IT IS BEST TO ASK: DESIGNING A STAKEHOLDER-CENTRIC APPROACH TO SELECTING SUSTAINABLE ENERGY DEVELOPMENT INDICATORS

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Abstract

Sustainable energy development is a complex and multi-dimensional concept that is integral to sustainable development. This paper offers an approach to selecting comprehensive and robust indicators to monitor progress towards this international policy objective. Numerous weaknesses in current indicator sets for sustainable energy development have been identified, e.g., lack of transparency, imbalanced representation of the pillars of sustainable development, and the absence of stakeholder engagement during development. Currently, no standardized approach to indicator selection exists. In this paper, an iterative process to indicator selection for sustainable energy development is presented. This process is rooted in stakeholder engagement to ensure a representative indicator set and reduce the potential for bias in indicator selection. A diverse and balanced group of stakeholders should be engaged through interviews, focus groups, and a Delphi survey to capture stakeholders' views of sustainable energy development within a particular setting. Based on stakeholder input, the main themes of sustainable energy development are identified, which corresponds to a thematic conceptual framework for indicator development. These results are connected to established indicators to produce a preliminary set of indicators. Subsequently, a set of indicator assessment criteria are applied to assess the quality of indicators and eliminate overly correlated indicators. In the end, a comprehensive and robust set of indicators for sustainable energy development is produced that reflects the context in question. To ensure the usefulness of the indicator set to decision-makers and stakeholders, information such as the necessary formulas and data sources should be provided.

Keywords

Sustainable energy development; Sustainability indicator; Energy indicator; Indicator development; Stakeholder engagement; Interdisciplinary research

Highlights

- Robust indicators are needed to track progress towards sustainable energy development
- Most current indicators for sustainable energy development are found lacking
- No standardized approach to indicator selection exists
- A stakeholder-centricapproach to indicator selection is presented
- Transparency in indicator selection is vital to ensure their usefulness

1. Introduction

In 2000, a new energy paradigm was introduced, where the economic, social, and environmental impacts of energy development were considered [1]. This paradigm was called sustainable energy development (SED) and highlighted energy's role in achieving sustainable development. The necessity of energy for sustainable development was further recognized with the introduction of the UN's Sustainable Development Goal (SDG) 7 on affordable and clean energy [2]. In an increasingly energy-intensive world with depleting fossil fuels and increasing environmental pressures, SED's importance is evident. This development involves improving access to modern energy services to advance well-being [3]. One of the main challenges of SED is to improve access and affordability while ensuring environmental sustainability and staying within "the carrying capacity of ecosystems" [1]. Currently, SED is viewed as a cross-cutting policy objective connected to some of the major social, economic, and environmental challenges the world is facing. Similar to sustainable development, SED is a complex and inherently vague concept [4]. Therefore, a clearer framework for what SED means is needed and how progress towards it can be measured.

Energy systems vary from one to another due to factors such as geographical location, availability of natural resources, and level of industrialization [5]. As a result, challenges on the SED path and actions for a sustainable energy future can differ significantly between energy systems. Therefore, a context-specific analysis of SED is appropriate [6,7]. Stakeholder engagement can be beneficial to understand better what sustainability concepts entail within a particular setting. Robinson recommends a discussion with the relevant stakeholders and communities to identify what a desirable and sustainable future could involve [4]. National priorities for energy development can be identified through context-specific analysis with stakeholder engagement and, thus, inform decision-making and policy development [8].

Tools to inform actions and monitor progress towards a desirable and sustainable energy future are valuable [3]. Sustainability indicators have long been used for this purpose. The usefulness and necessity of indicators to inform decision making and raise awareness were highlighted in the UN's Agenda 21 in 1992, which led to a substantial push for new indicators in the following years [1,9]. Despite this, there is no standardized approach to selecting sustainability indicators [10]. Numerous efforts have been made to develop indicators that measure one or more aspects of SED [1,11]. Many of these have been criticized for limitations, such as lack of transparency and presenting an imbalanced picture of SED [6,11]. Some have argued that a context-specific set of indicators for SED, reflecting the relevant challenges and national priorities, is necessary for it to be useful to decision-making and policy development [3,6,11]. Therefore, stakeholder engagement can be beneficial during indicator development to capture what a sustainability concept, such as SED, involves within a particular setting [8]. Decision-makers have started to recognize the weight of stakeholder engagement and public participation for effective decision making and to increase public

acceptance [12]. Nevertheless, it is not common practice to formally engage stakeholders during indicator development [11].

In this paper, a new methodological approach to indicator development is proposed based on a theoretical study of current methods. Stakeholder engagement is at the heart of this process, where stakeholder input provides a base for indicator selection. It is possible to capture a comprehensive and robust picture of what SED might entail within a particular setting by engaging stakeholders. Thereby, a context-specific set of indicators can be selected that reflects the relevant SED challenges and opportunities. An indicator set for SED can be produced through further refinement and comparison with the literature and established indicator sets. In the proposed methodological approach, an emphasis is placed on transparency to ensure usefulness and validity.

The objectives of this paper are twofold;

1) present an iterative approach to indicator selection based on stakeholder engagement
2) analyze how the proposed indicator selection process enhances established methodology

The paper is structured as follows: Section 2 briefly reviews the concept of sustainable energy development. The methodology of the literature review of existing indicators for SED is described in the third section. The results of that review and a proposed methodology for indicator development is presented in section 4. The value of this proposed approach is analyzed further in section 5. Finally, the paper is concluded in section 6, where the implications of this study and the next steps are presented.

2. Background

2.1 Sustainable energy development

The role of energy systems is to improve human well-being and raise living standards by providing modern energy services that advance social and economic development [1]. One of the most critical challenges facing the world is how to deliver energy services to all while minimizing the related environmental and health costs [1]. In general, sustainable energy development aims to address this challenge; advance sustainable development while minimizing negative environmental, social, and economic impacts [13]. To address that challenge, the current energy system, both on the supply and demand side, needs to be transformed [14]. The role of energy in furthering sustainable development was highlighted with the introduction of the UN's SDG 7: "Ensure access to affordable, reliable, sustainable and modern energy for all" [2]. SED is a complex and multi-dimensional concept with the ultimate aim of a sustainable energy future. However, what lies on the path towards such a future can vary based on context; for instance, the energy-related challenges facing developing countries compared to developed ones can differ significantly [6,8]. Some argue that SED and other sustainability concepts can be viewed as “essentially contested concepts”, as their interpretations can vary and they are products of “social, historical, and cultural constructs” [15,16]. Similarly, Heaslip

and Fahy [17] state that “communities’ perceptions and understandings of energy are complex and place-based and situated in cultural and political contexts.”

