resulting scope does not indicate where further impact assessment should focus. Such a scope potentially includes a long list of social impact subcategories. Among these categories, it is likely that not all are of equal relevance, or of equal priority, in terms of improving social performance. From a stakeholder perspective, some social impact subcategories may be urgent to consider, others may be important but not particularly problematic and some may be of little significance or may concern only a minority of stakeholders. This constitutes a limitation of direct ranking of impact categories. To overcome it, alternative approaches have been proposed in the literature, such as the gap analysis developed by Manik et al. (2013). The gap analysis consists in measuring the difference of stakeholders' perspectives regarding a level of "expectation" and a

level of “perception.” The “expectation” refers to the level of interest the respondent has with respect to an impact subcategory (i.e., is the subcategory important or not?), whereas the “perception” refers to the level of satisfaction of the current situation of the sector that the respondent perceives (i.e., is the subcategory currently well dealt with by authorities/companies or is the current situation problematic? that is, is the risks currently high or low?). In this case, the ranking is obtained by calculating a gap score as the difference between the scores of the two criteria. This approach is proposed in the current paper and is further presented in Sect. 2.2.

To conduct participatory approaches, several tools can be used, such as focus groups or surveys. To cover a large scope and to address representativeness through many participants, this paper focuses on a survey-based method. To apply these tools in S-LCA, systematizing access to the stakeholders themselves and measuring the level of representativeness of the respondents by considering the diversity of stakeholder profiles still need to be improved.

In this paper, a scientific approach has been proposed to systematize social impact subcategory hierarchization, taking into account the different bottlenecks identified, both for the hierarchization method itself and for the treatment of survey responses. For this purpose, the approach developed in this article uses Manik et al. (2013) criteria-based hierarchization and combines it with a new statistical protocol to measure the representativeness of the responses obtained. This approach has been tested on the value chain and on local community stakeholder categories within the French offshore wind sector. With a dozen commercial offshore wind farms (OWF) under development, France is strongly implicated in this industrial development.

The method presented is transferable to different sectors and applicable to different stakeholder categories. The method presents solutions to save time of S-LCA practitioners when applying participatory approaches, but also to enhance the legitimacy and representativeness of the hierarchization results. In particular, a methodology is proposed to build panels of stakeholders targeted as potential respondents of surveys and to verify the relevance of the responses.

The outputs of the application lead to define the scope in the initial phase of an S-LCA study by identifying the most relevant impact subcategories from stakeholders’ perspectives.

## 2 Method

The method illustrated in Fig. 1 is based on five main steps. It starts with (1) a literature review that leads to the identification of a list of social impacts and (2) the selection of a scoring method adapted to the objective of the study. Then (3) the stakeholder panel is established, and (4) the survey is designed. The method ends with the processing of the survey data (5).

### 2.1 Identification of social impact subcategories

The identification process consists of listing all the social impact subcategories that will be subject to the scoring step. Following the framework proposed by Bouillass et al. (2021), this identification began with the UNEP impact subcategories long list (UNEP 2020). First, a screening of the impact subcategories was applied to identify the ones relevant for the assessed system (e.g., OWFs) and remove non-relevant ones. Secondly, a contextualization was considered, which involved adding some social impact subcategories specific to the sector that were not present in the initial list from UNEP. This step refers to the so-called sectoral risk analysis (Bouillass et al. 2021). Scientific articles, as well as grey literature (e.g., reports of public meeting with stakeholders or interview, public reports from NGO), were used. To avoid omitting potential social impact subcategories as much as possible, the sectoral risk analysis review may be extended to substitute of the system assessed. This extended review is particularly relevant for systems that are at an early stage of development, or not yet implemented, for which the potential social impacts are generally unlikely to be fully documented. In practice, the literature review was carried out iteratively, using different key words in English and French. It began quite broadly, using for example

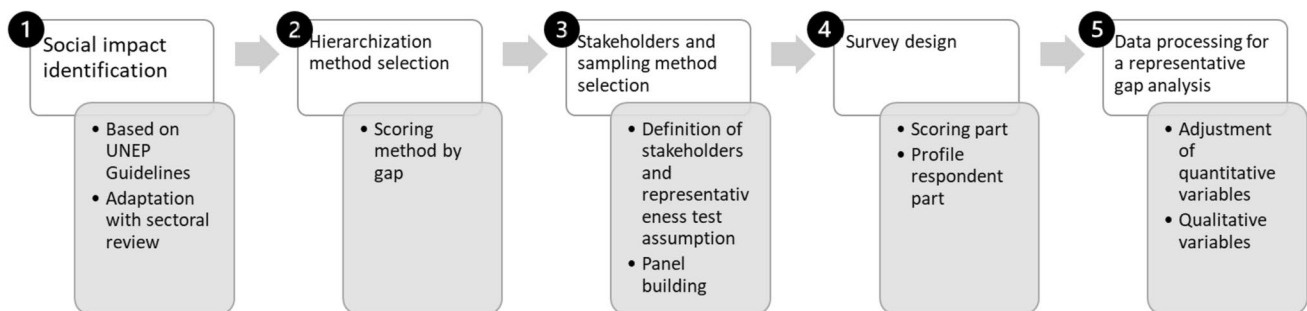


Fig. 1 Steps in the construction of the survey intended for social impact subcategories’ hierarchization by stakeholder consultation

the keywords “offshore wind” or “energy” associated with “social impacts” or “social sustainability” in academic search engines. As the different topics were identified, the keywords were targeted to consider in greater depth the different types of impacts identified, such as “offshore wind” associated with “dialogue,” “fishing” or “landscape.” To complement the information including grey literature related to current projects, documents in French were sometimes used. On this basis, different social aspects were identified and grouped together to propose social impact subcategories adapted to the sector. These social aspects were later used in the surveys submitted to the respondents representing the stakeholders’ perception for hierarchization (see Sect. 2.4). Regarding this stakeholder consultation, it should be noted that the terms may need to be checked and reword to ensure the understandability, for the respondents, of the social aspects represented by the impact subcategories (Mathe 2014). Social impact subcategories should be carefully defined and clearly named to avoid overlaps between them. Section 3.1 presents the selection of the social impact subcategories to be scored.

## 2.2 Hierarchization method selection

Hierarchization consists in ordering the different social impact subcategories identified. Beforehand, it is necessary to identify how these impact subcategories can be ranked. Hierarchization can be performed by the respondent by directly assigning a ranking. In this case, each impact subcategory is thus ranked relatively to the others. However, this approach has limitations, including the fact that it does not allow the same rank to be assigned to different impact subcategories. Thus, while it may seem relatively easy for the respondent to identify which impact subcategory should be in the first or the last position of the whole ranking, it may be more complex to differentiate between intermediate positions. Moreover, respondents are not able to assign a different order of magnitude between ranks when it is, in fact, possible that the impact subcategory or subcategories ranked in the first positions are significantly more relevant to the stakeholder than those ranked afterwards.

Conversely, a scoring approach based on several criteria may result in identifying impact subcategories of almost equal relevance, which may be very high, or very low for all of them. Hierarchization is then carried out in a second step during data processing of the survey results on the basis of the attributed scores. The scores are the quantitative responses related to the criteria that aim to characterize the different impact subcategories. The choice of the criteria strongly influences the results of hierarchization. Depending on whether the goal consists in revealing the most important impact subcategories, or those for

which there is a potential hotspot and more opportunities to improve the social performance, the criteria to be used are different.

Considering an emerging sector such as offshore wind power in France, the choice in this study was to focus on the potential hotspots, that is, the impact subcategories for which particular attention must be paid for improvement and monitoring purposes. Based on the method proposed in the S-LCA study by Manik et al. (2013), the scoring approach applied in this work consisted in measuring the difference between a level of expectation and a level of perception of the stakeholders about the impact subcategories. For this, each impact subcategory identified from the UNEP Guidelines list (UNEP 2020) or the sectoral analysis was scored from 1 to 5 according to two criteria, namely the “Expectation” criterion and the “Perception” criterion.

