C3 - Regional sustainability assessment of Energy Systems: Integrating stakeholder perspectives and conditions on a regional scale

AUTHORS

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Summary

To reach carbon neutrality a fundamental transition of the energy system is required. The transformation process is accompanied by far-reaching ecological, social and economic effects. These occur on different scales and depend on the specific design of the energy transition. By means of integrative sustainability assessments, the effects can be analysed comprehensively and estimated in advance. The paper presents the concept of an ex-ante integrative and transdisciplinary approach, which supports the sustainability assessment of possible future energy systems and the respective transition pathways. The focus is on regional energy systems, since a further decentralization of generation and transport capacities is to be expected. The concept integrates local specifics and perspectives through the involvement of stakeholders during several assessment steps. It is applied in a pilot region in northern Germany, where renewable energies already dominate the supply sector.

Therefore, the project's findings can be tested today under future conditions. The findings can support decision-making processes in political contexts, since different transition pathways can be compared adequately. Furthermore, the findings can facilitate the implementation of energy infrastructure projects. In this context, the results of the approach can be used for communication in order to promote local acceptance, and thus accelerate planning and approval processes. Possible regional reservations could be anticipated and taken into account for strategic consideration.

KEYWORDS

Regional sustainability assessment, energy scenarios - Integrative Concept of Sustainability (ICoS - stakeholder involvement

1. Introduction

In recent years the EU and Germany have announced ambitious climate goals to become climate neutral by 2050 and 2045 respectively. To achieve these goals, a fundamental transition of the energy system and further changes in society and the economy are necessary, and have already begun. In order to replace today dominant fossil fuels, the backbone of the future energy supply will be electricity mainly based on solar PV and wind. This is expected to lead to an increasing demand for spatial and temporal balancing, new business models and new consumption patterns, to name only a few of the expected adjustments. Inter alia, since renewable energy supply requires more decentralized installations, considerable and regionally differing alterations are expected. While, for example, surface mining for lignite is planned to be stopped, wind turbines and solar PV will be expanded in many regions, as well as storage facilities and electric grid assets. Moreover, new infrastructures such as electrolysers for the production of hydrogen are expected to be installed. All in all, this may not only induce changes in regional landscapes, but may also impact further environmental aspects and social and economic structures.

Sustainability assessments can play a pivotal role for monitoring and analysing these changes at all transition stages. Hence, sustainability assessment is not only induced by the growing public and political interest in the topic, but also by the necessity of a holistic evaluation to prevent other non-sustainable developments. Thereby, a global perspective of sustainability prevents neglect of the externalization of unfavourable processes.

To encourage regional sustainability assessment, in this work a systematic framework is presented to perform it without disregarding the global view. For this, the Integrative Concept of Sustainability (ICoS) is adapted to the regional context. The holistic approach is first and foremost supposed to provide information as objectively as possible. Conducted prospectively, in a second step this information can strongly support decision-making. Due to the holistic design, the field of possible users of the concept is wide-ranging. It can deliver new insights for researchers and provide an overview for policymakers, public administrations and energy companies. Moreover, it can facilitate communication and participation processes for local communities.

The regional orientation facilitates the identification of local disparities and awareness of the distribution of effects. It supports the realization of global or national development goals by translating them into on-site implications. This can benefit the prediction of local acceptance or resistance, but may also increase acceptability by the inclusion of regional stakeholder perspectives.

This work is presented as follows: In chapter 2 the general concept of ICoS is described, with concrete instructions for its application. In chapter 3 an example of implementation within the project ENSURE [1] is described; practical core issues are presented and underlying theoretical considerations are put into practice. The closing chapter gives first conclusions on the concept and an outlook for future developments.

2. Regional sustainability assessment

2.1 Integrated Sustainability Concept (ICoS)

The concept for regional sustainability assessment proposed in this work is based on ICoS and adapts it to a regional application. ICoS takes a holistic and integrative perspective on sustainability [1]. This includes the well-known economic, ecological and social dimensions. Conceptually ICoS combines the Brundtland report, the Rio documents and further discourse on sustainability. It is based on three constitutive elements: inter- and intragenerational justice, a global perspective and anthropocentrism. These elements are transferred into three goals that can be perceived as necessary conditions for sustainability, which itself is defined as ensuring minimum standards for a dignified life in the long term. The goals are designed to be globally valid. Each of the goals is concretised by five rules (Table 1. The rules are not intended to be infinitely valid but to be adapted in the future [2].

