An analysis of the influence of social preferences on the multi-criteria evaluation of energy scenarios

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Abstract

The aim of this paper is to critically reflect on the use of social preferences by means of weights in participatory multi-criteria evaluation (MCE). Insights are drawn from systems theory as the conceptual base and from empirical case study work on renewable energy scenario assessments for Austria at two different levels (national and local). In an MCE social preferences express the values of stakeholders; these complement the facts captured in the impact matrix describing the case/s studied.

In this two-level study, the social preferences expressed by stakeholders were first transformed into weights by employing the SIMOS method. For each criterion a weight was calculated, representing the importance of the criterion for a sustainable energy system. In a second step these weights were used as an input in an MCE (using PROMETHEE I). The same methodology was used for both case studies. Minor differences between the two MCE process levels occurred for practical reasons, such as timing. For example, no group weighting was carried out on the national level, and certain criteria were measured by different indicators on the two levels. Also, the scenarios differed somewhat by the degree of detail of the exploration, and the language used to describe the scenarios was more technical on the national level.

The influence of the weights on the rankings of the scenarios have been analysed through sensitivity analyses. The analyses exhibit very robust results for the local level, in particular for the highest ranked scenarios. The rankings of the less favoured scenarios change with substantial changes in the weights [provide some indication as to how much is considered 'substantial']. In the national case study the influence of the weights is somewhat more pronounced. The results show two clusters of scenarios which do not switch ranks, but within the clusters rankings change quite easily with weights.

This paper suggests that the application of a participatory MCE with social preferences as weights is a transparent and robust way of including different sets of stakeholder priorities into the analysis. The discussion explores in particular in which way the use of weights reveals a better founded display of social preferences, compared to some direct ranking of alternative scenarios by stakeholders on the basis of scenario presentations.

Keywords: social preferences, participatory multi-criteria evaluation, renewable energy, scenarios, sustainable energy systems

1 Introduction

Stakeholder participation is an important feature of transdisciplinary research, in particular of integrated sustainability assessment (Weaver et al., 2005). The main reasons for favouring the involvement of stakeholders include: (1) the gathering of extended information and knowledge about uncertain issues, (2) the inclusion of multiple perspectives of the affected citizens and stakeholders, and (3) the widening of the participation to increase legitimacy (Fiorino 1990). These perspectives can be captured by social preferences for sustainability criteria. In an MCE these preferences are usually transformed into criteria weights. In this paper we aim to critically reflect on the use of social preferences as weights in participatory MCE. We examine how social preferences can be transformed into weights (either as absolute numbers or percentages), what these numbers or percentages mean, how they influence the results of the assessment, and how this influence can be interpreted.

Our investigation is based on empirical work done in the field of renewable energy scenario assessment for Austria at two levels of aggregation (national and local) within the research project ARTEMIS sponsored by the Austrian Science Fund (cf. www.artemis-project.org). Between 2004 and 2006 we developed a methodology for evaluating scenarios up to 2020 that are based on renewable energy technologies (RETs) and their anticipated socio-ecological-economic impacts. The evaluation process was integrated in a participatory process, in which PROMETHEE, a multi-criteria aggregation method, was applied.

In this paper we focus on three stages of the project. (1) the forming and formulation of social preferences, (2) the transformation of these preferences into weights, and (3) the aggregation that leads to a ranking of the scenarios, based on the impacts of the scenarios and the weights given to the criteria. By describing these stages and their rationale, and by interpreting the results, we tackle the question how preferences can influence the evaluation of energy scenarios. This allows us to assess the usefulness and quality of the evaluation, in particular by studying whether issues of systems characteristics, principles of sustainable development and features of process orientation were addressed.

Because the form of assessment chosen is a transdisicplinary approach, the paper starts by linking the idea of transdisciplinary research to sustainable energy systems and by explaining the assessment process (section 2). The three stages mentioned above are described in detail in section 3. Section 4 provides an interpretation of the results by first looking at the methodological issues and then at the process-related ones. Section 5 concludes by scrutinising how successful the evaluation was in terms of pushing sustainable development forward and which role preferences played.

2 Transdisciplinary approach for analysing sustainable energy systems

2.1 Transdisicplinarity research

The challenges involved when attempting to move towards sustainable development in complex systems (e.g. energy systems) call for transdisciplinary research, i.e. the adoption of an application-guided, problem-solving-, dialogue-oriented, and participative model of science (Brand, 2000; Funtowicz et al., 1998).

Trandisciplinary research typically begins with the identification of a socially relevant and often complex problem[1], and aims at providing a solution. It is thus problem-driven and requires the cooperation of different disciplines (in the case of sustainable development, these might be social sciences, natural sciences, engineering sciences). Persons from beyond the realm of science (i.e. stakeholders, decision makers, citizens) are involved in the problem formulation as well as in the research process itself; their needs, interests, preferences and knowledge are gathered and considered in a systematic way. The data and information collected and analysed does not only comprise hard facts, but also soft ones, and is prone to uncertainty. Transdisciplinary research is situated at the science-policy interface and is embedded in social discourses. Transdisciplinarity is understood as being complementary to monodisciplinary and interdisciplinary research and thinking (Max-Neef, forthcoming; Kastenhofer et al., 2003; Hirsch Hadorn, 2003; Funtowicz and Ravetz, 1991).
Knowledge produced in a transdisciplinary way, in the context of an application, by people with heterogeneous skills and experiences, oriented towards social accountability, and with extended quality control, is often referred to as 'Mode 2 knowledge' (Kastenhofer et al., 2003). Most of the issues under the heading of transdisciplinarity (problem-driven and problem-oriented research, involvement of stakeholders, and focus on processes) are not only issues of Mode-2 Science, but also considered important in Post-Normal Science (PNS).[2] PNS, first developed by Funtowicz and Ravetz, shows a new type of scientific practice, which can manage complex science-related issues and thus provide a scientific foundation for sustainability and for multi-criteria decision aid (see Funtowicz and Ravetz, 1991; Funtowicz, 1994; Funtowicz et al., 1997; Luks, 1996; Luks, 1999). One key issue of PNS is uncertainty – which needs to be recognized and tackled in the process.
The advantages of an extended group of participants are manifold. Two often cited ones are: (1) the experiences and knowledge of laypersons and the public can provide additional information that serves to create new ideas for solutions, and that can provide insight into possible impacts which would otherwise have been neglected; and (2) only those who are integrated in the whole process, those who can state their preferences and needs, who can bring in their knowledge and experiences will feel bound by and responsible for the agreed actions. They will be willing to accept the results, even though they might have to face negative impacts and incur unavoidable costs in the transformation phase (Brand, 2000).
Participatory research is not only accompanied by positive effects. The biggest problem is probably the risk of failure. Participation can fail and lead to less trust in research and policy making, and less acceptance of the results. No result might be obtained or several possible results, where no agreement exists upon. It might be that some groups do not feel properly involved and thus begin to exert resistance which might slow down or even threaten the whole process. Risks related to the exclusion of important stakeholders, or the fact that due to social learning processes the representatives involved are much further into the issue than the groups they represent, do exist. Another problem is the sceptical perception of participants (especially citizens). They often think that it is a waste of time, as their arguments are not properly taken into ac-