“Expectation” referred to the extent to which a good performance was desirable or important with respect to an impact subcategory, that is, the level of interest a respondent had with respect to a given subcategory. “Perception” reflected what the current level of performance was according to the respondent’s point of view, that is, what their level of satisfaction was.

Then, as presented in Eq. (1), the difference between these two scores resulted in a gap for each impact subcategory. The greater the gap, the greater the difference between what the stakeholder ideally expected and what they currently observed.

$$\text{Gap score} = [\text{Perception score}] - [\text{Expectation score}] \quad (1)$$

According to this calculation, four situations are possible when determining the level of relevance of the different impact subcategories. For example, a high expectation score combined with a low perception score means that the respondent attributes a strong level of interest on the impact subcategory, and the current situation of the system being evaluated does not currently meet their expectations. In this case, the impact subcategory can therefore be considered as having a priority and needing an urgent improvement. Conversely, a high expectation score with a high perception score means that the respondent attributes a high level of interest to the impact subcategory, but there is no dissatisfaction. In other words, the impact subcategory is important, but there does not seem to be any urgency to improve the performance. If both scores are equally high or low, the gap between them will be low, meaning that either the subcategory does not generate a high interest to the respondent so the low level of satisfaction with the current performance is not problematic, or that the respondent considers the subcategory of interest but is satisfied with the current performance of the sector.

### 2.3 Stakeholders and sampling method definition

The purpose of this section is to present the methodological elements for determining whether the respondents to a survey, who constituted the “sample,” were representative of the considered stakeholder category. This involved determining whether the sample accurately represented all potential respondents, or the “population” in the statistical sense. This population is the set of individuals who share certain common characteristics and who can potentially respond to a survey. Many studies use surveys, for example, to measure the externalities of an infrastructure project. In such context, it may be a matter of collecting responses from certain residents or tourists and determining whether or not the response can be generalized to a larger group. Thus, the sample-to-population comparison is a common practice in socio-economic sciences (Ladenburg and Dubgaard 2007; Ladenburg 2009; Westerberg et al. 2013; Ladenburg et al. 2013). Based on this observation, this paper uses the notion of statistical population to define the category of stakeholder and thus conduct a sample-to-population comparison to ensure the representativeness of the hierarchization in S-LCA.

For the application of the comparison, at least one relevant descriptive variable had to be identified. Based on this variable, the sample of respondents was then compared with the previously defined statistical population. This paper’s proposal applied to hierarchization in S-LCA is to use the “stakeholder profile” variable as a calibration variable. For example, in the value chain actors stakeholder category, a calibration variable could correspond to the main type of activity among companies of the value chain, such as the supply of components, civil work, and R&D. For local communities, the descriptive variable could be related to the main professions outside of the value chain but present in the area such as farmers, fishermen, and public administration. The rates of these different profiles should therefore be determined at the level of the stakeholder category or categories addressed in the study. This can be carried out by collecting public data from statistical observation agencies. The relevance of calibration variables for data processing is presented in more detail in Sect. 2.5, but its use has to be anticipated at the survey design stage.

Considering the definition of the stakeholder population and its representativeness variable, a contact mailing list was established in the current study to identify potential recipients to whom the survey could be sent. Through the consultation of several sectoral cluster websites (i.e., structures that bring organizations together based on a common sectoral dimension), and a complementary literature review, a significant survey panel mailing list was drawn up. E-mail contact information and the associated name of the organization (e.g., company, authority, association, trade union)

can be collected automatically using a web scraping tool, and a large directory can be quickly built. To avoid attributing an excessive weight to a given organization, duplicate organization were removed from the panel in this case. Each response concerned a single organization. The sorting was based on a preliminary question at the beginning of the survey which aimed to identify the respondents who considered themselves to be stakeholders related to the system.

**Statistical population definition** In this work, local communities around an OWF operation site are assumed to include all the private and public actors present in a territory involved in the implementation of a project in France that are not directly involved in the wind power system value chain. The definition of the statistical population of a local community in the OWF context in France was based on an assumption that considered the distribution of the main profiles of participants observed in public debates on offshore wind energy. Based on the thesis by Bas (2017), the average distribution of stakeholder profiles was calculated from the information of public debates for four offshore wind farm projects: Courseulles-sur-mer, Fécamp, Saint-Brieuc, and Saint-Nazaire. This resulted in the following distribution of profiles: local NGO (37%), public administration (33%), professional fishing (12%), and navigation/nautical (21%). It should be noted that the distribution of the Local NGOs was rather dispersed with a standard deviation of 21% over the four debates. The fishing professionals were represented by entities such as committees and producers’ organizations, which explains the low number of people in public debates. On the contrary, the other profiles were linked to atomized organizations that are less clustered; therefore, more people were asked to represent them.

Some points should be taken with caution in relation to the assumption for the definition of the local community. Considering the example of professional fisheries potentially affected by the OWF sector, there is a risk that perceptions are “hierarchically controlled” by committees which then have full authority to represent fishermen and negotiate on their behalf (Kermagoret 2014). This precaution should be noted for the consultation of any stakeholder representative that aggregates views, particularly for political or negotiating interests. Besides, due to the complexity of contacting respondents to represent local residents and citizens profiles, which would require special survey methods (e.g., field survey), their perspective is assumed to be indirectly expressed through local associations and public institutions. Indeed, depending on the level of interest or controversy related to a project, it is common for citizens to group together and express their perspective through associations.

The value chain actor stakeholder category is defined as a set of local, national, or international companies which

conduct an activity in the offshore wind power sector. The assumption used to define the statistical population of the value chain actors was based on the census carried out by the French offshore energy observatory (Observatoire des énergies de la mer 2020). The following distribution of the calibration variable modalities is identified: assembly of components (12%), design / R&D (25%), manufacturing of components (19%), civil engineering (13%), operation and maintenance (14%), transport and logistics (8%), support services (9%).

**Sampling** For the sampling of the different stakeholder categories, a mailing list was drawn up from nine cluster websites and complementary sources. The estimated relevant clusters covered sectors such as renewable energy, marine energy, and diverse maritime activities. For the local community, the final panel included 342 different local stakeholders both public and private, while the value chain actors' panel included 640 stakeholders. At this stage, it should be specified that it was not possible to check one by one that each individual recipient of the survey was the most legitimate person of their organization to complete the survey. With a large-scale sampling approach, there is a probability that several surveys would fall outside of the scope of targeted stakeholder categories. Therefore, it is assumed that if a person chose to respond, they declared themselves competent.

Most of the stakeholder contacts obtained from websites, including industrial clusters, had support or business functions. However, the use of broad sampling also involved the collection of out-of-scope contacts. These out-of-scope contacts may include generic e-mails, undelivered e-mails, or redirections to various support functions (communications, IT, etc.) that may be considered as less concerned or competent about the social impacts of the system under study. Assuming that out-of-scope contacts would not answer the survey because they would not feel concerned, the final sample should include only relevant responses.

## 2.4 Survey design

Regarding the sampling approach, several general principles should be considered. First of all, the survey aimed to be a trade-off between the amount of data to be collected and the comprehensiveness of the responses. The survey should collect variables that can be used to check that the survey sample is representative of the population concerned (OECD 2007). At the same time, the survey should be quick to complete and should ensure anonymity. Indeed, because of the potential sensitivity of some aspects, non-anonymization may make people less willing to respond to the survey.

To cover both the impact subcategories scoring section and the respondent description section, the proposed survey was composed of three parts with a total of nine mandatory questions and one optional question. The complete set of questions addressed in the survey is available in the Supplementary Material section of this article.