Gunnarsdóttir et al. analyzed the concept of SED and presented four common interrelated themes; sustainable energy supply, energy security, sustainable energy consumption, and access to affordable modern energy services [13]. According to their analysis, the overarching goal of SED is to promote sustainable development. To do so, everyone should have access to modern energy services at an affordable price. These energy services have to be secure and reliable for them to advance social and economic development. In 2018, 789 million people did not have access to electricity, and 2.8 billion did not have access to clean cooking [18]. Even though these numbers have improved in recent years, social inequality regarding energy access is evident. To ensure environmental sustainability, a transition towards a sustainable energy supply with increased utilization of renewable energy sources and environmentally benign technologies is necessary, as highlighted by the second sub-goal of SDG7. For this to be feasible, these technologies have to become economically viable, which can be encouraged through, for example, innovative financial schemes, energy pricing reflecting external costs, and increased support for research and development [19]. The importance of international collaboration and financial support of clean and renewable energy, particularly in developing countries, is highlighted by one of SDG 7's sub-goals [2]. For SED to be realized, current consumption patterns need to change and become more sustainable through, for instance, increased energy efficiency and raised awareness of the negative impacts of energy production and consumption [11]. In recent years, global primary energy intensity has fallen to about 5.0 MJ/USD in 2017, indicating improved energy efficiency [18]. Nonetheless, a significantly faster improvement rate will be required to meet the goal of doubling the global rate of improvement in energy efficiency laid out in the 2030 Agenda for Sustainable Development [2,18]. Everyone needs to take action to push for more sustainable energy systems [13].

Multiple attempts have been made to measure SED progress through metrics and sustainability indicators that vary both in purpose and quality [5,6,11]. Sustainability indicators can serve an essential role in assessing a system's current status and monitoring progress towards a goal. Thereby, the indicators can inform decision-making and improve actions [10]. Indicators can be used to simplify complex concepts, such as SED, and communicate the critical underlying issues to policymakers and the public [8,20]. Additionally, complex interactions and key relationships within an energy system can be identified through the use of indicators [5]. Indicators measuring progress towards SED should take account of its complexities and underlying themes. One of the main challenges for the creation of appropriate SED indicators has been ambiguities in what the concept of SED encompasses, especially within the local context [5,6]. A situated analysis of the concept within a particular setting, especially when involving stakeholders, can further understanding and lead to a socially acceptable definition [7]. A context-specific set of indicators might be appropriate since the challenges and opportunities on the SED path can vary significantly between energy systems [21]. A

more thorough review of existing indicators for SED and the desirable characteristics of such an indicator set is provided in section 4.

3. Methods

An essential first step when conducting research is to assess the current state of the field and build on existing knowledge. For this study, a review of existing SED indicators and the methods for their selection was thought necessary. Such a review was conducted by Gunnarsdóttir et al. in the paper *Review of indicators for sustainable energy development* [11]. This study and proposed approach to indicator selection primarily builds on the results of that review. Gunnarsdóttir et al. 's study involved a comprehensive literature review to identify existing SED indicator sets. A so-called SALSA framework was applied to ensure a systematic search and review of the literature, where steps of Search, Appraisal, Synthesis, and Analysis (SALSA) were taken and an additional step of snowballing [22,23]. This search led to the identification of 82 relevant publications that included 57 different indicator sets for SED.

Gunnarsdóttir et al. [11] developed a set of assessment criteria to enable comparative evaluation of the indicator sets. These criteria were based on existing guidelines and checklists for indicator development, particularly the Bellagio STAMP principles [24]. Generally, the criteria reflect characteristics or actions thought necessary to develop a comprehensive and robust indicator set. The six indicator set assessment criteria were the following: transparency of indicator selection, transparency of indicator application, conceptual framework, representative, linkages, and stakeholder engagement. Transparency was thought essential to justify both methodological choices and enable the use of the indicators. The use of a conceptual framework aids in selecting balanced and representative indicators and can improve their organization. A set of sustainability indicators can only be representative if it reflects all three dimensions of sustainability by including economic, social, and environmental indicators. It is important to assess linkages within an indicator set to consider dynamics within the indicator system and eliminate overly correlated indicators. Stakeholder engagement has been found beneficial to capture the relevant issues and develop a representative and comprehensive indicator set.

The results of Gunnarsdóttir et al. 's [11] study show that there is room for improvement regarding the development of indicators for SED. In their research, the necessary steps for developing comprehensive and robust indicators are described. Furthermore, the strengths and limitations of current indicators are identified. Therefore, it is appropriate to create a more suitable approach to indicator selection for SED that builds on these results. A more thorough analysis of Gunnarsdóttir et al. 's results and a new approach to indicator selection are provided in the fourth section of this paper.

4. Results

4.1 Review of indicators for sustainable energy development

The importance of transparency of both indicator selection and application was highlighted in Gunnarsdóttir et al. 's study [11]. An indicator set's credibility and clarity depend on how much information is provided on the indicators themselves, how they were selected, and how they should be applied [6]. A lack of transparency makes it difficult to replicate or use an indicator set and, thus, affects its usefulness [6,11]. For instance, indicators can be misused or misinterpreted without sufficient information and guidance on how they should be applied [24]. The fifth Bellagio STAMP principle revolves around transparency and underscores the necessity of making information and data accessible to ensure that the public understands the indicators and their methodology [24]. Gunnarsdóttir et al. [11] considered an indicator set transparent if their presentation included the underlying indicators of a set, the approach to indicator selection, the methodology for indicator application including the relevant formulas, and data sources. Their review showed that a lack of transparency in both indicator selection and application is common for existing SED indicator sets. For instance, no justifications were provided for the selection of the IAEA's Indicators for Sustainable Energy Development (ISED) or information on how they should be calculated in their original presentation [25]. However, a later version of these indicators, with the updated name of Energy Indicators for Sustainable Development (EISD), included a detailed description of how the indicators were selected and how they should be applied [3]. Transparency was a guiding light when developing the indicator selection approach presented in this study, as detailed in section 4.2. Therefore, arguments are provided for the methodological choices made for the approach, and an emphasis is placed on providing a detailed methodology for indicator application.

Often, conceptual frameworks are used when developing indicators to structure the problem in question [26]. Through a framework, it is possible to organize and make sense of complex issues such as SED [27,28]. These frameworks provide theoretical underpinnings and guide the way indicators are selected [26]. The application of a conceptual framework during indicator development is thought to increase the transparency of the process, minimize potential bias, and increase how representative indicators are of the problem [29]. Four main types of frameworks have been used in the development of SED indicators: causal chain, issue- or theme-based, system dynamics, or a mixed approach of frameworks [11]. These vary mainly in how they structure and interpret SED [11,30]. Some version of a conceptual framework, most often a thematic one, was used to develop almost all of the SED indicator sets assessed by Gunnarsdóttir et al. [11]. Their analysis showed that causal chain frameworks had been abandoned mostly for thematic or system dynamics frameworks. These are more flexible and can capture the complexities and interconnections within SED [11,31]. To use the same examples as above, the original ISED were developed through a causal chain approach, while a thematic framework was used in the development of the later and improved EISD [3,25].