The first goal, 'securing human existence', focuses on the individual. It aims to cover the aspects that directly influence people's living conditions. Included topics are human health and the satisfaction of basic needs like food, water and habitation. Sufficient income from freely undertaken work, and a just distribution of access to resources between people of different generations and regions are also considered.

The second goal, 'maintaining society's productive potential', looks at capabilities of the community over time. It considers natural resources as well as artificial infrastructures but also knowledge. In this context, the term 'natural resources' exceeds resources used today, and includes possible applications in the future. Both the direct use of nature and the indirect use as a sink are considered.

The third goal, 'preserving society's options for development and action', is designed similarly to the second one, but instead of resources and knowledge it focusses on the potential for social cooperation. This includes the possibility for every individual to participate in decision-making, as well as cultural aspects to be preserved. It also considers how individuals interact, and thereby calls for fairness, solidarity and non-violence.

Goals		
1. Securing human existence	2. Maintaining society's productive potential	3. Preserving society's options for development and action
Rules		
1.1 Protection of human health	2.1 Sustainable use of renewable resources	3.1 Equal access for all people to information, education, occupation
1.2 Ensuring satisfaction of basic needs	2.2 Sustainable use of non-renewable resources	3.2 Participation in societal decision-making processes
1.3 Autonomous subsistence based on own income	2.3 Sustainable use of the environment as a sink	3.3 Conservation of cultural heritage and cultural diversity
1.4 Just distribution of chances for using natural resources	2.4 Avoiding technical risks with potentially catastrophic impacts	3.4 Conservation of the cultural function of nature
1.5 Reduction of extreme income or wealth inequalities	2.5 Sustainable development of human-made, human and knowledge capital	3.5 Conservation of social re-sources (tolerance, solidarity, etc.)

Table 1 - ICoS goals and rules

The concept has been applied in several contexts and countries. For example, on energy topics in Germany [3,4], biorefinery in Austria [5] or water resource management in Indonesia [6].

2.2. Assessment Approach

The proposed assessment approach can be divided into individual steps. Figure 1 shows an exemplar scheme of the evaluation. In practice, the specifications to be made at the beginning follow an iterative process, so that individual process steps are repeated and adapted through several feedback loops.