[1] Problems which are difficult to structure and translate into scientific questions can be called complex and lead to the necessity for a transdisciplinary confrontation with the problem (Scheringer et al., 2005).
[2] Müller defines Post-Normal Science as a special case of Mode-2 science, as it focuses on environmental issues (Müller, 2003).

count. Thus, instead of collaborating in a constructive way, they often either do not show up or only complain when they participate. It is important to assure them that their ideas are being considered and to apply appropriate control mechanisms. In citizens' participation the group of people joining is often a small selection, typically comprising better educated and more engaged citizens ('the usual suspects'). By contrast, single parents, workers etc. rarely participate.

Despite these challenges, there is nevertheless a need for participation of stakeholders in research and decision processes to solve complex problems in sustainability science.

2.2 Transdisciplinary research on sustainable energy systems

With regard to energy systems a particular large range of interests and potential consequences have to be taken into account. Several different fields within the social as well as the natural systems are affected in fundamental ways by the actions following decision-making in the field of energy. To meet the multidimensional nature it is important (1) to put a comprehensive set of assessment criteria together that covers a broad variety of aspects and that also includes social criteria[3] and (2) to elaborate the methodology for including stakeholders' interests. A participatory approach was chosen in ARTEMIS due to our conviction that cooperation between science and stakeholders is essential in order to advance towards a more sustainable energy system. In ARTEMIS it was decided to focus on renewable energy scenarios, rather than evaluating and ranking individual RETs, as it was suggested in Madlener and Stagl (2005) for promoting RETs through sustainability-guided policies.

The use of renewable energy can help in creating new businesses and local employment, enhancing social and economic cohesion, and improving the security of supply by reducing the dependence on imported energy sources. It is one key strategy to decrease CO_2 emissions and to meet reduction aims. Nevertheless, it faces many barriers, such as existing market distortions, capital-intensity of many RETs, various sources of uncertainty, objections of the population, etc.

Participatory approaches can help to identify and tackle such barriers, and to better exploit driving factors, in a way that allows achieving a high level of consensus and thus the chance for an enhanced durability of decisions and policies geared towards a more sustainable development of the energy system.

As a result, decision-makers are better prepared to decide about measures for sustainability-oriented energy policies. The participatory multi-criteria evaluation of RETs, and RET scenarios, helps the political decision-makers to better understand the relevant issues, to design policies and policy instruments, and to build a shared understanding among the stakeholders (social learning).

In the following, we briefly describe how transdisciplinary research was realised in the ARTEMIS project. At the *local level* the participatory process included three workshops and individual interviews of local experts. The first workshop was held with 18 local energy experts and politicians. The aim was to discuss and specify four energy scenarios pre-developed by the research team. In the two following workshops citizens and politicians were asked to name those criteria that are most important for them with regard to the local energy system and to rank these criteria according to their preferences.

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[3] In our opinion traditional studies of energy systems and system changes frequently underestimate the impact of the energy supply system on the organisation of society in general, and of people's daily life in particular.

At the *national level* two workshops were organised with stakeholders that are associated with renewable energy in Austria. The first workshop aimed at discussing the narratives of the scenarios and to roughly weigh the evaluation criteria. The aim of the second workshop was to further elaborate on the scenarios and discuss the intermediate results of the national ARTEMIS case study. Personal and telephone interviews were conducted with energy experts and stakeholders to offer an individual setting for further involvement in the selection of criteria, scenarios, and to get a better grasp on the social preferences.
Although starting from the same research question, the different spatial levels resulted in diverse approaches regarding:

- <u>Stakeholder involvement</u>: at the national level representatives from different interest groups were invited (e.g. ministries, NGOs) whereas at the local level community stakeholders and local energy experts (e.g. mayors, community councillors, installer) took part in the participatory process,
- <u>Scenario development</u>: The different role of the scenarios in the participatory process (discussion process vs. decision support process for project realisation) resulted in different kinds of scenarios. At the national level exemplary scenarios based on existing renewable energy scenarios have been developed, whereas the scenarios on the local level have been oriented towards the implementation of concrete projects.

Table 1: The energy scenarios at the local level

	Local Energy Scenarios 2020 for Raabau and Lödersdorf			
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Short narrative	"Electricity from renewable energies": The communities focus on large-scale electricity generation from RE.	"Renewable energy from small, private plants": The communities promote all kind of small-scale RETs.	"Reduction in energy demand and heat supply from large RETs": focus on energy-saving measures and local initiatives for centralised heat generation systems.	"Reduction in energy demand and heat supply from small, privately owned plants": focus on energy-saving measures and small-scale heating RETs.
Energy demand	increasing, 2% p.a.	increasing, 2% p.a.	constant, 0%	constant, 0%
RETs for heating	baseline	household based RETs: mainly pellets, wood chips, solar thermal;	wood chips-fired heating plants for several households, large-scale solar thermal systems	household based RETs: mainly pellets, wood chips, solar thermal;
RETs for electricity	small hydropower, photovoltaics, biogas	Small-scale PV	biogas	none
Share of RE achieved	64%	67%	81%	74%