The first section of the survey included three general questions about the respondent. Because the survey was addressed to stakeholders, the first question asked whether the respondent's activities were or could be influenced by the evaluated system. This enabled an initial sorting of the respondent's relevance.

- “Are your activities affected, or could they be affected, by the implementation of an offshore wind farm?”

The second section of the survey corresponded to the scoring of the social impact subcategories according to the gaping approach defined in 2.1. For this, each impact subcategory was scored twice. Based on the formulation by Manik et al. (2013), the related questions were presented as follows:

- “On a scale of 1 to 5, where 1 means ‘not important’ and 5 means ‘very important’, how would you rate the importance of the following issues in the context of the implementation of an offshore wind farm project?”
- “Currently, on a scale of 1 to 5, where 1 means ‘not at all’ and 5 means ‘fully’, to what extent would you say that offshore wind development meets the requirements of [impact subcategory]”

It should be noted that “no opinion” responses were proposed among survey responses so as not to force the respondent to answer by default.

An optional question offered the respondent the possibility of suggesting other impact subcategories that could be considered:

- “In your opinion, in the context of the implementation of an offshore wind project, are there other social issues specific to the territories that should be emphasized?”

This allowed verbatim data to be collected and ensured that the survey covered stakeholders' real concerns.

The third section of the survey included questions that aimed to characterize the profile of the respondent's organization.

- “Which of the following activities best describes your organization?”

Because this may be considered the most sensitive information, this part was placed at the end of the survey. Four

questions aimed to define the respondent. As explained in Sect. 1, the question about the main socio-economic activity of the respondent is crucial to determine the representativeness of the sample. It allows us to distinguish between the results of stakeholders who may a priori vary greatly depending on their activity. To avoid bias in the generalization of a respondent's answers to the entire stakeholder group he represents, the respondents were asked to qualify their location, the scope of their activity, and the interests they represented. Identifying a geographic location for the respondent also helps to verify the legitimacy to respond as a local community member potentially affected by OWF projects. According to the life cycle perspective, the respondent should also specify which stage of the project concerns them even if it is intuitive to think that, for our application to the French contexts, these were mainly the construction and the operation phases. Due to the territorial nature of the assessed system, the social impacts may differ from one site to another. Therefore, the respondents were also allowed to attribute their answers to one or more OWF projects from the proposed list. The detailed survey is presented in the Supplementary Material section. Finally, an optional question at the end of the survey allowed respondents to provide contact information for further consultation. This part can be adapted regarding the stakeholder category. For example, for value chain actors' stakeholder category, additional variables to characterize them more precisely could be requested (e.g., turnover related to the system assessed, size of the company).

## 2.5 Data processing for a representative gap analysis

Data from the survey corresponded to quantitative scores for calculating the gap and qualitative information about the respondent including the calibration variable. To the best of our knowledge, the use of a statistical representativeness test is not a widespread practice in the hierarchization of impact subcategories in S-LCA. However, the generalization of the results from a survey sample such as the one considered in this study to a larger population should be tested. This was conducted through sample-to-population comparison.

A significant difference between the sample and the statistical population distribution would mean a non-representative sample. This can be objectively identified by applying the statistical Pearson chi-square test. The chi-square test verifies whether the frequencies observed in the sample differ significantly from the theoretical frequencies of the statistical population. In practice, the test involved comparing these two frequencies. When applying the test, the comparison between the sample and the statistical population was carried out using the Formula (2).

$$x^2 = \sum_{ij} \frac{(O_{ij} - T_{ij})^2}{T_{ij}} \quad (2)$$

With

$T$ : theoretical profile distribution

$O$ : observed profile distribution

The calculated chi-square ( $x^2$ ) was then compared to the so-called chi-square critical value. The critical value of the chi-square depends, notably, on the number of modalities that the variable being tested can take. The chi-square critical value is provided by the chi-squared distribution table (Pearson 1900) and acts as a threshold which is used to determine the representativeness. In particular, if the  $x^2$  calculated is greater than this threshold, the test concludes that the sample is statistically not representative of the statistical population and vice-versa (Ugoni and Walker 1995). It is generally accepted that this statistical test requires a minimum of 30 responses, and that for each modality of the calibration variable, there should be at least 5 observations (Cochran 1954).

A dataset from a non-representative sample could be adjusted with a coefficient. Adjustment involved giving more weight to the responses for the profiles that were under-represented and vice-versa. Improving survey estimates, mainly by attributing weights to data collected with the survey with respect to an auxiliary variable, has been investigated in depth (Deville and Särndal 1992). A simple adaptation of the adjustment approach by using one single calibration variable was presented in (3). This adjustment on one variable could be decomposed into several calculation phases. First, the raw values of the sample and the population were identified according to the considered calibration variable (e.g., "stakeholder's profile"). Then the values were normalized, that is, their frequency was adjusted so that their sum equaled 1. The coefficients were obtained by dividing the normalized value in the sample by that in the population. A high coefficient meant that for the stakeholder profile concerned, the normalized value of the sample was low compared to the value of the population. In this case, the coefficient attributed more weight to their response than the one of the original sample. Conversely, if the normalized value of the sample and the population were close, the coefficient tended to 1. The closer the coefficient was to 1, the closer the sample was to the population and the less significant the calibration. Table 1 below presents a fictive dataset consisting of the raw values from the survey sample and the population, the corresponding standardized values, and the resulting calibration coefficient. In the proposed framework, the adjustment coefficient was applied to the gap score (4). Figure 2 resumes the gapping scoring method linked with the consideration of sample representativeness.

**Table 1** Calibration coefficient determination (fictive dataset)

	Sample	Population	Sample	Population	Coefficient
	Raw values		Normalized values		
Stakeholder's profile 1	45	400	0.35	0.40	1.16
Stakeholder's profile 2	85	600	0.65	0.60	0.92
Total	130	1000	1	1	

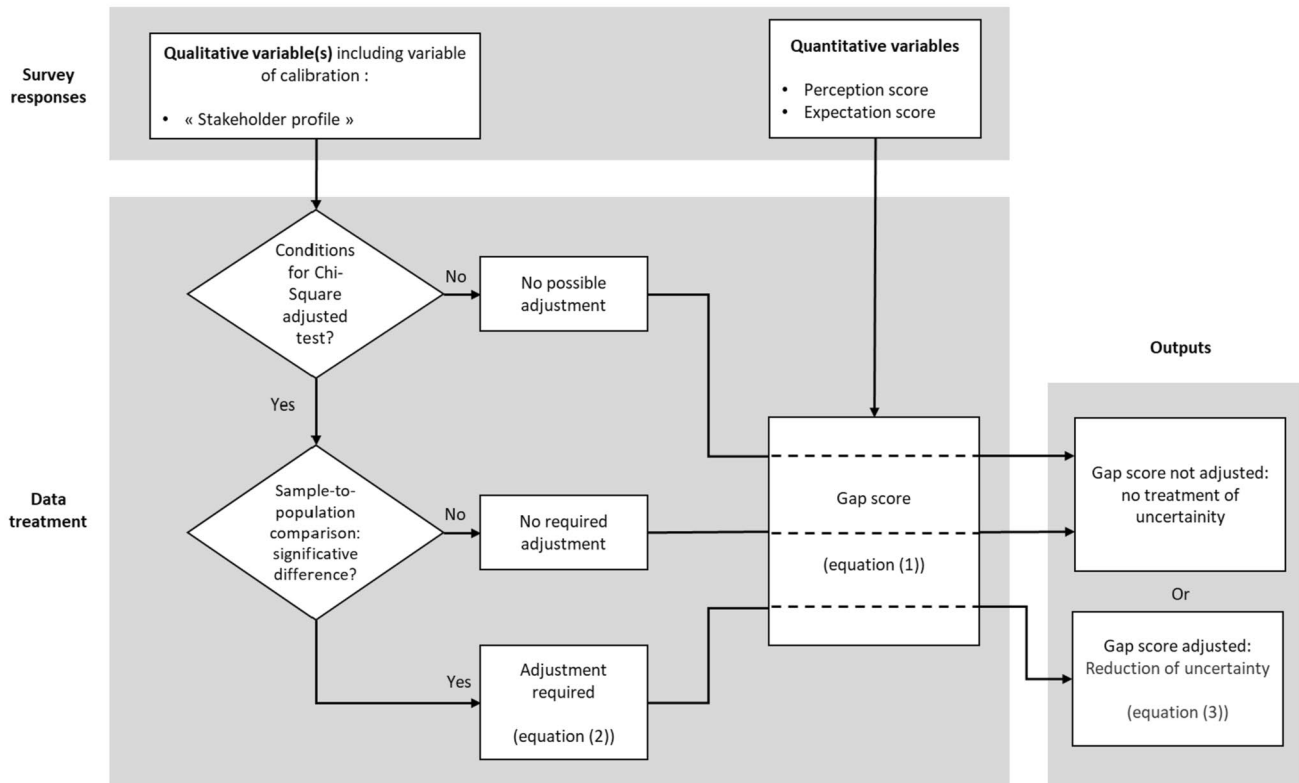
For J profiles : 
$$\text{Coef}_j = \frac{T_j}{\sum_{j=1}^J T_j} \div \frac{O_j}{\sum_{j=1}^J O_j} \quad (3)$$