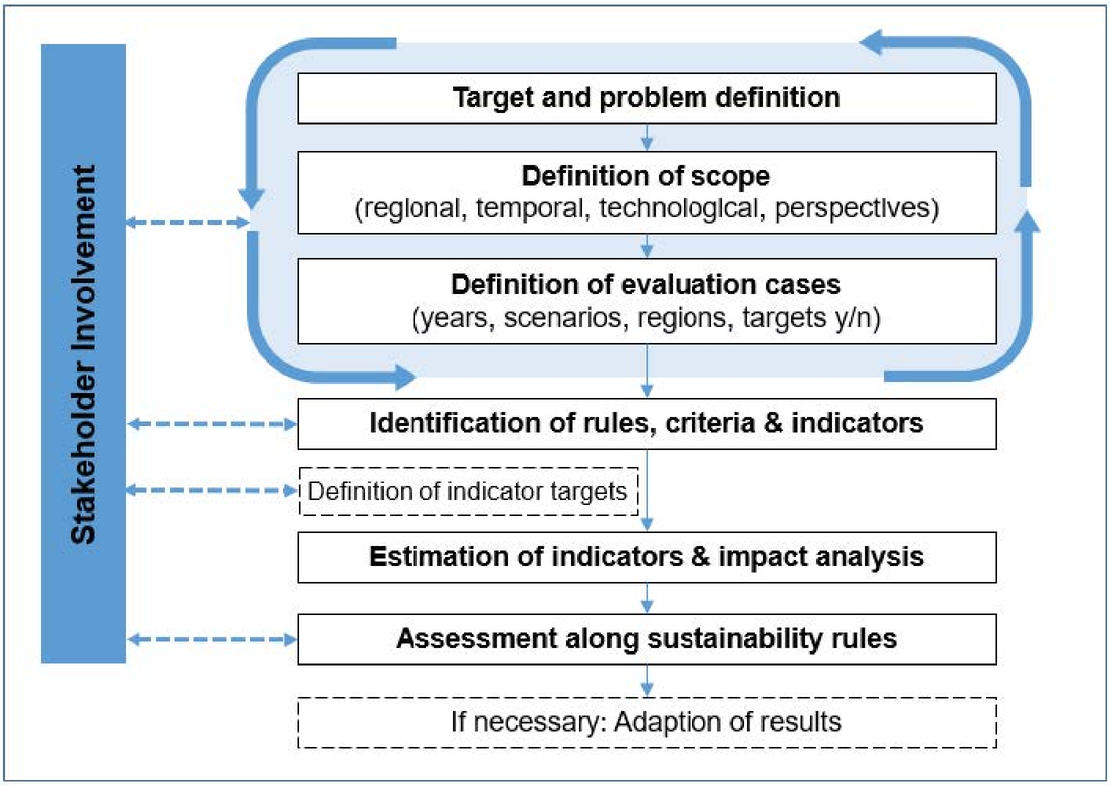

Figure 1 - Scheme of the assessment approach

Target and problem definition

In the first step of a sustainability assessment the target(s) and central questions should be defined. This step appears trivial, but a clear definition is vital for the following steps, since many decisions have to be made. Clear targets can provide orientation for these processes.

Stakeholder involvement

A characteristic of the concept is the involvement of stakeholder and civil society, i.e. the use of a transdisciplinary approach. The involvement has several advantages: in addition to informing people in the region, the inclusion of stakeholders allows for utilization of their regional knowledge and experience. This facilitates the recording of regional specifics, wishes and concerns, and thereby increases the legitimacy of the assessment. As shown in Figure l, stakeholders can be consulted during several steps depending on the context of the study. The more politically controversial the undertaking is, the earlier we suggest calling in stakeholders. However, stakeholders' opinions are not necessarily representative. Therefore, consideration of the stated content and responsibility for the assessment ultimately lies with the experts conducting the study.

Definition of scope

The question, 'what should be assessed?' is closely related to the first step. The definition of scope is usually subdivided into regional, temporal and technological dimensions. For regional sustainability assessments, the regional delimitation is essential. Practical aspects like data availability can play a role in this process.

Administrative units have the advantage that a large variety of statistics are available. Since these statistics usually can be aggregated, the aspect of data availability tends to widen the regional scope. On the other hand, one goal of the regional assessment is to distinguish preferably homogenous regions in order to compare them and keep the accuracy high. This homogeneity-aspect typically leads to smaller regional scopes, so that the combination of both approaches leads to the adequate regional scale.

Regarding the temporal dimension, ex-post, present age and ex-ante assessments are possible. In many cases, the scenarios or political goals to be evaluated already define the temporal scope. The technological scope is strongly dependent on the objective of the assessment, and requires the definition of clear system boundaries. Common categories for differentiation are generation, transport, and storage and usage of energy, but further categories can also be used. To avoid bias, cut-off-criteria should be defined consistently. For example, if electricity and gas are to be investigated and the electric grid is included in the assessment, gas infrastructure should not be neglected.

The definition of space and technology is closely related to different evaluation perspectives. To assess economic, ecological and/or social effects that are interrelated with the energy system, different perspectives have to be considered. Effects can be perceived as demand- or supply-driven, they can occur locally (in the study area), or outside the study area (supra- regional).