Table 2: The energy scenarios at the national level

	National energy scenarios 2020				
	Scenario A "Fast and Known"	Scenario B "Extension of Competitive Advantage"	Scenario C "Investments into the Future"	Scenario D "Extensive Use of Biomass"	Scenario E "Large Impact in Small-Scale Use"
Short description	Large plants, very short-termism, few new institutions	Large plants, high technical efficiency, few new institutions	High system efficiency, very long-termism, new institutions	Biomass energy plantations (SRC), new institutions	Small plants, extensive use of residue, new institutions
Additional electricity production from renewables (GWh)	9,086	8,931	7,642	9,631	9,725
Additional heat production from renewables (PJ)	66.4	61.6	34.4	93.4	53.0
Amount of renewable energy in 2002 (PJ)[4]	125	125	125	125	125
Additional amount of renewable energy in 2020 (PJ)	99	94	62	128	88
Percentage increase	80%	76%	50%	102%	71%

- Workshop organisation: at the *national level*, two workshops were complemented by several expert and stakeholder interviews, in order to receive collateral information and to get a better sense of individual perspectives. At the *local level* the participation process consisted of three workshops, as well as meetings and interviews for considering open questions. It also comprised an event at the end of the process, with the purpose to present and discuss the results and implications of scenario implementation with the stakeholders. Therefore, the participatory process on the local level was more intense with respect to group workings.

Different restrictions to participation processes could be observed during the processes:
On the national level the work of stakeholders generally includes the participation at workshops to represent interest groups. Since the research project has been independent from official governmental renewable energy programmes the attendance was

[4] Data based on IEA (2003).

not very high[5]. Nevertheless it was obvious that the stakeholders were in their professional setting and not hesitant to express their stakes and to question other people's interests and motivation (including the research team's). At the local level the attendance and commitment we experienced was higher. Stakeholders took part due to personal interest in realising a project with RETs, interest in ecological matters, general interest in the communities' future or because of an obligation they felt toward the mayors. One important reason was the perspective of starting the E5 process and being nominated as an E5 candidate community.[6] On the other hand, their commitment to participate in the process was on top of job requirements and other obligations, which resulted in late evening workshops (and the use of precious spare time).

At the national workshops the discussions were held by using essentially the same terminology as within the project team, and participants have been very critical and demanding concerning the scientific methods applied. This might be attributable to the fact that participants at the national workshops, on average, probably had a higher level of education and more routine in such tasks. At the local level, though, all working papers and presentations had to be "translated" into a non-scientific language, in order to avoid misunderstandings and the stigmatisation of the process as being aloof. The participants questioned the scientific method only to a very limited extent, even though much effort had been put in motivating the participants to ask questions freely.

In general, the participative approach towards the given research question was positive and fruitful. On the local level, a discussion process on the pros and cons of the use of renewable energy use was induced, and the results will form the basis for the planned implementation of the energy award programme "E5 community". On the national level, an input to the discussion process about possible energy futures was given, providing further insight into concrete impacts and into the structure of the different (and sometimes conflicting) interests. The stakeholders indicated that the approach is useful for them to structure the decision situation and to better understand the appropriateness of the scenario in view of specific interests.

3 From social preferences via weights and impacts to scenario evaluation

3.1 The importance of social preferences

Participation helps to generate shared views and mutually reinforces commitment and a sense of joint ownership about a certain issue. There are also ethical arguments stemming from the normative belief that people affected by a decision should have a right to participate in the decision-making (Weaver et al, 2005). This right implies the right of access to information and of stating their preferences. These preferences can be expressed in relation to assessment options, to the impacts of the options or to the assessment criteria used. In MCE approaches they are generally related to the evaluation criteria in the form of weights (see section 3.3). This allows the stakeholders to

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[5] In the National Workshop I: 7 attended out of 35, and in National Workshop II: 6 attended out of 23; whereas there was a strong discontinuity in the sense that the first and the second workshop were attended by different stakeholder representatives.

[6] "E5" is a programme for assessing and certifying local communities with respect to their attempts (relative to their potentials) to use energy more efficiently and to intensify the use of renewable energy as a contribution to a sustainable development (cf. www.e5-gemeinden.at).

express their preferences concerning a certain option via the detour of attaching weights to the criteria, thus representing certain aims. The social preferences can either be used on an individual basis or on a group basis, in case a group agreement can be reached. Integrating different sets of preferences in an analysis allows deepening the understanding that one best solution to a problem does not necessarily exist, but that the answer depends on the concrete structure of interests. A basic assumption in that approach is that there are several, also contrasting, legitimate perspectives. In our evaluation process, social preferences play an important role. They have been elicited in workshops and interviews and integrated in the multi-criteria aggregation. Moreover, they were used on an individual basis (an MCE was undertaken for each participant separately) as well as on group basis (on the local level, as only there agreement could be reached).

3.2 Eliciting the social preferences on both levels

As discussed in the last section the social preferences of the stakeholders are an indispensable element for a transdisciplinary integrated sustainability evaluation process. It is thus important to choose a method that enables to elicit these preferences carefully.

On the local level it was done in a two-step workshop. The criteria were known by the participants in the workshop beforehand, as they developed them jointly with the research team. In the 'weights workshop' the first step was to find a ranking of the criteria according to the social preferences of the participants, which was agreed upon by the whole group.

This first step was done in a playful manner by asking the participants, who stood in a circle around a table, to put the criteria (which were written on cards) in a rank from the least to the most preferred or changing the order, allowing for equal preferences and gaps. These gaps were achieved by means of blank cards between preference levels, enabling to put more weight on the criteria above this blank card and less weight on those below.

This was done around the table, one by one in several rounds (to the extent possible in the form of silent negotiation), until the group agreed in principle upon the ranking of the criteria. No verbal influence should be given, no one should dominate by talking a lot or in a very assertive way, in order not to unduly influence others. Questions relating to understanding could of course be posed.

The second step consisted of an individual process by assigning ranks to the criteria. The individual social preferences served to check the correlation of the individual perceptions with the group result and thus to check the robustness of the latter.