Thematic frameworks are flexible in structure and can capture the multi-dimensional nature of SED [32]. Their main criticism is that inter-linkages or dynamic interactions of different issues or themes are not captured adequately, leading to the over-simplification of complex problems [33]. To tackle this limitation, the UN has emphasized the importance of considering linkages among themes and indicators when applying a thematic framework [3,32]. This recommendation, a thematic framework accompanied by the consideration of linkages, was incorporated into the approach presented below.

Gunnarsdóttir et al. 's [11] fifth assessment criterion emphasized the consideration of linkages within an indicator set. Thereby, the interactions among indicators or components of an energy system can be identified, and overly correlated indicators can be eliminated [11,24]. Similarly, the second Bellagio STAMP principle highlights an analysis of the "system as a whole and the interactions among its components" [24]. Ideally, indicators should be meaningful on their own and together with other indicators of the set [34]. According to Gunnardóttir et al. 's analysis [11], more than half of the SED indicator sets were thought to consider linkages to some extent. They also stated that a more thorough assessment is needed of how this should be done well [11]. Indicator sets developed through a causal chain or system dynamics frameworks were thought to consider linkages between indicators, such as the original ISED [25] and Keirstead's Sustainability indicators for urban energy systems [35]. Other indicator sets that were thought to consider linkages were those that explicitly stated they did (e.g., EISD [3]), evaluated the correlation of indicators to eliminate overly correlated indicators (e.g., Doukas et al. 's Energy Sustainability Index [36]), and analyzed trade-offs between indicators (e.g., HELIO International's Sustainable Energy Watch [37] and the WEC's Energy Trilemma Index [38]). The consideration of linkages among indicators is recommended in the sixth step of the proposed approach to indicator selection.

Sustainable energy development is a complex and multi-dimensional concept, as discussed in the background section above. In its simplest form, SED involves considering the impacts energy development has on society, economy, and environment [1]. An incomplete picture of SED is captured if one or more dimension of sustainability is not represented. Gunnarsdóttir et al. [11] assessed whether social, economic, and environmental indicators were included in the set to analyze how representative indicator sets were of SED. According to their analysis, about 2/3 of existing SED indicator sets had indicators representing all three dimensions, while the remaining third excluded one or more dimensions. The economic aspects of SED were considered by most. In contrast, the social aspects often were not accounted for adequately, e.g., García-Álvarex et al. 's Synthetic Index of Sustainable Energy Development (SISED) [39] and Doukas et al. 's Energy Sustainability Index [36]. Gunnarsdóttir et al. [11] state that a more thorough analysis could be carried out of how representative indicator sets are of SED, including assessing whether an indicator set adequately reflects the contexts where it is applied. While SED's ultimate goal remains the same, actions and challenges on the path towards a sustainable energy future can vary considerably between energy systems, as discussed in the introduction and background section. In his review of the World Bank’s Regulatory Indicators for

Sustainable Energy (RISE), Urpelainen [21] argues that “the World Bank should replace the pursuit of one-size-fits-all best practices and instead focus on generating knowledge about the contextual fit of different policy approaches.” Therefore, a context-specific set of indicators that reflects the relevant challenges and opportunities for SED within a particular setting would be valuable [11]. The proposed indicator selection approach aims to develop context-specific indicators to ensure their representativeness and usefulness to policymakers.

By involving stakeholders during indicator development, it is possible to get valuable insight into the sustainability goals and objectives of different stakeholders and capture a comprehensive and representative picture of the system or problem in question [4]. A discussion with those affected by or who can affect the system in question, i.e., stakeholders, can be particularly useful for analyzing abstract concepts such as SED, especially considering that SED's meaning can vary based on context [4,7,8]. Multiple different benefits of stakeholder engagement have been identified, for instance, building trust and acceptance, increasing comprehensiveness, reducing bias by considering numerous viewpoints, and increasing the relevance and applicability of research [12,40,41]. Shortall et al. argued that: "stakeholder engagement is important in developing tools for assessing sustainability since there tends to be an absence of scientific consensus on the components of sustainable development" [42]. Furthermore, Shortall et al. argued that stakeholders' sustainability goals should dictate what is measured and, thereby, what indicators are selected [43]. By basing indicator sets on stakeholder input, they should be acceptable and of interest to stakeholders, which, hopefully, increases their usefulness and application [11,34,44,45]. Sovacool also recognized the value of stakeholder engagement during indicator development as it enables an analysis of complex concepts concerning metrics, allows for a targeted discussion that can present "insightful knowledge," and leads to the collection of data more recent than can be found in the published literature [46,47].

Gunnarsdóttir et al. 's [11] review shows that the involvement of stakeholders during indicator development has not become standard practice. Stakeholders or experts were engaged in developing only 1/3 of existing SED indicator sets [11]. For instance, it is unclear whether stakeholders were involved in the development of, e.g., Iddrisu and Bhattacharyya’s Sustainable Energy Development Index [31], Global Energy Institute’s International Index of Energy Security Risk [48] and US Energy Security Risk [49], and Marquez-Ballesteros et al.’s Urban Energy Sustainability Index [50]. Nonetheless, stakeholder engagement is becoming more popular with increased recognition of its value [11]. Various approaches to stakeholder engagement during indicator development have been taken. For instance, Sovacool conducted semi-structured interviews, a survey, and a workshop when developing an Energy Security Index [51], experts and relevant stakeholders were interviewed during a review process of the Energy Architecture Performance Index [52,53], and the World Bank's Regulatory Indicators for Sustainable Energy (RISE) are based to some extent on interviews with experts and their answers to a questionnaire [54,55]. For further development of EISDs at the national level, stakeholder consultation is encouraged, although no particular approach to this consultation is

prescribed [3]. An overview of which indicator sets did or did not involve stakeholders and whether they met the other assessment criteria described above can be seen in Gunnarsdottir et al. 's paper [11].

Before engaging with stakeholders, it is valuable to consider what strategy fits the purpose of the activity. Multiple different approaches exist for stakeholder engagement, and new methods are being continuously developed [41]. Generally, stakeholder engagement methods can be split into either participatory (two-way engagement) or informative (one-way) [41]. For the process presented here, a participatory approach is appropriate as the aim of the stakeholder engagement is to get an insight into what stakeholders believe SED entails. Three general approaches to participatory stakeholder engagement are identified from the literature on qualitative methodology and stakeholder engagement, as seen in Table 1. Mixed methods or a multi-method approach to stakeholder engagement appropriate, where one or more methods are chosen that complement each other [56–58]. A mixed-method approach is applied in this study's indicator selection approach to ensure comprehensive data collection.