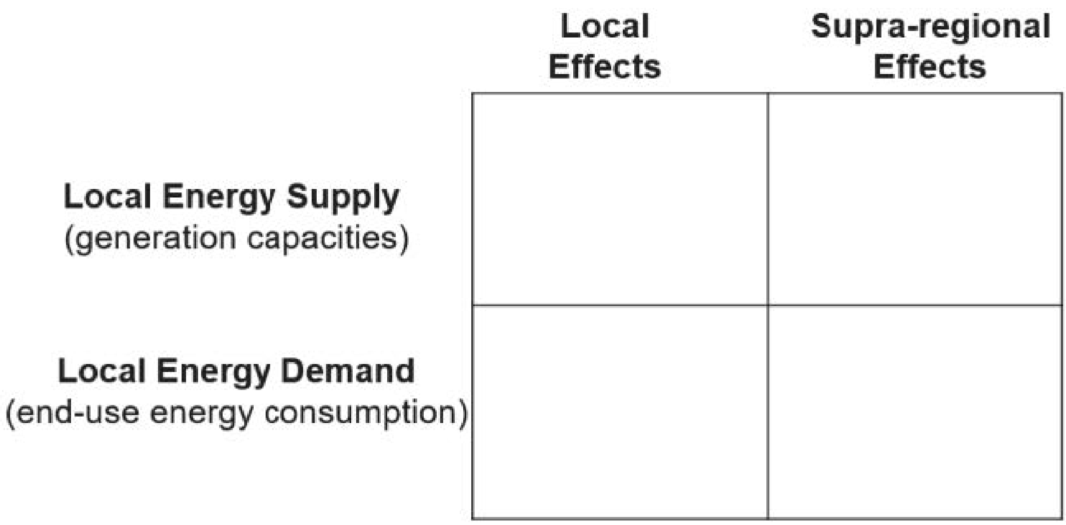

Figure 2 - Differentiation of evaluation perspectives

We suggest applying two different perspectives: a local one and a demand-orientated global one. The local perspective includes everything that happens in the region. From a technical point of view, from this perspective every asset of the energy system that is located in the research area is included. Practically, in many cases it is not possible to capture every asset, but this approach can serve as a guideline. Of course, it is not only the direct effects of these assets, like emissions or land use, that are considered, but also secondary effects and the different interdependencies, such as local acceptance or local added value. The target of applying this perspective is to capture as much as possible of the regional effects of the energy system. In contrast, the demand-oriented global perspective only includes the effects of energy supply for the actors in the study area, and not what the regional actors supply to extra-regional ones. It considers effects that appear worldwide to avoid neglecting burden-shifting. Here, the target is to include all the impacts that follow from the demand of the regional actors.

Definition of evaluation cases

The definition of evaluation cases must be distinguished from the definition of scope. Evaluation cases describe the possibility that different variants can be examined and evaluated for an evaluation object. These different versions can vary in the above-mentioned dimensions of time (e.g. today and 2030), space (e.g. district A and district B) or technology (e.g. fossil-based and renewable-based). If a comparison to (political) goals is made, the comparative case can be perceived as a hypothetical system that fulfils these goals.

Identification of rules, criteria and indicators

In this step, the sustainability rules of ICoS which are relevant for the system under review have to be identified. The rules are described by specific criteria and are operationalized using individual indicators. Individual indicators can address several criteria and rules. The selection process of criteria and indicators can be divided into a literature-based and a transdisciplinary approach, that are to be combined. For the literature-based approach, existing indicator collections and further literature on energy systems and sustainability give an overview of criteria and proven indicators for the relevant topics [e.g.7]. The transdisciplinary approach is characterized by stakeholder involvement in the selection process. Thereby, the knowledge of the local community can be utilized to secure the inclusion of region-specific circumstances. For practicability we suggest not to exceed 20 indicators. When collecting and evaluating the individual indicators, the spatial reference must be taken into account, and it must be differentiated and clearly pointed out which evaluation perspectives the indicators refer to.

Definition of target values

If the assessment is to be made against target values, the definition of indicator targets is necessary. Target values must be identified for the individual indicators and serve as a reference for the sustainability assessment. Political targets or statutory limit values, for example, can serve as the basis. However, such established values are not necessarily in line with sustainable development and should therefore be clearly justified. The involvement of stakeholders can help to set target values for individual indicators.

Estimation of indicators & impact analysis

For the estimation of the individual indicators different methods can be applied. In general, indicators can be described quantitatively or qualitatively. For environmental indicators, life cycle assessment (LCA) is a suitable method, which provides detailed information on energy technologies and processes based on the life cycle inventory (LCI) databases. Methods of environmental impact assessment (EIA) can serve as a guideline for the evaluation of local effects. Social and economic effects can be quantified using social LCA, life cycle costing (LCC) or macroeconomic input-output analysis. Model-based calculations can be supplemented by literature-based approaches and further empirical surveys and interviews.

Assessment along sustainability rules

The final evaluation is carried out separately for the overarching sustainability goals along the identified sustainability rules, which are covered by individual indicators. Since the indicator values are available at different scale levels, comparability must be established for the assessment. Therefore, various normalization and aggregation methods are available.

However, the approaches used should be presented to enable transparency and traceability, as well as verification of the robustness of the results. The estimation of the overall impact on the rule can include weights for the indicators. If weights are applied it can be helpful to generate them together with stakeholders. In a second step, the impact of the evaluation in respect of the rules is transferred to the three sustainability goals. Now the chosen evaluation cases can be compared to each other with regard to the goals. If sustainability targets were applied, for each evaluation case it can be stated whether or not it achieves sustainability (as defined by the targets).