By forming the average weights of the individual rankings and applying different cluster analysis (for a review of different methods see Backhaus et al., 1996), it showed that a group of five participants (45%) correlated strongly with the group result. Four participants differed rather strongly in their individual rankings from the group result, two of them very strongly. As can be seen in section 3.4 these differences do not have a strong impact on the evaluation results.

One important issue in this process was the order of the two steps. We decided to start with the group weighting process, as the inducement of a social learning process was one aim of the project. By discussing the importance of the criteria for a sustainable energy system in the group, the participants were motivated to rethink their opinion, and got more information about the opinion of the others and possible consequences of their preferences. We estimated this advantage higher than the disadvantage of having some of the participants influenced by dominating ones

On the national level the social preferences have been revealed by (1) stakeholder telephone interviews and a stakeholder workshop dedicated to discussing the sug-

gested set of criteria and to adding missing aspects. Then (2) individual stakeholder interviews have been performed to derive the individual criteria rankings. .
The basic process to reveal the social preferences has been in a different manner than at the local level. Only individual preferences have been collected in individual interviews. The interviews have been organised in a similar mode as on the local level: criteria have been printed on cards that have been put in order of priority given by the stakeholders, whereas the criteria represented aims in a more sustainable energy system.
The resulting ranking of criteria has been rather diverse among the different stakeholders. Nevertheless, the aim to have good climate change properties has been ranked very highly all across the variety. It was also obvious that certain criteria were given similar priority, e.g. if the economic aim to have minimal costs was ranked highly, then other economic criteria were ranked highly as well.

3.3 From social preferences to weights

The ranking of the criteria according to the social preferences of the stakeholders can be used as they are and put into PROMETHEE, or they can be transformed into weights (summing up to unity). For this step we applied a revised version of the SIMOS (Maystre et al., 1994; Figueira and Roy, 2002) method on both levels. In the SIMOS method, by having the criteria in an order, including blank cards, the weights for all criteria can be calculated. On each rank there is either a blank card or one or more criteria. Each card receives a position number starting from 1 for the least important card, to the number *n* for the most important card, where *n* is the total number of cards. The sum of the positions of this rank divided by the total number of criteria belonging to this rank gives the basic or non-normalised weight. The blank cards get a position number but no weight is calculated for them as they do not represent criteria. The calculated weights do not sum up to 100. To norm them, they are divided by the sum over all positions excluding the blank cards and multiplied by 100.
The revised SIMOS method goes one step further. The ratio between the most and least important criterion is not fixed anymore. It is important that stakeholders are encouraged to express their perception of this ratio, by saying how much the first criterion is more important than the last one in the ranking. This is usually a number between 3 and 20 and is needed to calculate the weights with the SIMOS revised method. So if this number is 5 and the first criterion has got a weight of 20%, the last must get a weight of 4% (Maystre et al., 1994).
In tables I and II in the Appendix the weights for the group preferences on the local level and the range of the weights on the national level are given.

3.4 From weights and the impact matrix to the scenarios ranking

The weights are one 'ingredient' for the multi-criteria analysis. A second one is the impacts of the scenarios in form of a matrix. These together with preference functions[7] for the criteria are needed to run Decision Lab (commercial software for applying PRO-

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[7] Other than the weights, the preference functions are key information that has to be specified in the particular MCE tool and potentially affects the results. For both case studies they were derived from an expert workshop and included in the sensitivity analysis of the results but not further discussed in this paper. It should be stated though that they do have an affect on the results and have to be handled with caution.

METHEE). PROMETHEE aggregates the information by an outranking procedure and finally ranks the scenarios both completely and partially.

PROMETHEE is a widely used multi-criteria assessment method (Brans et al., 1986; Brans and Mareschal, 1999). With this algorithm alternatives are compared in pairs for each criterion. Alternative actions are ranked by a positive (the flow summarising the outranking and thus preference power of the option) or a negative flow (the flow summarising how strongly this option is less preferred than others). The higher the positive flow and the lower the negative flow the better is the option. Two versions of PROMETHEE can be differentiated. PROMETHEE I allows for incomparabilities, if the positive and the negative flow of one option is higher than those of another one. These two options are not comparable.

PROMETHEE II uses the net flow (the difference of positive minus negative flows), which permits a complete ranking of all actions. In addition to the ranking Decision Lab has got different features. One is the image of the stability intervals. They show the intervals for weights, which do not lead to a change of ranks. The higher these intervals are, the more stable is the result. Here we defined a criterion to be stable if the stability interval exceeds +/- 50% of the weight given to the criterion (see Tables 3 and 4 in the Appendix

As already mentioned above, in the ARTEMIS case studies local and national renewable energy scenarios were the options evaluated in the multi-criteria framework.

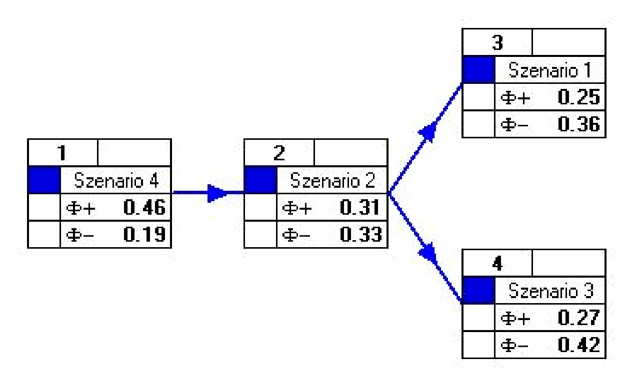
The impact matrix for the local level is mainly based on three sources: (1) GEMIS 4.3 (Ökoinstitut, 2005; Umweltbundesamt, 2005) a German/Austrian database on life cycle data for a large number of RETs. It delivers ecological data such as greenhouse gases, cumulated energy/material demand; etc. Wherever the data from GEMIS were not specific enough, or did not fit the local situation, they were extended with or replaced by (2) information from expert interviews. In these cases all available information was used as a basis for a qualitative appraisal. (3) The information for social criteria was gained from interviews with 11 inhabitants of the case communities and transformed into a qualitative rating by the project team. Table I in the Appendix shows the impact matrix applied, that contains the impacts along each criteria for the four scenarios considered, as well as the group weights.