Table 1
A general overview of approaches to participatory stakeholder engagement

Approach	Brief description	References
Individual interviews	One-on-one, often, semi-structured interviews with open-ended questions that allow for an in-depth analysis of stakeholder views. Multiple interviews are required to capture the opinion of all stakeholder groups, which can be time-consuming and expensive.	[41,57]
Focus groups	The opinion of a diverse group of stakeholders is captured through open-ended questions asked in, for instance, focus groups, workshops, and advisory groups. These are often also semi-structured. Focus groups can lead to constructive discussions among stakeholders, albeit, generally, a less in-depth analysis of individual stakeholder opinion. Not an appropriate approach for topics that can be sensitive or personal.	[41,57,59,60]
Surveys and questionnaires	A more structured approach to stakeholder engagement, usually, with closed-ended questions that can be used to capture the opinion of many stakeholders. It can be more fitting in the later stages of a project, such as to validate the initial analysis, assess whether results are generalizable, and to quantify qualitative results. Often, a cost-effective approach.	[41,57]

According to Gunnarsdóttir et al. 's [11] analysis, the only indicator set that fulfilled all six assessment criteria were the *Energy Indicators for Sustainable Development* (EISD) [3]. The *EISDs* were thought to be "transparent and clear, based within a conceptual framework, representative of the problem in question, consider interconnections within the set, and based on stakeholder input" [11]. Despite being the highest-scoring SED indicator set, the EISD do not seem to be used by many. Gunnarsdóttir et al. [11] argued that the lack of consideration of how the indicators and their results

should be communicated could explain its unpopularity. Effective communication can involve a visual presentation of indicators, storytelling, and transparency, improving the indicators' usefulness and interpretability [28,32,34]. Furthermore, some flaws in the EISD were identified. These include overemphasizing the economic impacts of energy development while undervaluing social ones, demanding data requirements, and lacking institutional indicators [3,6,11,31,61]. The developers of the EISD emphasize that the indicators need to be "read in the context of each country's economy and energy resources" [3]. To an extent, the EISD set is not fully developed until it has been implemented at the country level to reflect country-specific conditions. A "national coordinating mechanism" is suggested to assess the circumstances and identify national priorities that make "use of the widest possible consultation and participation of all stakeholders involved" [3]. Gunnarsdóttir et al. [11] conclude their study with a similar recommendation stating that the EISD set should be used as an initial basket of indicators for further refinement through stakeholder engagement and critical analysis. This recommendation aligns well with the proposed indicator selection approach.

4.2 Overview of the indicator development process

The objective of this study is to present an improved approach to indicator development that builds on established methodology and is rooted in stakeholder engagement. Transparency and clarity of the proposed approach are emphasized as current SED indicators have been criticized for a lack thereof [6,11]. This indicator development process is based on stakeholder input to ensure the relevancy and usefulness of the indicators. Thus, the output of this process is a set of context-specific indicators for SED. Considering the characteristics and objectives within a particular setting during indicator development adds significant value to the indicator set and captures elements missed in global or national-level indices [62]. The main downside of context-specific indicators is that they do not necessarily allow for comparisons of country performances. However, according to van Zeij-Rozema et al., it is possible to compare different indicator sets, even if they are context-specific, when indicators are selected and developed through the same process [62]. Finally, even though the proposed approach is designed for SED indicators, it can be used to select indicators for other aspects of sustainable development and capture what abstract sustainability concepts entail within a particular setting.

The indicator development process presented here consists of seven main steps, as illustrated in Figure 1. The first step of the process involves engaging stakeholders through semi-structured interviews and focus groups to determine what SED involves in that context. In the second step, the interviews are analyzed according to established qualitative methodology to identify emerging themes, stakeholders' sustainability goals, and potential indicators. In the third step of the process, interviewees are engaged again through a Delphi survey to verify the identified results. In the fourth step, these verified results are presented as SED's main themes in the context, which corresponds to an issue- or theme-based conceptual framework. In the fifth step, results are connected to established

indicators to produce a preliminary set of indicators. Pre-determined indicator assessment criteria are applied in the sixth step of the process to ensure the suitability and quality of indicators and eliminate unsuitable ones. This sixth step includes considering the interrelation of indicators and, thus, preventing overly correlated indicators. The seventh and final step involves presenting a finalized set of indicators with enough detail to ensure their usefulness and easy application. Therefore, a mixed-method approach is taken in this process where quantitative and qualitative methods are combined [58].

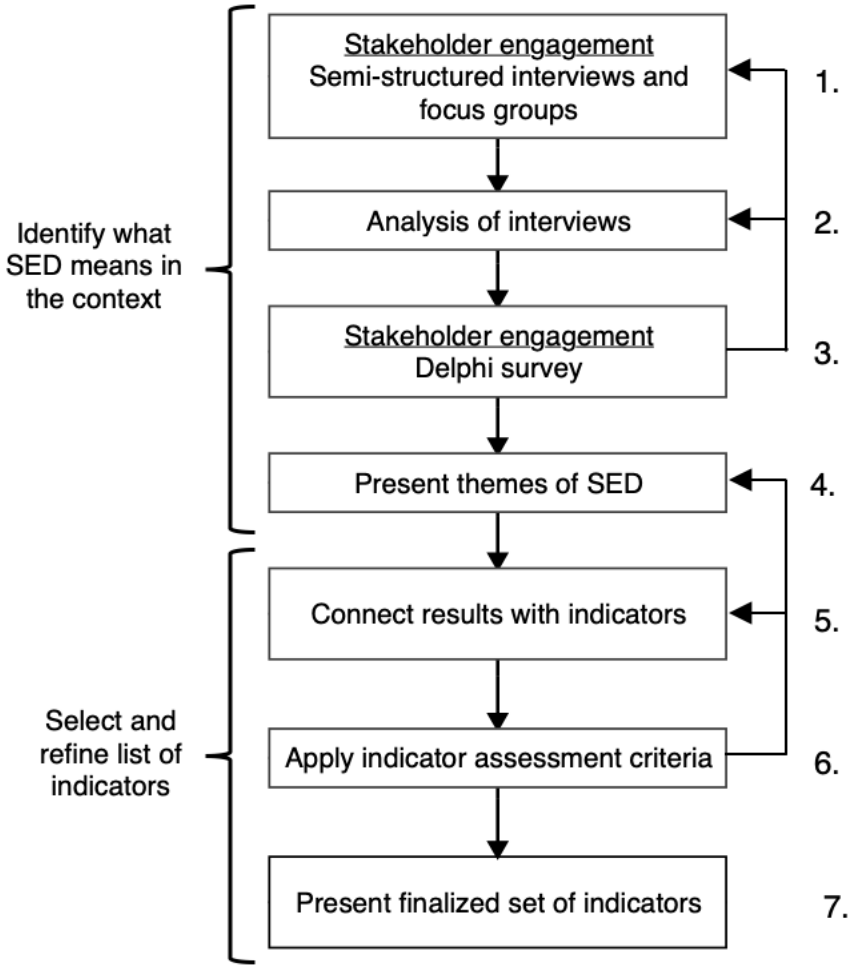

Figure 1: Diagram of the indicator development process and its seven main steps. Arrows shows the progression of the process and indicate that steps can revisited if necessary. Diagram generated by authors based on approach presented by Shortall et al. [43].