3. Case study: district of Steinburg

As part of the ENSURE project, the concept is being applied in a case study for the evaluation of four scenarios of a regional energy system at the district level in Germany. Since ENSURE is an ongoing project, we present the process steps that have been carried out so far, together with the first findings, but not the final results of the assessment. The case study focuses on the district of Steinburg in northern Germany. The district has been characterised by the generation of energy for decades, exporting the majority of the electricity it produces to other parts of the country. There have been two nuclear power plants, which are in the process of decommissioning or are being dismantled. Today, renewable energies already dominate the supply sector, i.e. onshore wind power, and important infrastructures in the form of electricity, gas and heating networks are available (Figure 3). Important substations connect large offshore wind parks and act as international interconnectors (NordLink) and hubs for power transport to southern Germany (SuedLink). The rural region is located close to the high demand area of the Hamburg metropolitan region. It also serves as an important location for industrial sites (chemistry, cement). Thereby, the district is very representative for many regions in Germany, since it incorporates various generation-consumption structures.

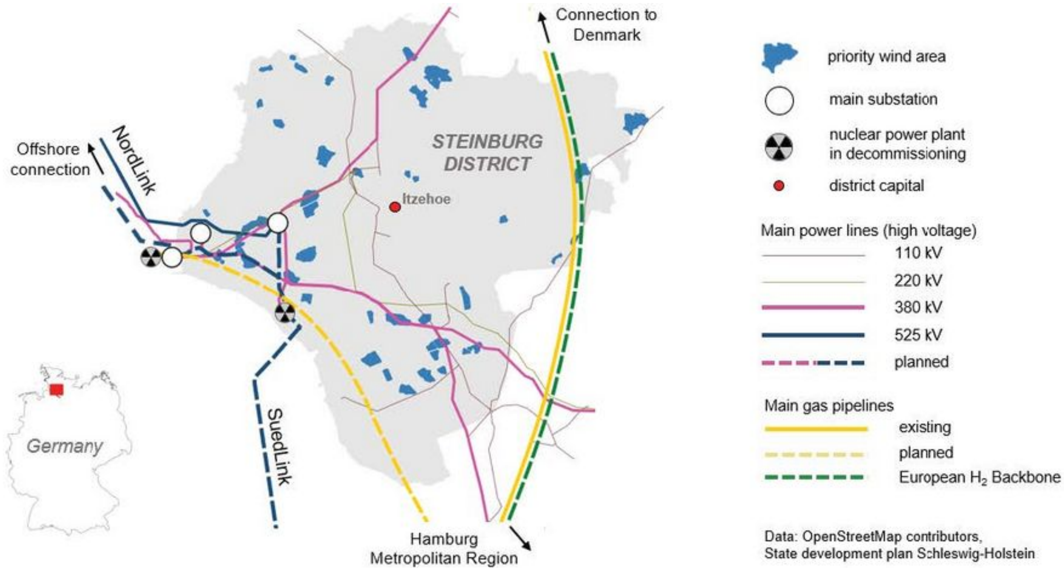

Figure 3 - Main energy infrastructure in the district of Steinburg

Target and problem definition

The regional sustainability assessment aims to holistically assess different scenarios, which have been developed for Germany and adapted to the region. The evaluation should reveal the multiple effects of imaginable local energy systems, in order to be able to offer stakeholders a scientific basis for deciding on their position towards the alternative scenarios.

Stakeholder Involvement

The study aims to consider the diverse needs, values and wishes of different interest groups in the Steinburg region. In particular, possible local specificities, for instance geographical, socio-economic or cultural are to be identified. Therefore, we are consulting representatives from local public administration, non-governmental organizations and companies in a series of three workshops. Particular emphasis is placed on appropriate representation of the social spectrum in the stakeholder workshops in order to capture the attitudes of the individual, but also of society as a whole. The involvement of the stakeholders is not aimed at obtaining a representative opinion, but rather taking different views and expectations into account.

Definition of scope

The subject of evaluation is the regional energy system of the Steinburg district in 2050. This includes the energy supply and transport of all locally relevant energy carriers and forms, i.e. electricity and heat, fossil, biogenic and synthetic gases and fuels, biomass and coal. Thereby the provision of energy for mobility (passenger and freight transport), industry, commerce, trade and services as well as in private households is taken into account. Examining the entire energy system, the relationships between individual energy carriers is incorporated. This relationship is highly relevant in future energy scenarios due to the increasing coupling of the energy sectors with the electrification of fuels and heat.