On the national level (1) GEMIS 4.2 Austria and GEMIS 4.3 (Ökoinstitut, 2005; Umweltbundesamt, 2005) have been the main source for environmental impacts of technology and among other sources (Neubarth, Kaltschmitt, 2000; Haberl, 2002) for costs and ecological justice (area demand). And, furthermore, (2) expert interviews with an energy economist and sociologist have been performed to inform the social and some economic-technical impacts of the scenarios. Table II in the appendix gives the national impact matrix.

Having developed the impact matrix, the weights and the preference functions for the criteria, PROMETHEE was applied to aggregate the given information and result in a ranking of the scenarios.

The resulting ranking of the local scenarios based on the group weighting is depicted in Figure 1.

PROMETHEE I: partial ranking



PROMETHEE II: complete ranking

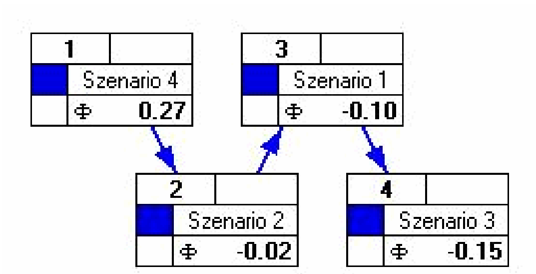


Figure 1: Ranking of scenarios at the local level (based on group weights)

Scenario 4 is ranked first, as it fulfils the criteria best. It focuses on the reduction of energy demand and support of small, private RET plants. Scenarios 1 and 3 (both including large power plants) are ranked last because their environmental and social impacts are relatively negative. However, if costs or regional economic development are given very high weights (more than 26% for costs and more than 35% for regional economic development) they rank first or second.
For all participants' weighting schemes scenario 4 is ranked first, scenario 2 is in 8 out of 11 cases ranked second, scenario 3 in 3 cases. Scenario 1 is always ranked last, except for one participant who ranked it third. The results of the participants give a first idea of the stability of the results, in particular for the first rank. Further sensitivity analyses and their interpretation are provided in the next section.
Table 3 in the Appendix gives the stability intervals for the group weighting evaluation. It can be seen that the interval exceeds ± 50% of the weight for all criteria, except for the lower limit of dust (the range is 0.265% points to small), the upper limit of import dependency (by 1.8% points), for the upper limit of costs (0.74% points), and for the lower limit of diversity of technologies (2.3 % points).

On the national level the results of the MCE rankings are more diverse, depending on the specific sets of weights derived from 18 individual stakeholder interviews. The most common ranking though is that Scenario C "Investment into the Future" is ranked first, followed by scenarios E "Large impact in small scale use" and B "Extension of competitive advantage". Scenario A "Fast and Known" and scenario D "Extensive Use of Biomass", two scenarios with rather centralised production systems, are

clearly ranked lower. The increase of the share of renewable energy in the total energy supply for Austria (heat and electricity supply) varies between plus 50% and 102% from 2002 in 2020 and is highest for scenario D "Extensive Use of Biomass".
The performance of the national scenarios along the evaluation criteria, summarised in the impact matrix, suggests already a basic ranking (see sensitivity analysis with all weights set equal). The weights are additional information put on top of that and do influence the ranking. They can potentially change the ranking, and especially where the differences between the scenarios' performances according to the impact matrix are small, the additional weight on the criteria can make a difference. If the differences are severe enough it becomes visible in a change of scenario ranking. It is crucial to treat the "exact" results of Decision Lab with caution since there is uncertainty in the data and the method to reveal and transform social preferences into weights. For that reason we define the stability of the result according to a minimum stability interval, which is relative to the weight. Figure 2 represents the partial ranking of the national ARTEMIS scenarios if all weights are set equal. This reveals the pattern of the impact matrix itself. All changes in the order and form of ranking in the other rankings are due to the impact of weights. Table 4 in the Appendix shows the stability intervals of the ranking and indicates that it is a very stable ranking in the sense that all stability intervals are beyond ±50% of the weight.

Obvious insights from that:

- Two basic groups of scenarios (1) C, E, and B and (2) A and D;
- Distinct distance between the scenarios in the ranking;
- Parallel ranking of C, E and B in the partial ranking, since none of them is better both in the positive flow (Φ+) and in the negative flow (Φ-);
- The scale on which the scenarios are ranked is rather big (± 0.41) which represents the range of the net flow (Φ).

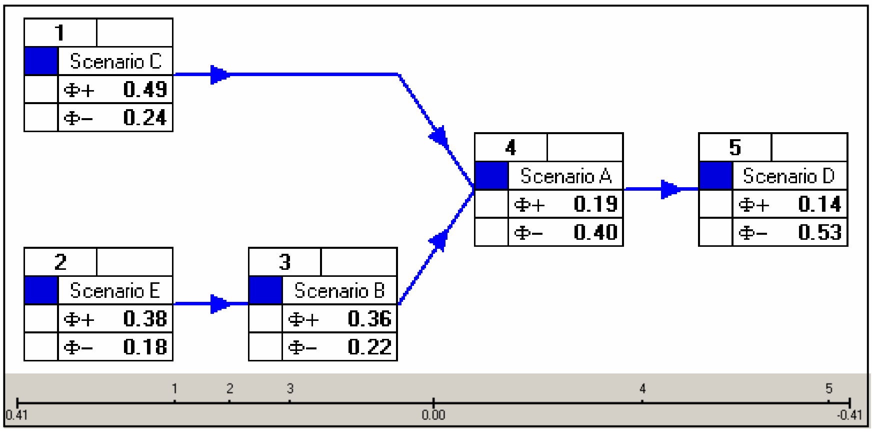


Figure 2: Partial ranking of the national ARTEMIS scenarios with weights set equal

4 Interpretation of the influence of the weights

4.1 Method oriented interpretation

The most important finding on the local level is that weights do have an influence on the MCE results, however, the first rank (scenario 4) is extremely stable. In sensitivity analyses (see below) scenario 4 always remains ranked first, except if some weights (costs, regional economic development) are increased substantially, i.e. to a weight more than 25% in the basic run.