The purpose of the stakeholder engagement is to determine what sustainable energy development means to the different stakeholders and, thereby, what it entails in the context. Thus, the indicators can reflect the relevant issues. A combination of stakeholder engagement methods, i.e., semi-structured interviews, focus groups, and Delphi survey, is proposed to capture diverse viewpoints that can provide the most holistic and comprehensive picture of the energy system as possible. The aim is not to reach a consensus among the different stakeholders, but rather capture

different perspectives and get input from every interviewee. The robustness of results is increased by engaging interviewees several times to verify results, albeit, this also increases the likelihood of stakeholder fatigue.

The proposed approach is an iterative process that allows for the repetition of steps if deemed necessary, as indicated by arrows in Figure 1. For instance, the first couple of steps, stakeholder interviews and qualitative analysis, might need to be revisited if the Delphi survey results indicate a lack of saturation in stakeholder views. A more thorough analysis of what SED entails might be required if there is a considerable lack of agreement in stakeholders' answers, and multiple new aspects are added in the survey. This iterative nature of the process even further increases the robustness of results.

Each step of the indicator development process is described in detail in the following sections, along with methodological justifications for choices.

Step 1: Semi-structured interviews and focus groups

A necessary first step to stakeholder engagement is to identify the stakeholders. Freeman defined stakeholders as "groups and individuals who can affect, or are affected by, the achievement of an organization's mission" [63]. For the approach presented here, stakeholders affect or are affected by the energy system where the indicator development process is applied. Several different methods can be used to identify stakeholders, such as mind mapping, brainstorming, generic stakeholder lists, value chain, and life cycle approaches [41]. For this process, a top-down analysis of the system is suggested. A combination of mind mapping and a value chain approach is used to identify the main stakeholder groups. After a trial-and-error period, this combination of methods was thought to have a broader scope and include more stakeholder groups than one single approach did. For instance, if only a value-chain approach is chosen, influential stakeholders of the system, such as international and national-level decision-makers, are not necessarily included. A generic initial mind-map of the stakeholders of an energy system can be seen in Figure 2. There, stakeholders are split into two main groups. Firstly, the "value chain" that captures the supply and demand side of the energy system. Secondly, "value chain influencers & enablers," representing those that can affect or are affected by the system but are not part of its value chain. This mind-map should be further expanded to include more specific sub-groups that reflect the energy system in question and, if necessary, update over-arching groups.

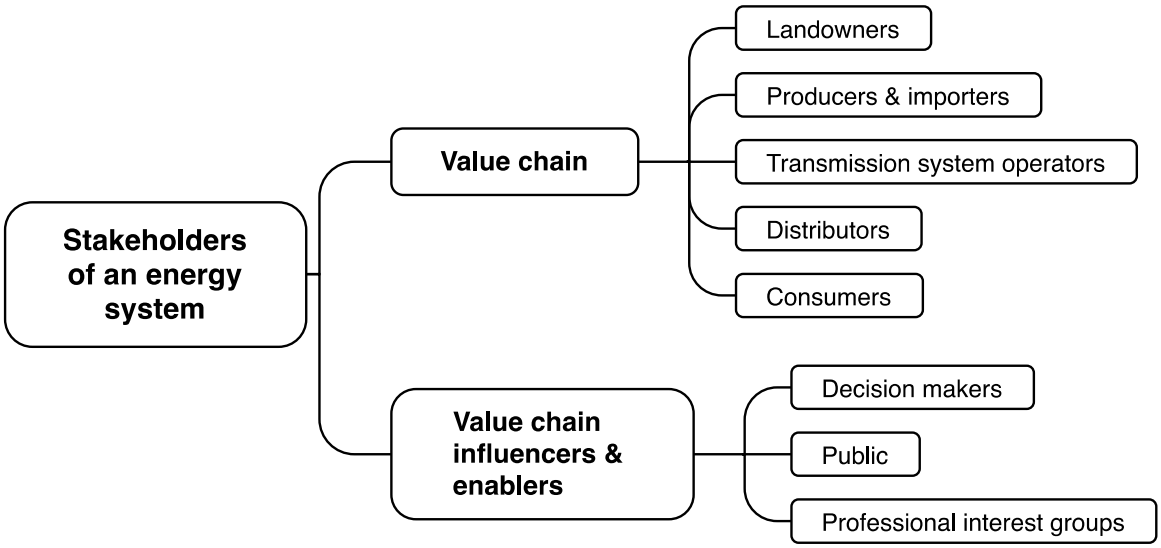

Figure 2: A generic mind-map of the stakeholders of an energy system. This mind-map should be further developed to reflect the energy system in question.

In this approach, purposeful sampling is carried out with maximum variation to ensure the selection of a diverse group of stakeholders that can provide a comprehensive and balanced picture of the energy system [41,57]. An attempt should be made at having an equal gender ratio and interviewees of a variable age range. A stakeholder map can aid in the selection of a balanced group of interviewees that represent the different stakeholder groups. In this approach, stakeholders representing each of the sub-groups of the "value-chain" and "value chain influencers & enablers" should be engaged, see Figure 2.

Generally, more informed stakeholders of the system that are more directly involved in the workings of an energy system are found within other sub-groups than the public. By interviewing more informed stakeholders individually, a greater emphasis is placed on their expert knowledge than the input of stakeholders with perhaps less understanding of the system. Representatives of all sub-groups except the one for the public are considered experts of the system and interviewed through semi-structured individual interviews. The public's opinion is captured through focus groups, both at locations where energy development has directly affected the local community and where impacts are less direct.

Focus groups have been found to lend themselves well to exploring topics that are not necessarily well understood by participants as group dynamics can aid with a discussion [16]. When selecting participants for the focus groups, a community-based participatory approach is suggested where a member or organization of the community is involved in finding participants for focus groups [64]. Thus, a representative group of the community is engaged, the researcher's bias in selecting participants is reduced, and financial costs are minimized [64].

Before stakeholders are engaged, an interview guide is developed consisting of open-ended and non-leading questions that start a conversation on SED [65]. The individual interviews and focus groups should be semi-structured to allow for the flexibility to clarify the interviewee's answers and delve further when deemed necessary and of particular value [57]. The purpose of these interviews is to assess what SED means in the context in question, which involves asking about the current status of the energy system and identifying the main challenges and opportunities for SED. If the opportunity arises, it is also possible to invite stakeholders to reflect on potential indicators.

