Sustainability Assessment of Concepts for Energetic Use of Biomass: A Multi-Criteria Decision Support Approach

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1 Introduction

A usage of biomass for energy supply is attracting attention among a variety of stakeholders, such as politicians, power suppliers or the public. This energetic use of biomass is thereby often associated with sustainability, e.g. due to its less pronounced contribution to climate change or the preservation of fossil energy reserves [5]. Contrary to other renewable sources, as wind or solar, biomass can be stored and used for a steady and reliable production of electricity. Moreover, it could be used not only for electricity production, but also for the production of heat, cooling, fuels or lubricants and other products of petrochemistry. This makes biomass an especially versatile option for further energy challenges [12].

There arises also an increasing social awareness towards sustainability, which can be subdivided into the three dimension environmental quality, economic prosperity and social equity [15, 16]. This development is of growing importance for technologies and infrastructure with respect to energy supply [16]. Concerning the major advantages as renewable energy source or as resource for the chemical industry in combination with a growing demand for sustainable concepts, biomass represents a suitable and interesting option. Therefore, it seems to be of special interest to identify efficient concepts for biomass usage on a regional scale under sustainable criteria.

But, despite the mentioned advantages, the public perception of the energetic use of biomass has recently been characterized by decreasing acceptance. Expanding

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monocultures are viewed critically, as they would result in considerable land-use changes and affect biodiversity negatively. Additionally, the associated increasing transport activity results in noise disturbance as well as air pollution. Moreover, the use of food crops for energy production is also a controversial issue from an ethical perspective. This is a matter of particular interest in cases where areas are used for food production, nature conservation or grassland [5, 8].

Hence, it becomes apparent that the assessment of potential concepts for the energetic use of biomass is of multi-criteria nature and should imply not only economic, but also environmental, social and technical aspects. For that reason, methods of Multi-Criteria Decision Analysis (MCDA) seem to be adequate for assessing potential concepts of biomass-usage. Since the given problem concerns both energy supply and sustainability, it is necessary to develop and apply an appropriate method based on MCDA for the assessment of alternative concepts for the energetic use of biomass with respect to sustainable development.

2 Assessment of Concepts for Biogas in a Rural Area

As mentioned before, a suitable method for the sustainability assessment of biomass potentials on a regional scale is to be developed. One initial point is an already conducted study, where the MCDA-method Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) is applied on the sustainability assessment of different concepts for the use of biomass [5, 6]. PROMETHEE was chosen as approach due to its consideration of discrete alternatives, as well as its transparency and ability of generating additional information through the whole decision process [13, 14, 16]. In this study, PROMETHEE was applied exemplarily on small-scale and large-scale biogas plants, as well as on a new concept of bioenergy villages in a rural area in Lower Saxony in Germany. Thus, the focus of the application was the comparison of different concepts for the use of biogas on a local scale [5, 6].

Moreover, a criteria-hierarchy has been developed to cover the different dimensions of sustainability. From an ecological perspective, the choice of criteria represents the impact of the use of biomass for energy supply not only on air, soil and water, but also on biodiversity and the preservation of resources. The economic criteria arise from the different stakeholders as the operating company, employees, heat clients, farmers and the region itself. At this point it should be mentioned that the determination of values for some criteria is challenging due to conflict of interest. An identical criteria could be assessed in a contrary way, as the following example points out. While farmers prefer high prices, the operating company and the villagers are better served with cheap biomass. The social aspects of sustainability had been categorized by sub-categories, such as acceptance, participation, psychological consequences and employment. Additionally, a fourth dimension, the technical dimension, was introduced, because the efficiency of the technical conversion of biomass is seemed to be of particular importance and is closely connected to the corresponding alternative [5, 6].

Based on the presented approach, further adjustment concerning the application of PROMETHEE on a broader scale shall be discussed, in particular to address the special needs of assessing sustainability and considering conflictive stakeholders.

3 The PROMETHEE Approach

The PROMETHEE approach belongs to the methods of Multi-Criteria Decision Analysis (MCDA). The goal of any method of MCDA is to deliver a decision support for at least one decision maker, based on his or her individual preferences due to a set of multiple criteria. Moreover, the application of the different methods should make the whole decision process more transparent and elicit further information from the involved decision makers. Thereby, methods of MCDA facilitate a better understanding of the decision problem as such [2, 7].