1. From weights and the impact matrix to the ranking of scenarios.

Although the local impact matrix provides some first ideas of the result, it is nevertheless necessary to see how robust the result is and how social preferences can influence it. The following sensitivity analyses were applied:

- Certain groups of criteria were given a high weight. For giving 70% to the *social criteria* the result is similar to the basic result. Scenario 4 remains first, but there is no incomparability between the least ranked scenarios 1 and 3 anymore, as scenario 1 is clearly ranked last. The stability intervals are very high, thus extreme weights are needed to change the first rank in favour of scenario 3 (for instance more than 51% for social justice, 26% for costs or 35% for regional value added). It has to be said, however, that the sum of the weights for the social criteria was only 16% in the basic group weighting schemes, thus the increase of weights in this sensitivity analysis is very strong.

  If 70% weight is put on the environmental criteria the result equals that of the basic result, the stability intervals are even a bit higher.

  When weighting the technological and economic criteria very strongly (about 70%) the result changes. Scenario 4 is still first, but the other three scenarios are incomparable and very close together. Thus, scenarios 1 and 3 are no longer worse than scenario 2. The result is less stable, and the intervals are very small, but only for the ranks 2 to 4. Scenario 4 loses its first rank to scenario 3 again, with a bit lower changes in weights than in the basic run, such as more than 30% for social justice or more than 22% for costs.

  The net flow, which gives the preference index, is distinctively smaller for the analysis with high weight on technological-economic criteria than in the other sensitivity analyses, which means that the differences of preferences are small in this case. For the other two analyses the range is bigger than for the basic result, indicating big differences of preferences for the scenarios.
- Adapted versions of two scenarios: Scenarios 1 and 3 were changed by using liquid manure for the biogas plant instead of maize. Their evaluation is better but they still remain on 3rd and 4th rank. However, the stability intervals for the weights do change; the rank of the first scenario does switch earlier, e.g. if costs are higher weighed than 20% or if regional economic development is higher weighed than 28%. The same is true, if in scenarios 1 and 3 the heat, produced by biogas plants, is used instead of loosing it by blowing it into the air.
- Five criteria appear to be rather often instable (taken the group result and single results with the individual weights). They are either weighted highly or moderately, but never low. It will be seen that the same is true for the national level. As we define stability as depending on the weight (+/-50%), criteria with high weights require a higher interval to be stable and are thus slightly discriminated.

On the national level, sensitivity analyses indicate that weights have influence on the MCE rankings. Considering the 16 scenario rankings we find that they differ compared to the ranking with equal weights in the following points:

- There are still the same two basic groups of scenarios (1) C, E, and B and (2) A, and D;
- The distance of the scenarios to each other gets smaller, especially between A and D and C and E;

- Consequently more parallel rankings appear in the partial ranking;
- Stability intervals do not exceed the ± 50% and quite a few of the resulting rankings cannot be seen as stable;
- The scale is getting smaller in most cases (range of net flow is smaller)[8].

Only three out of the 16 resulting individual rankings are stable in every respect, meaning according to all the indicators. Certain indicators appear to be more often instable. The methodological assumption is that these indicators represent criteria, which have rather similar impacts across the scenarios compared to the other criteria; as which are: CO_2 equivalents (13 out of 16 rankings are not stable in CO_2), employment (11 out of 16), costs (9 out of 16), social cohesion (8 out of 16), and impact on public spending (8 out of 16).This means that according to these criteria the ranking of scenarios changes easily if the weights change.
It is noticeable that the most highly weighted criteria are among the most instable criteria. This is even stronger than in the local case.
Further sensitivity analyses on the effect of weights on the ranking show that if the social block of criteria (regional self-determinacy, social cohesion, social justice, and noise) is dominant, the ranking changes in a very stable manner to E-C-B-D-A. The social criteria correlate strongly with the degree of decentralisation of the energy system, which is highest in E ("Large impact in small scale use") and C ("Investment into the future"). If the economic-technological block of criteria (costs, diversity of technology, employment, effect on public spending, import dependency, technological advantage, security of supply) is dominant, certain observations of change can be made but no uniform ranking is produced as is the case with the social criteria. The net flow is distinctively smaller than in the other sensitivity analyses, which means that the scenarios do not differ as much. A general effect is, though, that the scenario D ("Extensive use of biomass") is ranked higher with dominant weight on economic-technological criteria. The foremost weight on the environmental criteria block (climate change properties, air quality properties, water quality properties, rational use of resources, landscape quality, ecological justice) shows that the opposite effect, namely that scenario D is ranked lower and all the rankings are on a very large net flow range.

2. <u>What can be seen from the data in the impact matrix</u>
From the local impact matrix it is already possible to recognize the good evaluation of scenario 4. Except for 'costs' scenario 4 has never got the worst evaluation, but for most criteria the best. For scenarios 1 and 3 it is the other way round. This explains without applying a multi-criteria aggregation the basic result that scenario 4 is the best and scenarios 1 and 3 are rather poorly evaluated.
The data of the impact matrix in the national case study does suggest the final ranking in a similar manner (see section 3.4) as on the local level but is a bit more ambiguous. It is obvious from the impact structure that the scenario D "Extensive Use of Biomass" is performing badly along most of the environmental criteria which is due to the fact that we have been using life-cycle analysis data, which includes also emissions from processes and transport preliminary to the final energy conversion.[9] In contrast to

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[8] A smaller range of net flow indicates that the scenarios are closer together according to their impacts, so consequently they do not differ that much from each other.

[9] The generation of biomass as an energy resource involves, in contrast to other renewable energy sources, a lot of transport and environmentally harmful processes, such as (artificial) fertilising etc.

that, scenario D has the best performance in the criterion ‘costs’. Furthermore, the data of the impact matrix suggests that, generally, the social criteria discriminate against more centrally organised energy system (scenario A, B, D).