The output of these interviews gives an insight into what the stakeholders believe to be essential for SED and what challenges or uncertainties are facing the energy system – enabling a situated study of SED [7]. No more interviews are needed once a representative from each stakeholder group has been engaged, and saturation in interviewees' responses has been reached where no new ideas or perspectives are being introduced. The outcome of the process, indicators for SED, should reflect stakeholders' sustainability goals identified from these interviews [43]. Before interviews, the interviewees' permission to record the interview should be obtained to allow for a transcription of interviews. During stakeholder engagement, one needs to be aware of the interviewer's influence on interviewees or stakeholders and the interviewer's own bias when collecting and analyzing the data [57].

Step 2: Analysis of interviews

A grounded theory approach is proposed for the analysis of interviews. Grounded theory is a systematic methodology for social research with the central aim of discovering theories from qualitative data [66]. The methods prescribed by this approach were considered suitable for the indicator development process as they are flexible enough for the researcher to be able to adapt their data collection approach if necessary. Furthermore, this approach enables a systematic analysis of qualitative data. A combination of maximum variation sampling with a grounded theory approach has been found useful as: "any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared dimensions of a setting or phenomenon" [66,67].

The main steps of the grounded theory approach for data collection and analysis are seen in Figure 3 below. The central research question presented here is, "what do stakeholders believe SED entails?" This question should be kept in mind throughout the stakeholder engagement process. According to grounded theory, data collection and analysis should be a "simultaneous process," as indicated by the circle in Figure 4 and the iterative arrows in Figure 2 [57,66]. Therefore, interviews should be transcribed as soon as possible. Thus, the remaining data collection can be guided by prior interviews' successes or failures and, for instance, used to try out emerging themes or ideas on interviewees [57]. Transcribed interviews are coded and, subsequently, similar codes are grouped to construct initial categories or themes [57,68]. Through the constant comparison method, patterns in

the data are found, and themes are further refined [66]. Thus, frequently mentioned issues are translated into codes and themes. Eventually, the grounded theory process leads to the generation of theory [66].

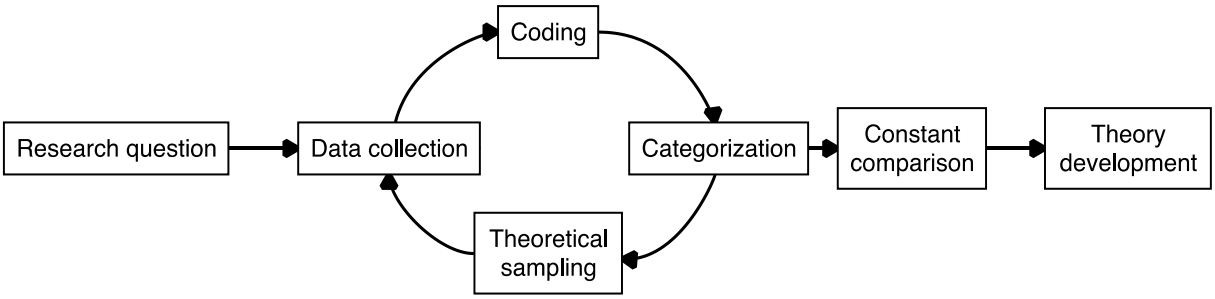

Figure 3: Diagram showing the main steps of qualitative data collection and analysis according to grounded theory. Diagram generated by authors based on methodology by Glaser and Strauss [66] *and Strauss and Corbin* [68].

For this process, the generation of a theory is not necessary. The purpose of this analysis is to identify what stakeholders believe SED should entail in the context. An emphasis is placed on identifying the various goals and necessary actions needed to realize SED according to stakeholders. Shortall et al. argued that sustainability goals serve as a suitable first building block for indicator development [43]. Therefore, identifying themes that correspond to stakeholder goals and associated actions suffices in this approach, and a theory is not needed.

Step 3: Delphi survey

Following a qualitative analysis, a Delphi survey is developed to verify the identified themes further. While the semi-structured stakeholder interviews served as a comprehensive collection of stakeholder input, the Delphi survey aims to reduce and refine qualitative results. The Delphi survey technique is a structured stakeholder engagement method consisting of two or more rounds of anonymous surveys with controlled feedback between rounds. The premise of Delphi surveys is that a structured group of individuals is more accurate than individuals or unstructured groups [69]. The technique is widely used in various fields to obtain the opinion of diverse stakeholders or experts, generally to reach a consensus among the group [69,70]. For instance, the Delphi technique can be used as a forecasting method for scenario building based on expert or stakeholder input [71]. Several examples can be found where a Delphi survey is used in the development of sustainability indicator, for instance; Shortall et al. for a sustainability assessment framework for geothermal energy projects [43], Jónsson et al. for soil indicators for sustainable development [72], and Lim et al. for indicators for Australian road infrastructure projects [73].

For this process, the purpose of the Delphi survey is to get interviewees to verify identified themes and, potentially, add missing elements of SED that might not have been mentioned during the interviews. If potential SED indicators were mentioned during the interviews, it is possible to get stakeholder feedback on those through the Delphi survey. Two rounds of a structured online survey

are sent to interviewees, where they are asked to assess the importance of the themes and sustainability goals for SED on a Likert scale from 1-5. A minimum average score of importance for themes or indicators to pass between rounds needs to be determined before sending out the survey. The first round of the Delphi survey allows for the suggestion of missing SED elements. Before the second round, the overall results of the first round are sent to participants. Feedback between rounds is an essential feature of a Delphi as it allows participants to reassess their initial responses with the knowledge of the opinion of others [71]. The second round includes updated themes according to results from the first round and comments from interviewees. For instance, themes that do not reach the pre-determined minimum score of importance and, thus, are not considered significant for SED in this context could be deleted between rounds. The average rating of importance should not only be considered but also whether answers vary significantly. Shortall et al. suggested that the standard deviation of responses could serve as a measure of agreement in the participants' answers [43].

The results of the Delphi survey are verified themes of SED according to stakeholders. These results serve as the basis for the selection of sustainability indicators to measure progress towards SED. The researcher might need to revisit previous steps of stakeholder engagement if multiple new elements are in the first round of the survey which indicates a lack of saturation in stakeholders' views or if there is a significant lack of agreement in the participants' answers, as indicated by iterative arrows in Figure 1.

Step 4: Themes of SED

The fourth step of the process involves presenting the themes of SED as analyzed from the interviews and verified in the Delphi survey. These verified themes and stakeholder goals align with a thematic conceptual framework for indicator development, where the main issues of a topic are organized into its underlying themes or issues [30]. Conceptual frameworks are found to clarify and increase the transparency of indicator selection [11,32]. When using a thematic framework, problems are often grouped into the three pillars of sustainable development; economic, social, and environmental. As mentioned in section 4.1, the main criticism of thematic frameworks is that linkages between issues are often not considered, leading to oversimplification [10]. Linkages between indicators and underlying issues of SED are considered in step 6 of this process to address this flaw. A thorough analysis of what SED means in a particular context-based on stakeholder input minimizes bias in selecting indicators and makes the indicator set more representative of the problem. The SED themes presented in this fourth step of the process have been validated. Therefore, no previous actions need to be revisited, as indicated by a lack of iterative arrows in Figure 1.