From the two kinds of MCDA-methods the approaches of Multiple-Attribute Decision Making (MADM) seem to be appropriate, because they are used to analyse a set of discrete alternatives. One subset of MADM methods are Outranking approaches, to which the PROMETHEE approach belongs. PROMETHEE was developed by Brans [3] and has already been used in various applications for assessing sustainability [1, 14]. It is based on pairwise comparisons of alternatives due to the multiple criteria and enables the inclusion of weak preferences and incomparabilities. For these pairwise comparisons six specific kinds of preference functions are recommended. There are several enhancements of PROMETHEE from PROMETHEE I up to VI, where as PROMETHEE I and II are the most frequently applied versions. The aim of PROMETHEE I is to find a partial preorder, which can be transformed in PROMETHEE II through the determination of net outranking flows into a complete preorder [4]. With respect to the given problem, PROMETHEE is considered as an appropriate approach for different reasons. Firstly, as MADM-method it analysis a set of discrete alternatives. Furthermore, it is possible to consider criteria not only of quantitative, but also of qualitative nature simultaneously [3, 4]. Since its application improves the transparency of the decision process, it also helps both to structure that process and to prompt the decision maker to rethink about the whole decision problem, whereby new findings could arise [2, 4]. In addition, since the outranking approaches are additive methods, it is possible that under certain conditions an application of PROMETHEE and the Multi-Attribute utility theory (MAUT) leads to identical results [10]. A further advantage of PROMETHEE is, that a broad spectrum of sensitivity analysis can be applied for revealing additional information concerning the decision problem and process, respectively [9].

Thus, PROMETHEE is an approach which attempts to deal with vague preferences by the decision maker and criteria of different nature. It helps also to structure the decision process and makes it more transparent. Furthermore, with respect to MCDA-methods, it is also recommended to apply not just one single approach, but to combine different approaches. As every approach has its own advantages and drawbacks, this gives the opportunity to compensate especially undesirable drawbacks [13].

4 Outlook on Potential Enhancements

Further adjustments to the application of PROMETHEE shall be discussed to make it more suitable for the assessment of concepts for biomass usage with regard to sustainability aspects. The adjustments have their origin not only in issues which come along with sustainable development or energy supply, but also in the application on a broader scale with a variety of stakeholders. As energy supply and sustainable development are especially emotional topics in combination with the consideration of stakeholders with possibly very conflictive positions, it is typically a field of cognitive biases [11]. For that reason, the adjustments of the application of PROMETHEE are aimed both at the inherent integration of stakeholders with contrary positions and the consideration of cognitive biases through the decision process.

As mentioned in section two, one drawback of the original approach was that stakeholders could express contrary preferences to some criteria, as in the case of the price for biomass. It can be expected that the differences between stakeholders widen with increasing scale, so that on regional scale with a lot of stakeholders, the consideration of their individual evaluation due to different criteria is of special interest. Therefore, the inherent implementation of individual preferences, whether a criteria should be maximized or minimized, in a decision support approach based on PROMETHEE, shall be facilitated. On a regional scale it is also necessary to consider a greater variety of potential alternatives. Conceivable alternatives in addition to biogas plants or bioenergy villages could also be industrial plants as biomass-to-liquids plants, bio-refineries or plants producing biocoal. This broader spectrum comes along with a growing number of potential stakeholders, too. Moreover, in that context it would be meaningful not only to assess biomass usage concepts on their own separated from other potential options. The combination of the decision with respect to biomass usage with already existent or further potential solutions, e.g. in combination with wind power or photovoltaic, represents therefore another reasonable enhancement.

In order to deal with cognitive biases in the decision process, the approach of structured decision making (SDM) [11] represents an interesting basic concept. SDM can hereby described as a code of practice how to improve and structure the decision process. It explicitly implies approaches to reduce cognitive biases, such as the phenomena of representativeness due to the weighting, or the availability of information by assigning values to the alternatives for different criteria for example. Based on that idea, it seems reasonable to add further procedural steps based on behavioural sciences, through which cognitive biases are reduced when determining weights and values or facts, respectively. While the originally developed SDM-approach combines MAUT with methods of decision analysis, it would be interesting to use PROMETHEE as an initial method. This seems reasonable, as Løken argues that PROMETHEE is appropriate as basis for decision support, as it helps to structure the decision problem and makes it more transparent. Thus, it is particularly suitable for combination with a second method for decision support, which could be applied afterwards [13]. Additionally, the assumption of Outranking methods, that the decision maker is not entirely aware of his or her preferences, supports rather the application of PROMETHEE compared to MAUT, if one wants to deal with cognitive biases. Another aspect of SDM which could be added for a sustainability assessment of biomass usage concepts is the construction of alternatives, rather than the assessment of ex ante determined alternatives [11]. As it is the aim to assess different concepts for the use of regional biomass potentials, the construction of alternatives could represent an active process to reveal new innovative concepts.

It can be concluded, that the application of MCDA-methods enhances the transparency of subjective decision processes and helps further to identify potential conflicts of objectives through the implementation of sensitivity analysis.

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