Adjusted gap score = 
$$\text{Coef}_j \times \text{gap score} \quad (4)$$

The relevance of questioning the representativeness of sample responses can be also observed through disaggregated results. In this work, disaggregation consisted in expressing a quantitative result (e.g., perception score) according to one qualitative variable (e.g., the different groups identified within a stakeholder category). Observing score responses according to stakeholder profiles highlighted the potentially different ways of perceiving the impact subcategories between the different profiles of stakeholders. This information provided transparency on panel characteristics and possible biases that may be generated by

aggregating the scores to the whole stakeholder category level. To highlight the relevance of representativeness, this paper presents firstly disaggregated results, and then aggregated results with and without adjustment.

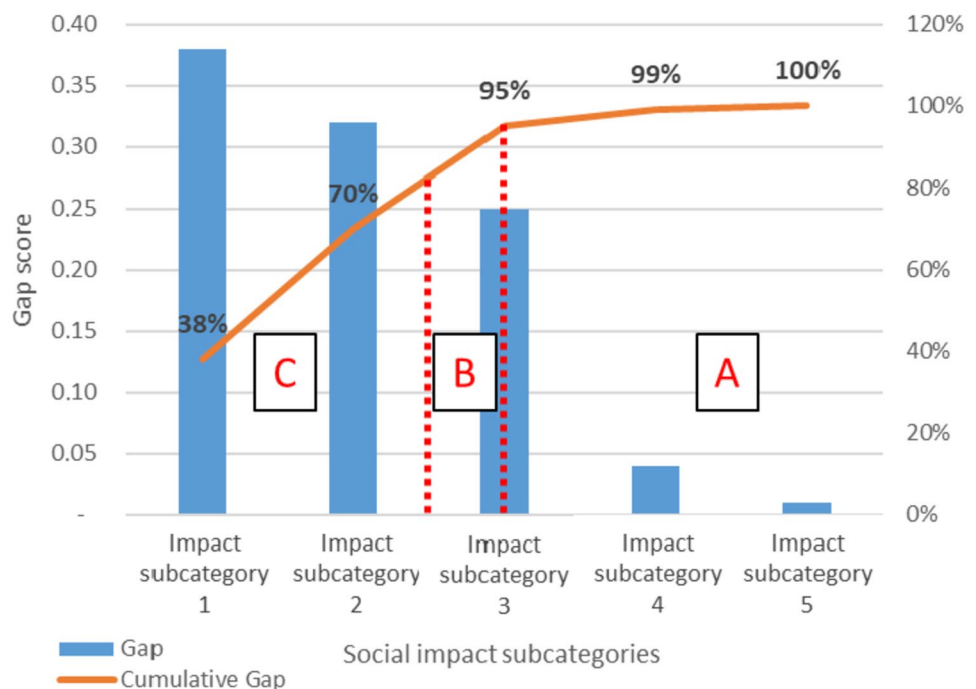
Theoretically, a complete S-LCA should cover all impact subcategories identified in the initial sectoral risk analysis. However, due to time and resource limitations, this is not always possible. Given the potentially wide scope of S-LCA, the practitioner must ensure the most appropriate use of time and resources. Therefore, they may have to find a balance between the feasibility of including a sufficient number of impact subcategories while still being able to assess them with a certain level of detail. For the sake of efficiency, this trade-off should be defined precisely and at an early stage in the study. This issue can be addressed by adapting the Pareto approach as illustrated in Fig. 3. This is a widely accepted approach to



**Fig. 2** Decision tree for a representative gap analysis



**Fig. 3** Visual representation of the results using the Lorenz curve derived from the Pareto approach and applied to S-LCA impact subcategory hierarchization (adapted from Janusz and Andrzej 2014)



meet trade-off rules and can be applied in different fields (Janusz and Andrzej 2014).

In this work, adapting the Pareto principle involved using cumulative information depending on the number of impact subcategories, as a cumulative adjusted gap score. For example, if the three first impact subcategories represent 95% of the total cumulative score, the relevance of spending time and resources on assessing the other impact subcategories to achieve 100% of the impact assessment can be questioned.

The Pareto principle states that, for many events, roughly 80% of the consequences come from 20% of the causes. Based on this principle, the Pareto chart is used in many fields as a tool to highlight the most important factors among a set of them. The approach consists in representing individual values of these factors in descending order and selecting the number of categories that cover at least 80% of the cumulative score. However, in S-LCA, a systematic threshold of 80% may not always be achievable or not always meaningful. Instead, a more adaptive definition of the threshold is proposed in this report rather than applying the fixed threshold of 80%. Thus, instead of using this fixed threshold regardless of the case study, a percentage of the scope covered by the hierarchized criteria may vary depending on the context and available information for the analyzed case studies.

In general, whatever the reasons for assessing a limited list of impact subcategories (e.g., lack of resources and/or information), the study should highlight this point and specify the scope limitation. Thus, the percentage of the

scope covered should be clearly specified, and if possible, justified. This information may contribute to transparency on the scope finally retained. Due to the iterative aspect of S-LCA, flexibility can be introduced, particularly in the context of developing systems for which very little information is available. In these cases, in-depth comprehensive analysis with more categories assessed should be carried out as the system becomes better known, and more information becomes available.

### 3 Results and discussion

The presented hierarchization approach is related to the first phase of application of S-LCA according to ISO 14040 general life cycle assessment framework and UNEP guidelines, namely the goal and scope definition step. By helping to define the goal and scope, hierarchization aims to determine which social impact subcategories should be considered a priority for the further inventory analysis and impact assessment phases. This section presents the application and results of the proposed hierarchization framework for a case study of the French OWF sector. Results of data surveys consist in a ranking of the social impact subcategories from the largest to the smallest gap. This paper presents the detailed application for the local community stakeholder category, as well as a brief summary of the results for the value chain actors' stakeholder category.