Figure 4 shows the scope of the system under review. The regional sustainability assessment considers both a local and a demand-orientated global perspective. The local perspective takes into account all relevant effects within the Steinburg district related to the energy system. This includes all energy infrastructure and related impacts by the generation, transport, storage and use of energy (source principle). The demand-oriented global perspective considers all effects induced by the energy demand of the Steinburg district, according to the 'polluter pays' principle. This includes all effects of generation, transport, storage and use of energy along the life cycle, regardless of their location. For the case study it is assumed that the local energy demand is primarily covered by the local supply.

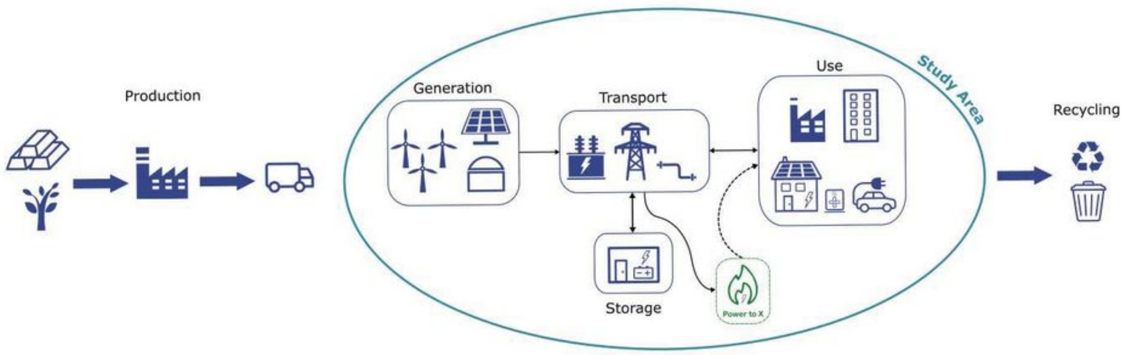

Figure 4 - Scope of the regional sustainability assessment

For the assessment, the generation capacities (e.g. electricity, heat) and the energy consumption must be "translated" into specific technologies. Assumptions for technological developments in 2050 are based on scientific literature considering the current state of the art, as well as trends in future technological developments and market shares.

Definition of evaluation cases

In the ENSURE project, four different scenarios will be evaluated, which have been developed for the EU and regionalized at network node level. The regionalized scenarios describe the energy system in terms of production (supply) and consumption (demand) of different energy carriers and sectors. The quantified scenarios form the basis for assessment.

- Scenario A '85% reference scenario', assumes a GHG reduction target of ca. 85 % by 2050 compared to 1990.
- Scenario B 'Ambitious climate protection', aims to keep an increase in average global temperatures compared to the pre-industrial era to well below 2°C, in line with the Paris Climate Agreement. This will result in net-zero emissions by 2050 at the latest.
- Scenario C 'Europe', assumes climate neutrality by 2050 through integration into the European transition. Electricity is primarily provided at optimal locations across Europe.
- Scenario D "Decentralized", suggests climate neutrality until 2050 by a more load-related energy provision. This means that the locations for generating electricity are as close as possible to the (domestic) consumers.

Identification of rules, criteria and indicators

Eleven sustainability rules have been identified as relevant for the system under review. The identification of related criteria was based on literature analysis and the involvement of local stakeholders during two online workshops. The first workshop discussed local perspectives in order to co-evolve region-specific criteria for the assessment and to collect topics neglected so far. For the stakeholders, fairness and justice were central concerns. The creation of local added value and the participation of the local population were named as central factors to increase the identification with local infrastructure and thus to promote acceptance.

Participation formats that ensure early involvement of the population during planning and decision-making processes of energy infrastructure allow local needs and suggestions to be taken into account. The second workshop aimed to specify individual criteria in more detail and concretize their objectives. Financial participation opportunities were highlighted in the first workshop, aiming at a fair distribution of benefits. However, these participation options can be designed very differently and may lead to desirable as well as undesirable effects.