Step 5: Connect results with indicators

The primary purpose of this fifth step is to produce an initial set of indicators. Some potential indicators might have been suggested during stakeholder engagement that can be used as a starting point. In this step, results are connected to established indicators that can measure progress towards

the identified themes and sustainability goals. To find suitable indicators, an analysis of the multitude of different indicators and indices for SED that exist is necessary. The review of existing SED indicator sets carried out by Gunnarsdóttir et al. [11] is useful during this step to find high-scoring and potentially valuable indicators. As described earlier, the EISD can serve as a good starting point for further refinement through stakeholder engagement to reflect the context in question [3,11]. Indicators that lack clarity on what they are set out to measure and how that should be done are not useful [11].

If no established indicators represent a particular theme or sustainability goal appropriately, an attempt should be made to develop a new indicator. Multiple different indicator criteria exist to aid in developing indicators, as discussed in the following step of this process. These criteria can be used to guide the development of a new indicator. The need to develop new indicators is expected to be minimal since such a vast number of indicators for SED exist.

Step 6: Apply indicator assessment criteria

At this point, multiple indicators have been connected to the themes and sustainability goals, but their quality has yet to be assessed robustly. This sixth step of the process involves refining the preliminary list of indicators to ensure the quality of individual indicators and consider how representative the indicator set is of the problem in question. This step will lead to the elimination of indicators based on the below pre-defined criteria. Additionally, it might identify gaps in representation where new indicators need to be added to the set.

Numerous criteria or checklists exist that enable a systematic analysis of the suitability of indicators, e.g., Bellagio STAMP principles and OECD's criteria for indicator selection [24,74]. These often consist of characteristics found common in useful indicators and, thus, deemed necessary to ensure an indicator can serve its purpose [44]. A review of existing indicator criteria allows for the identification of common themes and the creation of more robust indicator assessment criteria. The best and most suitable indicators can be identified using such a framework, and indicators missing the necessary characteristics can be adjusted or eliminated. The indicator assessment criteria proposed for this process can be seen in Table 2. These criteria should be used to assess the initial set to ensure the quality and suitability of indicators. In the end, all indicators of the set need to meet these criteria.

Table 2
Indicator assessment criteria based on commonly used criteria for indicator selection

Criteria element	Brief description	References
Interpretability	Simple, easily interpreted, and applied.	[6,24,29,34,44,74–77]
Trends	Sensitive to changes and shows trends over time.	[24,29,34,44,74,75]
Grounded in research	Theoretically sound and measured based on standardized measurement methods that enable international comparison of indicators.	[6,24,34,44,74–76,78]
Data availability and quality	Based on data of good quality that are available or readily collected. Data are collected regularly and reported with a minimal time lag to report current information.	[6,24,78,79,28,29,34,44,74–77]
Linkages	The interrelation of indicators should be considered to eliminate correlated ones. Indicators should be meaningful on their own as well as together with other indicators of the set	[11,24,28,34,44,80]

A few common criteria for indicator selection are not included in this list, such as whether indicators are representative, relevant to policy, acceptable and of interest to stakeholders, and whether a transparent methodology and conceptual framework were used in their development. The process proposed here should produce indicators that already meet these criteria.

If an indicator is found unsuitable or overly correlated with another one, it might be necessary to revisit previous steps. For instance, step 4 - themes of SED to recall what exactly the indicator was supposed to capture and step 5 to review how and why a particular indicator was chosen. The iterative arrows in Figure 1 show this possibility.

Step 7: Finalize set of indicators

If this process is followed, it should produce a comprehensive and context-specific indicator set for SED. As discussed in section 4.1, the communication of indicators and their results is important to ensure their usefulness and application by stakeholders [32,75] [11]. Effective communication includes disclosing the methodology for both indicator selection and application, such as underlying indicators of the set, the necessary formulas, and data sources [11]. According to the Bellagio STAMP principles, effective communication is enabled through: "use of clear and plain language, present information fairly and objectively that helps to build trust, use of innovative visual tools and graphics to aid interpretation and tell a story, and make data available in as much detail as is reliable and practicable" [24]. The OECD, similarly, highlights the significance of visualization of indicator results as it can influence interpretability [28]. Graphics of the results can be useful to a larger group of stakeholders instead of raw data that might be too technical [34]. These graphics should be accompanied by short summaries or explanations for general stakeholders, while decision-makers or key influencers could receive more detailed descriptions when appropriate [34]. The utilization of a thematic framework helps with organizing the indicators and connecting them with

relevant issues. Furthermore, a thematic presentation of indicators lends itself well to being connected with relevant policy processes and goals [32].

A periodic review of indicators is necessary to ensure that the indicator set captures the most pressing SED issues at the time. The 8th Bellagio STAMP principle highlights this point, which states that an indicator set should be "subject to continuous review and revision" [24]. SED is a relatively young concept that is still evolving to some extent, highlighting the necessity of a regular review of an indicator set [13]. This review could involve reiterating some prior steps of the above process, such as a repetition of the Delphi survey, to ensure the indicator set's continued relevance. Periodic stakeholder engagement and repeated data collection could enable a longitudinal study of stakeholders' views of energy development [58].

5. Discussion

If the proposed approach for indicator selection for SED is followed with rigor and consideration, the six criteria for indicator set assessment laid out by Gunnarsdóttir et al., and discussed in section 4.1 above, should be met [11]. The transparency of indicator selection should be ensured by using the process itself. The clarity of the indicator application should be sufficient since the necessary indicator methodology and data sources are provided, as instructed in the seventh step of the process. In the fourth step of the process, qualitative results in the form of SED themes are connected to a thematic framework and, thus, a conceptual framework is used to frame the problem. In the same step through the conceptual framework, the representation of the social, economic, and environmental impacts of SED should be examined. Linkages are considered in the sixth step of the process, as one of five indicator assessment criteria to ensure the suitability of indicators. Finally, the entire process is built on stakeholder input. A diverse group of stakeholders is engaged three different times through both interviews and a survey to ensure the robustness of results. Hence, if the steps of the proposed approach to indicator selection are followed, a comprehensive, robust, and context-specific indicator set for SED should be produced.

What is unique about the proposed process is the fact that both quantitative and qualitative methods are used. First, qualitative data are collected through interviews that, subsequently, are quantified through the Delphi survey. In the end, qualitative methods are used to produce a quantitative tool – indicators. Generally, these two research approaches are not mixed, sometimes referred to as the "quantitative-qualitative divide" [81,82]. Nonetheless, some have started to recognize the value of integrating the two for a more robust analysis or "to fully understand their phenomenon of interest" [81]. For instance, a theory can be developed through qualitative research, especially when using the grounded theory approach, and then this theory can be tested through quantitative methods [81]. The argument made here is that the two approaches, quantitative and qualitative, complement each other to produce a more robust set of indicators.