**Table 2** Definition of impact subcategories related to local communities around an OWF site in France. Apart from local employment, which is directly transposed from the UNEP, all the other social impact subcategories have been adapted to the sectoral context

Social impact subcategories adapted to sectoral context	Aspects considered in the literature	References
Access to energy facilitated	Storage capacity and energy density Renewable energy availability	(Azapagic et al. 2016) (Santoyo-Castelazo and Azapagic 2014)
Fair sharing of maritime and terrestrial spaces	Land occupation Effect on professional fishing Effect on recreational activities	(Santoyo-Castelazo and Azapagic 2014) (Schupp et al. 2021; Buchholzer et al. 2022) (Hooper et al. 2017)
Investments in favor of the territory	Amount of fiscal benefits	(CGEDD 2021)
Benefits and technology transfers	Share of local content	(Allan et al. 2020; Connolly 2020)
Attractiveness of the territory	Evolution of tourist frequentation	(Ladenburg 2009; Westerberg et al. 2013; Smythe et al. 2020)
Consideration of quality of life and absence of related detrimental effects	Level of visual and noise impacts Public preference for a technology	(Hirschberg et al. 2004; Santoyo-Castelazo and Azapagic 2014; Troldborg et al. 2014) (Maxim 2014)
Respect for the rights of residents	Local benefits for residents Real estate price evolution	(Liu 2014) (Jensen et al. 2018; ADEME 2022)
Quality of the dialogue between local stakeholders and decision-makers	Trust rate in electricity developers Number of meetings with local communities	(Hooper et al. 2017) (UNEP 2020)
Extent of citizen participation	Participatory funding of projects	(Oiry 2017)
Safety management and industrial risks	Maximum fatalities per major accident Probability of accident with a civilian	(Hirschberg et al. 2004) (SSPA Sweden A 2008)
Local employment (UNEP 2020)	Number of direct and indirect jobs Qualitative characterization of created jobs Social clauses	(Henningsson et al. 2013; Liu 2014; Troldborg et al. 2014; Maxim 2014; Atilgan and Azapagic 2016; CRE 2018; Santoyo-Castelazo and Azapagic 2014; Azapagic et al. 2016; Kahouli and Martin 2018; Roinioti and Koroneos 2019) (WavEC 2012; Podevin 2017) (CRE 2018)

### 3.1 Social impact subcategories for French OWF sector

This section presents the final list of social impact subcategories included in the surveys. For the hierarchization of impact subcategories related to the local community stakeholder category, the focus was on people who are located at or near OWF siting areas. These stakeholders were based along the French coastline. Some of them were linked to pre-established activities that may be of major economic importance for the territories (e.g., tourism sector, professional fishing) or concerned by the well-being and amenities offered by the territory (e.g., quality of life, landscape). Regarding these social concerns of local communities, white

and grey literature such as public debate reports or stakeholder booklets, and opinions expressed by the media are widely available (CNDP 2021). This cross-review allowed a list of impacts to be adapted to the considered system then submitted to local stakeholders for hierarchization. The final social impact subcategories list is presented in Table 2. Job creation issues were by far the most recurrent in the literature.

Regarding the diversity of profiles included in this category, the literature review required a significant adaptation of the proposed UNEP Guidelines list. It should be noted that the UNEP “Delocalization and migration” impact subcategory was neither considered nor adapted, because no literature was identified on this subject in relation to the evaluated system (i.e., OWFs).

**Table 3** Calibration variable for the local community stakeholder category related to French offshore wind farm sites

Variables	Modalities	Sample (N= 50)	Population (Public debates)
Local community profiles (calibration variable)	Local NGO	33%	38%
	Public administration	14%	33%
	Professional fishing	8%	12%
	Navigation / nautical	45%	21%

**Table 4** Calibration variable for the value chain actors' stakeholder category related to French offshore wind farm sites

Variables	Modalities	Sample (N= 82)	Population (Sectoral observatory)
<b>Value chain profiles</b> (calibration variable)	Assembly of components	7%	12%
	Design / R&D	32%	25%
	Manufacturing of components	16%	19%
	Extraction of raw materials	0%	n/a
	Civil engineering	8%	13%
	Operation and maintenance	13%	14%
	Transport and logistics	5%	8%
	Support services	19%	9%
	Other	0%	

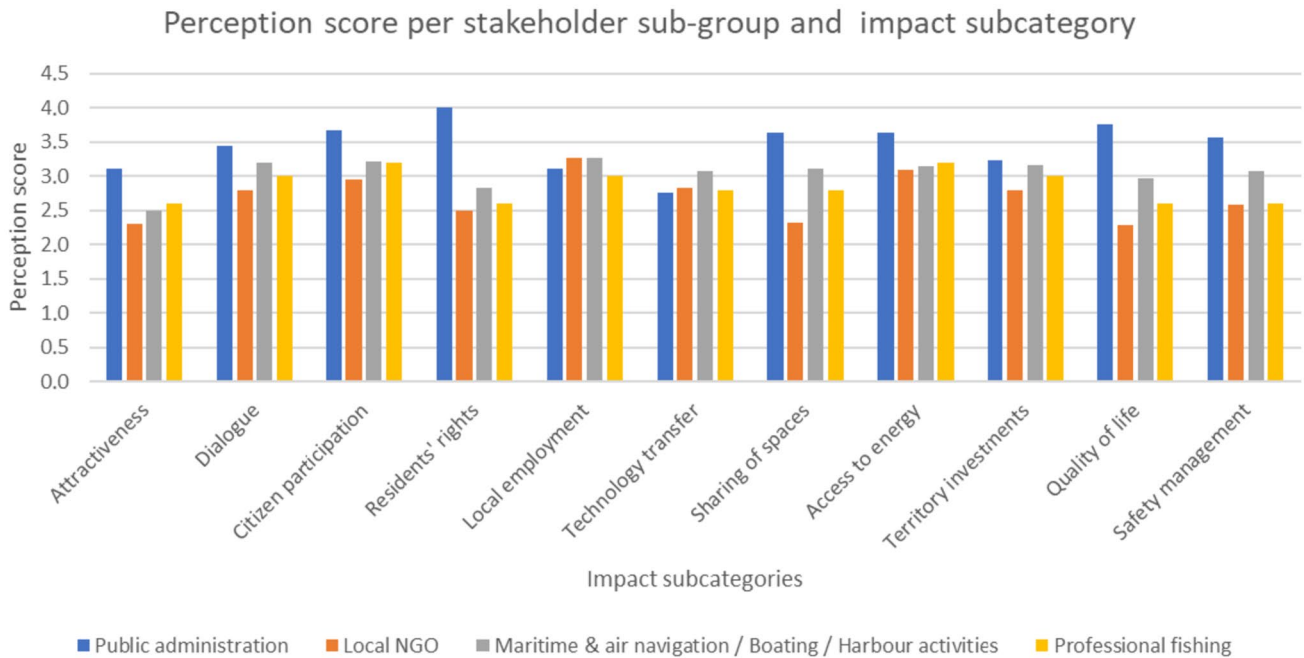
Conversely, for the value chain actors' stakeholder category, it was assumed that the UNEP social impact subcategories were sufficiently clear. They were therefore listed without adaptation, including fair competition, promoting social responsibility, supplier relationships, respect of intellectual property rights, and wealth distribution.

### 3.2 Stakeholders' samples analysis and representativeness test

For the local community stakeholder category, the survey collected 50 responses, i.e., a 16% response rate. As expected, almost all of the respondents were located in coastal areas involved in the implementation of an offshore wind farm. For the value chain actors' stakeholder category, the survey collected 82 responses, i.e., a 13% rate. In

contrast to the local communities, it appears that not all companies were in a siting area. This meant that the economic benefits and job creation within the value chain did not all concern the local scale. The Brittany area on the French west coast (mainly the Brest and Saint-Nazaire sites) was the best-represented area in the sample. Details of the distribution of the various descriptive variables can be found in the Supplementary Material.

As explained in Sect. 2.5, the chi-squared adjusted test was then applied. According to the results, neither the sample of local community nor the sample of the value chain actors were fully representative of their respective statistical populations. For the local community (Table 3), the navigation and nautical actors were found to be over-represented in the sample (45%) compared to their presence within the statistical population (20%). On the contrary,



**Fig. 4** Disaggregated perception scores according to stakeholders' profiles within the local community category

public administrations were under-represented in the sample (14%) compared to the statistical population (32%). For the value chain actors (Table 4), the main difference was an over-representation of support services and design / R&D.