Therefore, the target direction and the factors influencing the indicator were discussed with the stakeholders. The stakeholders advocated community energy systems. Positive experiences were made with wind farms largely financed by residents and with a local non- profit foundation that implements social projects in the community and is financed, among other things, by income from the local wind farm. According to the stakeholders, this has increased its acceptance. The aspects mentioned by the stakeholders will be taken into account in the evaluation of the criterion.

In total, 15 criteria have been identified for the regional assessment. As shown in Table 2 the criteria relate to different evaluation perspectives and cover both local and/or supra-regional effects. The identified criteria must be described by quantitative and qualitative indicators. An extensive analysis of energy-related indicator collections was conducted. This resulted in a set of more than 60 indicators. The selection of the final indicators is in progress.

Identified criteria and addressed sustainability goals	Local Effects		Supra-regional Effects		ICoS rule
	local energy supply	local energy consumption	local energy supply	local energy consumption	
I Securing human existence					
1 Pollutant emissions	✓	✓	✓	✓	1.1
2 Other emissions (noise, light)	✓	✓	-	-	1.1
3 Energy import dependency	✓	✓	-	-	1.2
4 Energy poverty	-	✓	-	-	1.2
5 Employment effects from renewable energy	✓	-	-	-	1.3
6 Financial participation opportunities	✓	-	-	-	1.5
II Maintaining society's productive potentials					
7 Land use/consumption by the energy system	✓	-	-	✓	2.1
8 Renewable cumulative energy expenditure	-	-	-	✓	2.1
9 Non-renewable cumulative energy expenditure	-	-	-	✓	2.2
10 Material consumption of the energy supply	-	-	-	✓	2.2
11 Greenhouse gas emissions	-	-	-	✓	2.3
12 Energy-related hazardous waste	-	-	-	✓	2.3
Pollutant emissions	✓	✓	✓	✓	2.3
13 Regional added value through renewable energy	✓	-	-	-	2.5
III Preserving society's options for development and action					
14 Procedural participation opportunities	✓	-	-	-	3.2 / 3.5
Financial participation opportunities	✓	-	-	-	3.2 / 3.5
Land use/consumption by the energy system	✓	-	-	✓	3.4
15 Human rights in the supply chain	-	-	-	✓	3.5

Table 2 - Selected criteria for the regional sustainability assessment concerning different evaluation perspectives and sustainability rules

Next steps

For the assessment we will use model-based and non-model based indicators, which describe the single criteria. For the estimation of each indicator, different methods will be applied.

Environmental indicators are to be calculated using LCA based on life cycle inventory data of individual technologies. Local environmental aspects will be considered using methods of environmental impact assessment. Regional input-output-analysis will provide information about regional economic effects. For criteria that cannot be expressed using quantifiable indicators, the evaluation will be done qualitatively based on findings from the scientific literature, the workshops and our own assumptions. The comprehensive assessment of the four scenarios will be carried out comparatively along the individual sustainability rules and goals. The results of the sustainability assessment as well as the entire assessment approach will be presented for discussion in a third workshop in the region. The results will be finally adapted if needed.

4. Conclusion and outlook

The paper proposes a concept for a regional sustainability assessment which provides profound information on alternative socio-technical transformation paths on a regional scale. The concept combines global aspects along the life cycle of the entire energy system with local aspects within the area of interest. In contrast to previous approaches, the concept illustrates different evaluation perspectives for individual indicators. This is of great importance, as the energy transition is being implemented at the local level. Model-based evaluations often neglect local specificities such as the expectations and needs of the population or region-specific environmental issues. Therefore, the concept follows a transdisciplinary approach by involving stakeholders during various process steps. The concept is being applied at the district level in Germany. Consulting stakeholders in several workshops has proved fruiIful in order to develop region-specific criteria for the assessment. The concept can be adopted by other regions on different scales. It will help to contribute to a better understanding of regional differences regarding the energy transition. These differences go beyond technical or geographical aspects such as the diverging potentials of renewable energies. The findings from the sustainability assessment can support decision-making processes in political contexts, since different transition paths can be compared adequately.

Future work will include examining the transferability of the concept to other regions and contexts. Therefore, the concept is to be tested with practitioners from the energy industry and regional planning. Comments on the practicability and coverage of the purposes of a sustainability assessment should be discussed and integrated into the concept. In addition, aspects such as options for weighting and the quantification of individual criteria must be further developed. The findings of the regional approaches can also provide input for subsequent multi-criteria decision-making (MCDA) approaches.

Acknowledgement

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