3. From social preferences to weights

As mentioned in section 3.4, we used the SIMOS method to normalise the preferences given in a certain order. If the weights for the criteria do not sum up to 100%, then PROMETHEE has got a function to normalise the numbers in such a way that they sum up to unity.
On the local level, a sensitivity analysis that gives the rank of the criterion instead of weights (the first one has the highest rank, 13 in our case) leads to the same result as the basic one.
The MACBETH (Bana e Costa and Vansnick, 1999) method offers another option to obtain weights from ordered criteria. We used this method to obtain the weights for the criteria in the local case study; they were very close to the original ones and did not deliver any other result of the scenarios’ evaluation.
A way to present results graphically in Decision Lab is by means of GAIA planes (cf. Brans and Mareschal, 1990), shown in Figure 3 and 4. In GAIA planes the criteria, options and a decision axis are mapped onto a two-dimensional plane. In Figures 3 and 4, the line between the origin and point pi is the decision axis (also referred to as ‘decision stick’), which represents the condensed weighing of the criteria (cf. Geldermann and Zhang, 2001). The decision stick can be moved by changing the weights. The criteria, represented by green squares, are plotted along axes that show synergies and conflicts among criteria. If criteria are oriented in the same direction, they exhibit synergy potentials, whereas if they look in opposite directions, then they present trade-offs (potential conflicts). If options and criteria are located in the same direction, then the options are good options, judged by the criteria concerned. While the GAIA plane is a useful tool for visualising results, and for undertaking sensitivity analysis, it has shortcomings (cf., e.g., Omann, 2004). For instance, it is only valid for PROMETHEE II (complete ranking), and it can only be used for a subset of the total information.

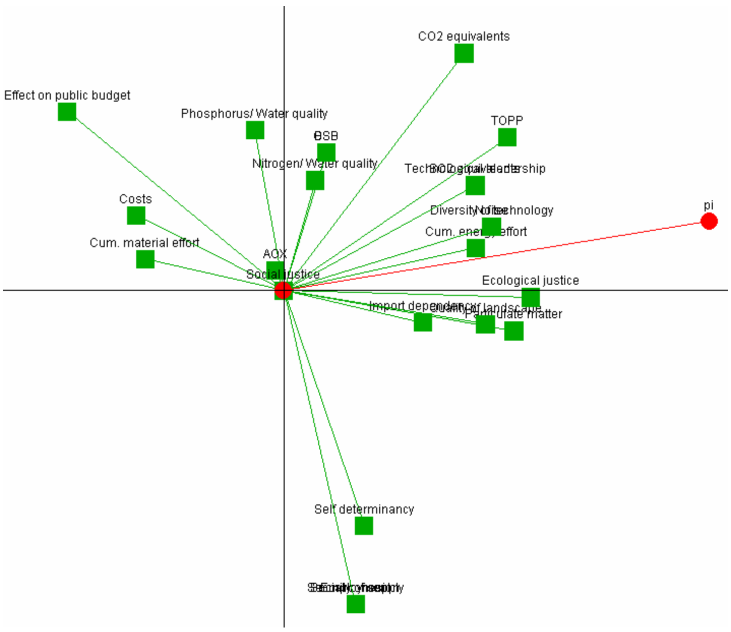

Figure 3: GAIA plane for national level criteria, equal weights

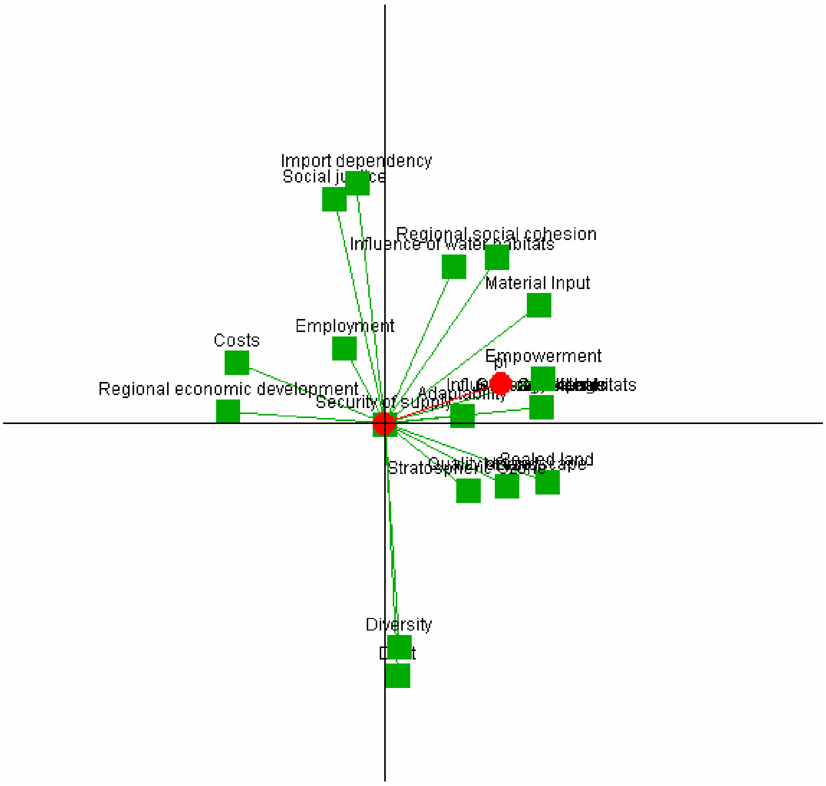

Figure 4: GAIA plane for the local level, group weights

Figure 3, the analysis of the GAIA plane for equal weights on the national level, suggests that many criteria were pulling in the same (or at least a similar) direction, so that apparently significant synergy potentials among the criteria exist. In contrast, figure 4 (GAIA plane on the local level for the group weights) shows that while a great many criteria pull in one direction, the economic criteria point in the other direction, so that trade-offs with the other criteria exist.

4.2 Process oriented interpretation

In the following three process-oriented interpretations, challenges of an integrated assessment and the way we addressed them are given. They show crucial parts of the process, which means that the way they are addressed do influence the results beside the issues treated in the section above.

Selection of stakeholders:

The question of whom to include in a participatory process depends on the issues at stake, the scale and objectives of the study, etc. Depending on who they are (practitioners, technicians, theoreticians, politicians, etc.), their way of approaching the task of weighing criteria will differ. It is a major challenge to find an approach that takes these differences properly into account. In our local case, the group was rather homogeneous regarding their intellectual approach and interests, but at the national level stakeholders reacted differently and came from different backgrounds. Consequently no group ranking was obtained, and also the individual rankings had to be considered in a differentiated way when interpreting the MCE results.