At this stage, not considering the representativeness bias would lead to a risk of generalizing results that do not correspond to the real distribution of stakeholder profiles. Adjustment is a solution that does not eliminate this bias but may help to reduce it. Therefore, the adjustment coefficient is applied according to Eq. (2) presented in Sect. 2.5. For the local community stakeholder category, adjustment coefficients ranged from 0.45, for stakeholders related to navigation and nautical activities, up to 2.33, for public administrations that were the most under-represented in the sample. In the case of the value chain actors, the coefficients ranged between 0.48 and 1.74. These coefficients were then applied to the gap values of each social impact subcategory.

### 3.3 Hierarchization results

This section provides first a descriptive overview of the responses at the disaggregated level. Next, it presents and discusses the responses at the aggregated level.

#### 3.3.1 Disaggregated results

The difference in response scores is illustrated through the consideration of sub-groups of stakeholders inside the local community category. Based on scores associated with the criterion “Importance,” responses do not vary greatly between respondents. Respondents tended to score the importance of the different impact subcategories relatively highly. However, the perception scores showed a higher variability according to the profiles. The perception scores are presented in Fig. 4.

For most social impact subcategories, public administrations assigned a higher perception score than that of other profiles. According to the perception criterion defined in Sect. 2.2, this result means the public administrations had, on average, a higher level of satisfaction than the other stakeholder profiles for the different impact subcategories addressed. Conversely, local NGOs assigned a lower average perception score than that of the other profiles.

These disaggregated results lead to two main findings. Firstly, they support the assumption that the profile of the respondents has an overall influence on the perception of the social impacts of offshore wind systems. By considering the local community stakeholder category as a homogeneous group, there is a risk of information being masked. Therefore, the interpretation at the aggregate level should be considered prudently. Based on these results, this work recommends the disaggregated data to

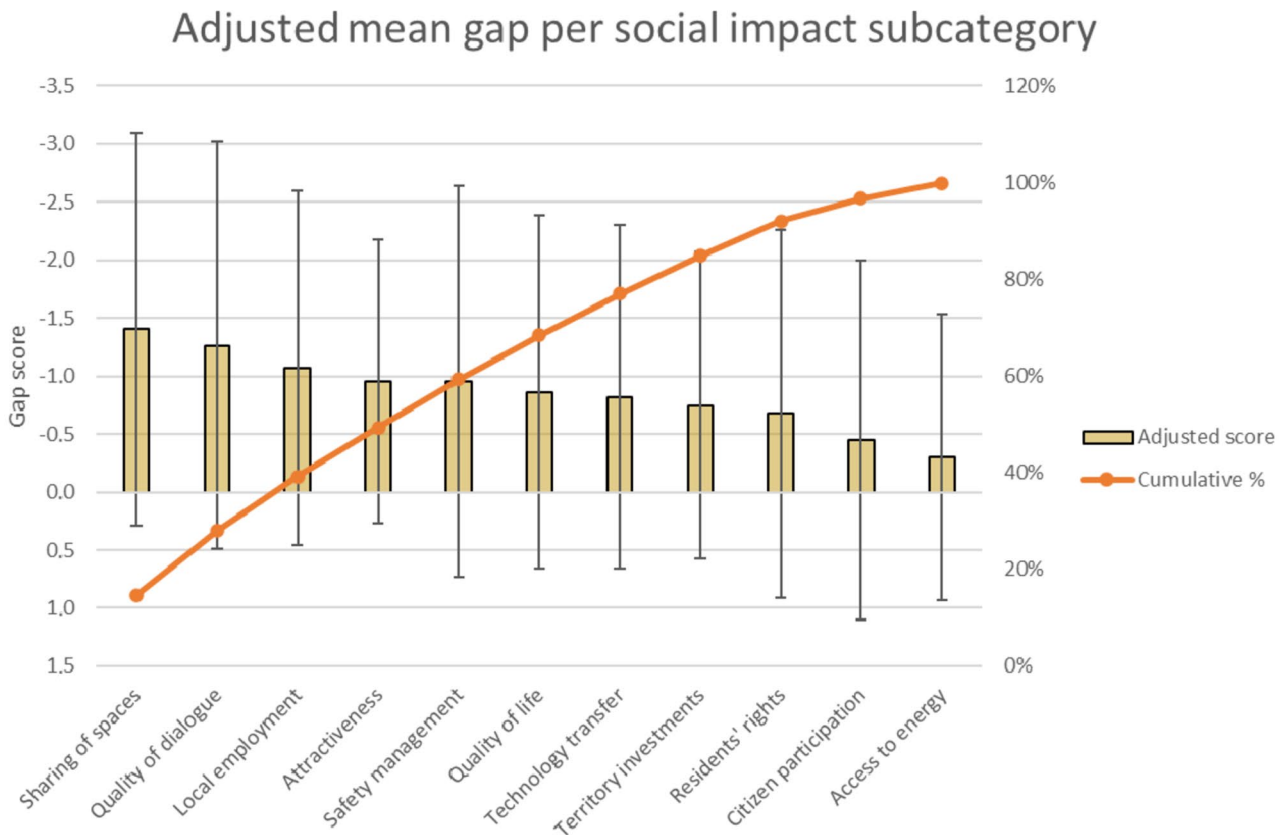
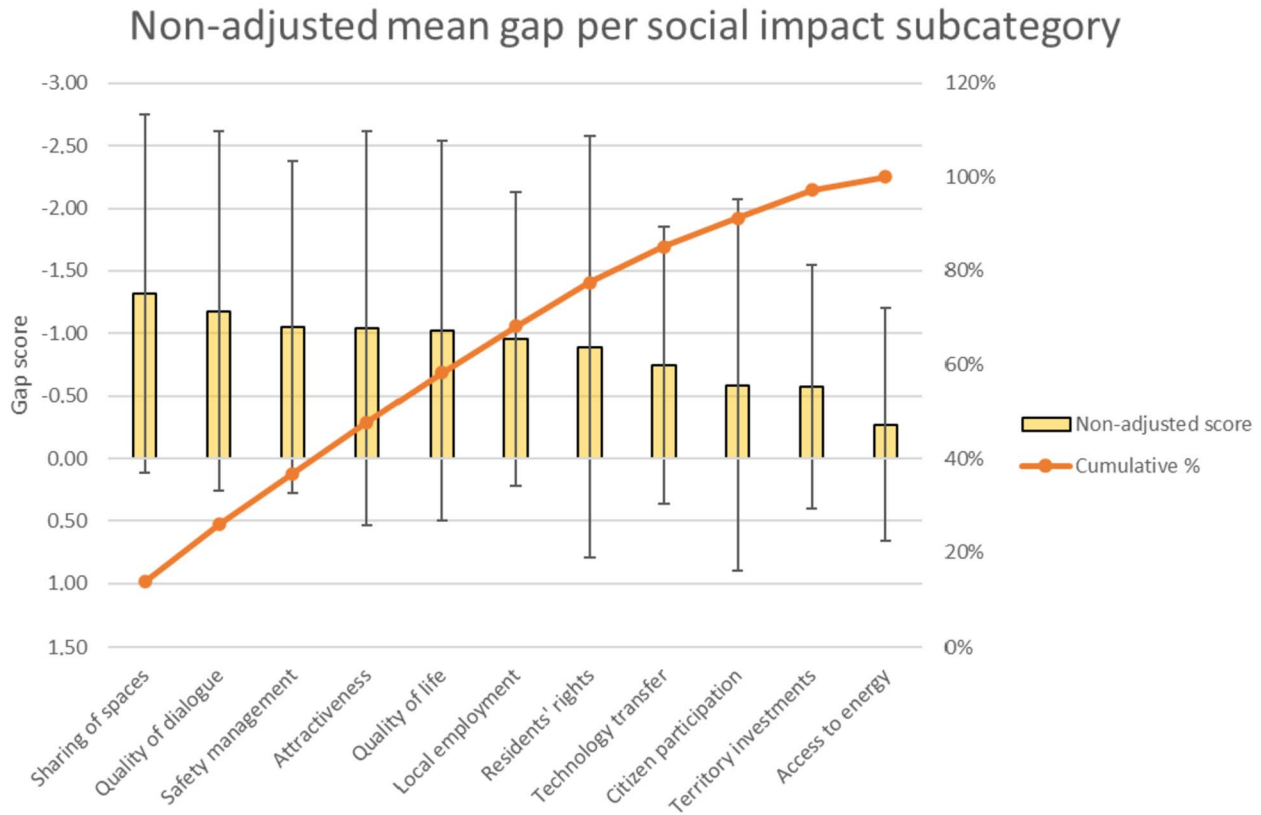
**Fig. 5** Hierarchization results of local community impact subcategories with Pareto–Lorenz curve (in red). **A** (top) Sample without adjustment. **B** (bottom) Adjusted sample based on distribution hypothesis