One of the main strengths of this process compared to the established methodology for indicator selection is the increased transparency of indicator selection, where all the underlying steps are laid out and justified. A common criticism of current approaches is the lack thereof [11]. Increased transparency of indicator selection builds credibility and legitimacy while reducing the researcher's bias in the process [6]. Furthermore, the usefulness and potential application of the methodology is increased [24]. The iterative nature of the process where steps can be revisited if necessary, such as a lack of saturation of stakeholder views, even further increases the robustness of the process.

Another strength of this process is the structure provided for stakeholder involvement. Multiple benefits of increased stakeholder engagement have been identified, as discussed in section 4.1 above. Many argue for the necessity of stakeholder engagement during indicator development; nonetheless, this has not become standard practice [11,34,44]. In this process, stakeholders are engaged from the beginning to evaluate what SED means within a particular setting and provide a base for indicator selection. Then, stakeholders are engaged again to verify the identified results. This approach is particularly useful in the analysis of complex and multi-dimensional concepts such as SED. The process promotes the selection of a representative and comprehensive indicator set while reducing the potential for the researcher's own bias in both the qualitative analysis and indicator selection. A diverse group of stakeholders is engaged to capture different perspectives of SED. Thereby, stakeholders' trust in the process is built, which might eventually lead to the application of the indicator set and consideration of its results by many different stakeholders. For indicator sets to be used, they need to be acceptable and of interest to stakeholders and the public [34,44].

The stakeholder engagement in this process can lead to multiple by-products of the indicator selection process. For instance, a thorough analysis of the relevant stakeholders, their opinions regarding energy development, and an understanding of what SED involves within the context can be valuable. These by-products can inform decision-making and the development of energy policy towards SED that is acceptable to stakeholders. Through the Delphi survey, it is possible to determine the level of agreement among stakeholders on the different underlying issues of SED. It can be useful to policy- and decision-makers to know whether stakeholders agree on, for instance, the necessity of a particular action or if there are some controversial topics related to energy development.

The indicator selection approach presented in this study is fairly generic and could be applied to develop indicators for other topics related to sustainable development. The only adjustments that would have to be made are a new version of the stakeholder map and a review of the relevant existing sustainability indicators. A process rooted in stakeholder engagement is useful to further understanding of abstract sustainability concepts, such as SED [83]. The first four steps of the proposed process can be taken solely if the goal is only to capture what a sustainability concept involves within a particular setting and not develop relevant indicators. Therefore, the generalizability of the proposed approach is considerable, both for the development of any sustainability indicators and context-specific analysis of whatever abstract sustainability concept. Scherhaufer et al. [84]

highlight that there is “a need for integrated ways of cooperation between stakeholders, policy-makers, and researchers to produce knowledge which is usable in both a scientific and practical context.” The approach presented in this study could meet that need to some extent.

When applying this process, researchers should watch out for a few potential pitfalls of the process. Seven indicator development steps are outlined, which can lead to a lengthy and costly process. Stakeholder engagement is both one of the main strengths and potential downfalls of the presented method. Depending on the approach, stakeholder engagement can be time consuming and expensive. Therefore, researchers need to spend time before stakeholder engagement to carefully select a balanced and diverse group of interviewees, ideally with stakeholders representing multiple stakeholder groups. The number of interviews necessary can be reduced through careful planning, and saturation in interviews might be reached more quickly. Furthermore, engaging the same stakeholders several times can lead to stakeholder fatigue [85]. The fifth step of the process, where results are connected to established indicators, can also be time-consuming. By looking at reviews of indicator sets such as the one done by Gunnarsdóttir et al., this process can be sped up by, for instance, eliminating indicator sets that lack the necessary transparency from further analysis [11]. In this process, an attempt is made to reduce any potential for the researcher's own bias in selecting indicators. Nonetheless, there is always some opportunity for this. Researchers should be aware of their own bias throughout the process, particularly in the final steps where stakeholders do not reaffirm results.

One step that is not included in this process, but perhaps should be, is to connect indicators with policy targets or benchmarks. This process is always more complicated for qualitative indicators that might not have a quantitative goal. Nevertheless, when possible, it would be beneficial to compare indicator values to the relevant targets and benchmarks [24]. Sometimes, indicators can also lead to the creation of targets and baselines [34]. As mentioned above, one of the strengths of a thematic framework is that a thematic presentation of indicators or a problem lends itself well to being linked with policy processes and targets [32]. Identifying and connecting relevant targets and benchmarks with the indicators would require some additional analysis that is not included in the process presented here.

This indicator selection process does not necessarily lead to the creation of an index that can be presented as a single score. Creating an index requires assigning weights to indicators and evaluating the significance of indicators in relation to each other. Weighting can be politically sensitive and lead to subjectivity, especially when indicators are qualitative and quantitative [86]. However, presenting the results of an indicator set or index as a single score can be of value. For instance, the status of complex and multi-dimensional problems such as SED can be communicated clearly to decision-makers and stakeholders and allow for comparisons between energy systems [28]. However, when reporting a composite index, the status of an entire system often is shown, but not its underlying dimensions [72]. A lot of information can be lost through aggregation due to the

"information iceberg" effect [87]. Therefore, if a composite index is created, the underlying indicators and their scores should be provided to allow for further analysis.

As discussed in section 3, the approach to indicator selection proposed in this study is based on a review of existing SED indicator sets carried out by Gunnarsdóttir et al. [11]. Several limitations to that study were identified. These are related mainly to the indicator set assessment criteria applied in the study, including how they were evaluated and that some important criteria were missing, such as effective communication. Furthermore, there is always the possibility that some existing indicator sets for SED were not found through the literature review. These faults of the review could have affected the development of the proposed indicator selection process.

6. Conclusions

Comprehensive and robust indicators are needed to track progress towards sustainable energy development. This study aimed to present an approach to the development of indicators for SED. A transparent iterative indicator development approach was proposed with stakeholder engagement at its heart to ensure that indicators are representative, comprehensive, and useful to stakeholders, and to reduce bias in the selection of indicators. A mixture of qualitative and quantitative approaches to get the best of both worlds even further enhances the process. Through this process, the emerging issues of SED and stakeholders' objectives are identified, which can shape the development of sustainable energy policy. The monitoring of such policy and relevant actions would be enabled then through the resulting indicator set. Therefore, the methods presented here should be of practical value to policy and decision-makers. The importance of transparency and stakeholder engagement for indicator selection is highlighted throughout this process. The same applies to sustainable energy policy development or policy development in general. Public participation is essential, if only to increase the relevance of policy actions and promote stakeholder acceptance. Even though the process presented here is linked to SED, it could be applied to develop indicators for any abstract sustainability concept. The first few steps of the process could also only be taken to further understanding of a sustainability concept within a particular setting. A natural next step is to implement the process somewhere for the development of an indicator set for SED and, thereby, demonstrate its usefulness.

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