be considered at a resolution higher than the stakeholder category level, at least to complete the information from aggregated results. This information should help to nuance the hierarchization results and make them more transparent, then to anticipate questions about the limits of further S-LCA results. Second, it highlights the necessity to question representativeness with regard to the further aggregation of the results. For example, according to these results, a hypothetical over-representation of public administration profiles in the sample could lead to an overestimation of the perception score compared to the overall real perception of members of the local community stakeholder category. Based on these observations, aggregation of scores must be applied carefully and taking into consideration representativeness issues.

#### 3.3.2 Aggregated results of the hierarchization of social impact subcategories

Figure 5 presents the results of hierarchization of social impact subcategories, including the difference between the non-adjusted ranking (Fig. 5A) and the adjusted ranking (Fig. 5B).

Thus, considering the non-adjusted gap score, the results of the survey lead us to prioritize the impact subcategory “sharing spaces” (1.32), followed by the “quality of dialogue with the developer” (1.18) and the “safety management” (1.05). Applying the adjustment changes the order of several impact subcategories. For example, local employment is ranked 6 without adjustment, but is ranked 3 with adjustment, replacing the “safety and management” subcategory. Other subcategories, such as the “sharing of spaces” (–1.4) and the “quality of dialogue with the developer” (–1.26) are still ranked on the top. Among the results, the adapted impact subcategories related to “sharing of spaces” and “quality of dialogue” seem to have a priority according to the consulted stakeholders. Conversely, “access to energy” appears in the last position of the gap analysis results. The electricity supply, which is the function of the assessed system, does not appear as a crucial issue for the sample according to the gap analysis result. Employment issues, which are by far the most recurrent in the literature, are not ranked in the first place by stakeholders, who considered sharing space as an issue with higher priority in this study. It should be noted that these results represent a specific socio-economic context, and differences could be found in other territories. For example, areas with problems of access to energy could assign a much higher priority to this impact subcategory.



It should be noted that the standard deviation presents a high value. In this work, the standard deviation should not be considered as an uncertainty, but as the variability of the respondents' perspective. Indeed, even if all individuals in the population are interviewed, the standard deviation will persist. This information is crucial and conveys the highly heterogeneous nature of respondents' perspectives. This can be explained by the polarizing nature of settlement projects in a territory such as offshore wind in France. Respondents' perspectives vary widely depending on whether they are in favor, against, or neutral about the offshore wind development.

Based on the scores obtained, the Pareto approach provides information on the scope depending on the number of social impact subcategories selected for the next S-LCA steps. Depending on the selected social impact subcategories, information on the proportion of the scope covered can be provided transparently. Rather than specifying only how many of the impact subcategories are retained, it is recommended to also specify what proportion of the total cumulative gap is retained. The Pareto approach highlights the fact that the cumulative gap increases rapidly when the priority impact subcategories are retained. Conversely, if the study already covers a certain number of subcategories, adding the subcategories with the lowest priority will not result in a significant increase in the cumulative gap, although considering them may be time-consuming.

Regarding the Pareto approach and the cumulative gap for the local community results, a threshold of 80% coverage is reached with seven social impact subcategories. It is interesting to note that employment issues, by far the most recurrent in the literature, are not in first place. This indicates that it may not be sufficient to rely on literature

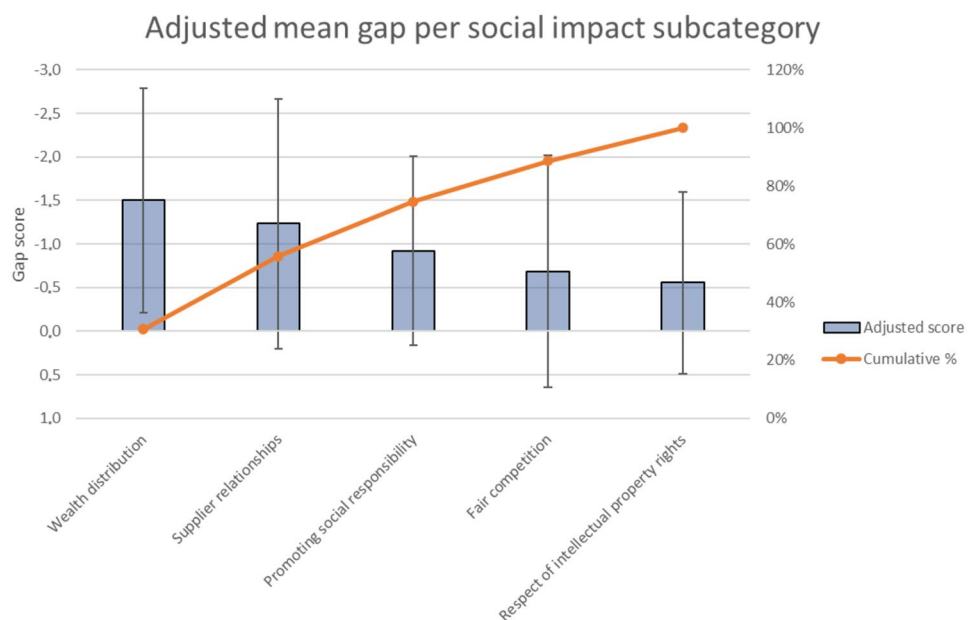
reviews alone in order to achieve results that adequately reflect stakeholder perspectives.

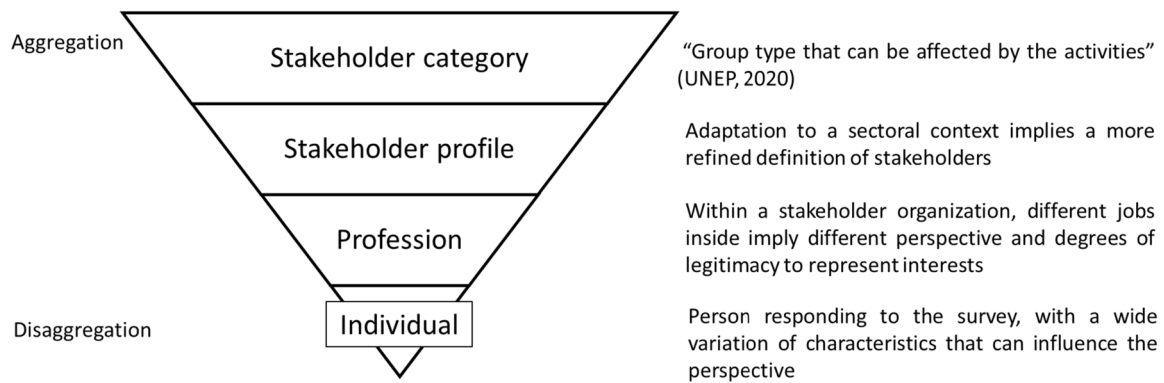
Overall, some asymmetries exist between these results and what is generally emphasized in reports and public debates. In general, the impact on employment is more frequently highlighted than other social impacts. However, in our results, the subcategories related to "sharing of spaces" and "quality of dialogue" are ranked in a higher position. Conversely, "access to energy," which is also presented as an argument by OWF developers, is found in the last position in the survey results. The electricity supply, which is the function of the assessed system, does not appear as a crucial issue for the panel and based on the survey criteria. The implementation of offshore wind farms repositions the production of energy close to local community consumers and reveals the externalities it generates. By extension, this may lead to unfavorable impacts being emphasized more than favorable ones. This finding may be in part explained by the specificities of the territories addressed in this analysis. Local communities in sites where access to energy may be more difficult or instable than in French territories could rank this category differently.

Figure 6 shows the adjusted results of the social impact subcategories hierarchization for the value chain actors' stakeholder category. It should be noted that the adjustment of the responses in this case does not change the ranking of the impact subcategories compared to the non-adjusted ranking. The 80% coverage threshold is reached with four impact subcategories. Wealth distribution appears as the impact subcategory with the largest measured gap.

Despite the findings in this section showing the interest of considering sample adjusting to better represent stakeholders' perspectives, the robustness of the adjustment could be

**Fig. 6** Hierarchization results of value chain social impact subcategories with Pareto–Lorenz curve (in red)—adjusted sample based on distribution hypothesis





**Fig. 7** Main levels of bias aggregation data between the respondents and the stakeholder categories

discussed and may provide a perspective for further study. In this work, only one calibration variable was used. To make the fit more accurate, and thus the results more robust, several calibration variables could be used in a single adjustment. Using several calibration variables for the hierarchization of impact subcategories requires, however, identifying in advance which variables could influence the allocation of scores for each impact subcategory to include questions in the surveys to characterize these variables.

Focusing on variables that may influence the perception of different impact subcategories, the disaggregated characterization of stakeholders should be further explored. Indeed, as presented in Fig. 7, different levels of bias can exist between the commonly used level of aggregation in S-LCA, i.e., the stakeholder category, and the smaller entities of participatory approach, i.e., the individual level.

This work proposed to consider the stakeholder profile level as an intermediate disaggregated level, but other levels should be considered to increase panel transparency and potentially more reliable adjustment. Indeed, it is highly likely that the respondents' occupation in a stakeholder organization influences the perception of social impact subcategories. Considering the example of the fishermen profile within the local community category, there may be differences of perspective between a fisherman versus a policy officer in a fisheries committee. Designing the survey to collect a profession variable such as “respondent's occupation” variable should bring, at least, more transparency about the degree of legitimacy of the respondent. This information could be provided by adding a question on the job category with a baseline list such as the following: self-employed / engineer / business manager, support (HR and communications), technical and operational. Beyond professions, inherent bias can exist related to diverse socio-economic characteristics such as age, level of education, income, geographical area. Including these potential additional variables would make the study of representativeness more accurate and make the results more robust at the level of a stakeholder

category, but would also require more answers to ensure representativeness per subgroup. Furthermore, as a reminder, in this work, duplicate organizations were removed from the sample. It should be noted that considering the views of only one person within an organization could be limiting when aiming to reflect the perspective of an entire organization. Indeed, an organization may include many people, potentially with different perspectives. This diversity of perspectives within a given organization might be overcome by allowing as many respondents as possible from each organization to answer the survey rather than just one per organization. In this case, to avoid over-representation, the responses should be averaged per organization before being considered for the aggregated results. Also, as a reminder, the stakeholder profiles for the local community were defined in this case based on the profiles of participants in public debates. This may be limiting in terms of representing the perspective of the people who live in the area but do not participate in the debates. Other methods of defining profiles among the local communities' stakeholders could be used. For example, consultation of several experts on the subject could make it possible to collect and group together information on the profiles of stakeholders related to the considered system.

## 4 Conclusion

This work proposed a method for systematizing the hierarchization of social impact subcategories, typically included within the sub-steps of the goal and scope definition phase of S-LCA studies. This method, based on a participatory approach enabled the construction of a stakeholder panel based on publicly available information. It resulted in a satisfactory number of responses and a hierarchical ranking of the social impact subcategories to be considered in the S-LCA study. These results allow the practitioner to identify which social impact subcategories to prioritize for the inventory analysis and impact assessment phases of the S-LCA.

The method allows the practitioner to be transparent about both the characteristics of the respondents and the scope that will ultimately be covered by the study.

In general, participatory approaches appear to be time-consuming for the practitioner. The survey and sampling method proposed in this work can be redeployed and facilitate the application of such participatory approaches. The value of such approach is that (1) it provides an automatized strategy to quickly identify a large set of potential respondents to surveys representing a given stakeholder category's perspective, (2) it relies on a ranking approach based on two criteria that provide more comprehensive information on the relative importance of different impact subcategories than a direct ranking, and (3) it allows the representativeness to be checked and considered to adjust the hierarchization results.

Based on the scores from a hierarchization, explorations should be carried out to define an optimum threshold of impact subcategories to be retained. This would involve defining rules to identify a compromise between the breadth of the scope (i.e., the number of social impact subcategories to be retained considering their hierarchization score) and the depth (i.e., the further analysis to define and assess impact indicators). In addition, future work could be oriented towards combining the results of the prioritization with a weighting of the social impact subcategories following the impact evaluation step. Indeed, these two operations could converge. However, weighting can be a tricky exercise. When weighting is coupled with an aggregation operation to combine the impacts into a single score the aggregation should be conducted carefully, to ensure that it does not result in effects being masked, or unfavorable impacts being offset by other favorable impacts. Surveys can be used to potentially collect a large number of responses. Given the preparation time, it is essential to make the best possible use of this tool. In this work, the survey focused on prioritizing social impact subcategories and collecting descriptive variables. However, survey results could also be used for broader applications, such as materiality matrix or stakeholder mapping purposes, insofar as they provide a better understanding of the involved stakeholders.

The proposed method based on systematizing sampling and testing the representativeness of respondents implies certain conditions. These conditions relate to the type of sector considered in the study. The reuse of this approach is applicable to structured sectors, namely sectors composed of numerous organizations that are listed and identifiable, and for which descriptive statistics are available. Web scraping linked to industrial clusters appears to have great potential. For instance, for France alone, more than 170 clusters are identified among the main industrial sectors (Sibilles 2016). This method for accessing stakeholders therefore appears to be transferable to many systems.

It should be noted that the survey format may be limiting in terms of studying the social impact subcategories in greater depth. Future research should aim to improve the survey format and optimize its use. This involves, for example, identifying the possible links between this phase of S-LCA studies and the next ones. An optional question could be included to identify respondents who are interested in further consultation (e.g., by interview or focus groups) to study the impact subcategories being ranked as a priority in greater depth. Such consultation could be used to identify indicators and/or collect primary data related to certain indicators.

Various improvements could consolidate this participatory approach. This work should be considered a first attempt to provide a tool that makes the S-LCA goal and scope definition phase more inclusive. This may help to better account for the complexities of the different stakeholder profiles, and consequently lead to an S-LCA that better reflects people's concerns, which is essential for decision-makers to better identify improvement opportunities and social aspects to be carefully monitored.

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**Data availability** The datasets generated by the survey research and analyzed during the current study are available from the corresponding author upon reasonable request. The online version contains supplementary material.

## Declarations

**Competing interest** The authors declare no competing interests.

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