Definition of criteria:
Participatory processes are usually characterised by limited time. Even if criteria are clearly defined by the researchers, as we tried for our studies, it is difficult to transfer this distinctness into workshops, interviews, or whatever other form of participatory approach. Two promising ways to overcome this problem are (1) to explain criteria repeatedly and (2) to disrupt discussions whenever uncertainty is observed. However, both interrupting and influencing running processes may lead to other problems. The definition of criteria in the cases was a good example for the demand of different rhetoric in transdisciplinary projects. We even differentiated between three kinds of rhetoric. There was the language of the research team, being experts of integrated sustainability assessment and renewable energies. In the national stakeholder group, an external rhetoric for experts in the area of energy was needed, whereas in the local group a clear and simple language explaining the specific terms was used. This led to different naming and explanation of some of the criteria which actually meant the same on both levels.

Dominance of certain stakeholder:
The dominance of certain stakeholders is a common problem in participatory approaches and calls for sensitive reaction of the facilitator and a combination of group and individual participation schemes. The group agreement in the local case was strongly dominated by one person in spite of a professional facilitator. All participants agreed but nevertheless the weights do not reflect their individual preferences in total.
A possible solution may be – as done on the national level – to abandon the aim of obtaining a consensus group ranking, but this results in other deficiencies for the MCE and the challenge to interpret several individual rankings or aggregate them.

5 Discussion and conclusions

In this paper we have tackled the potential role and influence of weights reflecting social preferences in participatory MCE studies. Sensitivity analyses show that the rankings are quite robust at the local level, especially regarding the highest ranked scenario, whereas the stability of the rankings at the national level is essentially restricted to certain robustness within two groups of scenarios.

Content related discussion and conclusion:
A direct comparison between the two levels of analysis is hampered by differences in the sets of criteria used (impact matrix), the different application of weights (i.e. lack of group weighting at the national level), and different patterns in the participation of stakeholders. Conclusions drawn from comparing the two levels should therefore be treated with great caution.
Nevertheless comparing the weights set on the criteria in the national and the local level, the different priorities are obvious. On the national level the 'impact on climate change' is clearly ranked highest followed by the 'effect on public spending', and 'security of supply'. These could be characterised as macro issues. Whereas on the local level the highest priority was attributed to 'regional economic development' followed by 'air quality', 'impact on climate change' and 'employment'. Different issues are predominant in the discussions on the different geographical and institutional scale.

On a more specific level, we have grouped the criteria into blocks (economic-technological, social, environmental) and also looked at visualisations of the relevance and direction of criteria in GAIA planes. The analysis of the GAIA plane for equal weights on the national level (figure 3) showed that a great many criteria were pulling in the same direction, pointing to significant synergy potentials among the criteria used. The GAIA plane on the local level (figure 4) for the group weights show also a lot of criteria being pulled together in one section, except the economic criteria which show in the opposite direction, building thus trade-offs with the other criteria. This phenomenon is also indicated by the sensitivity analysis putting a high weight on the economic criteria, which favours the scenarios otherwise ranked on the low places.

<u>Methodological discussion and conclusions:</u>
An integrated assessment process, such as an MCE, is usually applied to support decision-making. An evaluation process ought to be appropriate in the sense that it leads to 'good' decisions. But what is a good decision in the case of sustainable development, and how can we judge whether evaluation processes and decision-making procedures for sustainable development are appropriate or not?

First of all, an evaluation is not just a single action, but the interplay between the evaluation process, the possible evaluation results and the resulting decisions and problem solving capacity. Therefore, in deciding what is appropriate, emphasis needs to be placed not only on the results of the evaluation, but equally on the processes that accompany the evaluation. In the context of the present paper, successful evaluation aims at supporting those energy system(s) considered as most adequate for moving towards sustainable development. It is inextricably linked to the peculiarities of sustainable development, to the characteristics of complex systems (such as the energy system), and to the related challenges in the research processes. We can thus find requirements for successful evaluation and categorise them into three groups: (1) systems characteristics and functions; (2) principles of sustainable development; (3) decision making procedure (cf. Omann, 2004). Successful fulfilment of these categories is likely to guarantee an appropriate and successful evaluation. They serve for analysing the MCE processes in ARTEMIS and to draw conclusions about their quality and success.

(1) We started to define sustainability for an energy system from a systems perspective and not from perceiving sustainability as being three-dimensional. The dimensions we used involved linkages to other systems (above and below in the hierarchy) and interconnectedness, needs and wants of subsystems and actors in the energy system, resilience of the addressed systems and efficiency. That way we aimed for taking into account the relevant criteria as well as different spatial scales. Energy systems are not static, they are dynamic and evolving. When evaluating scenarios leading up to 2020 this dynamic factor (e.g. changing political conditions) ought to be taken into account. Unfortunately, this was hardly done in the research underlying this paper, due to lack of appropriate literature, data and models. Data for many of the criteria used are highly uncertain, limiting the confidence that can be put in the results obtained. Tackling this uncertainty and integrating it in the MCE leaves room for further research, for instance by using fuzzy data and an MCE method allowing for fuzziness.

(2) The evaluation process needs to be designed in such a way that the energy systems under consideration support sustainable development. Therefore, principles and characteristics of sustainable development have to be considered. By setting a sustainable energy system as overall objective of the evaluation and then operational-

ising this objective by defining criteria and indicators, the normative aim of sustainable development was accommodated.
Two important components of sustainable development, social justice and democracy, were explicitly taken into account. The first one by having it as one evaluation criterion and the second by inserting a strong participative element in the process and thus respecting multiple perspectives as well as by defining empowerment of citizens as one evaluation criterion.

(3) It is important to focus on the total process of the evaluation, starting with problem identification and ending with the evaluation or the actual decision. We have placed the focus on both, the process of the evaluation as well as on the results. Concerning the issues of group processes we allowed for non-agreement within the group (which was the case on the national level). The participatory process was accompanied by an evaluation of the social learning of the participants (for results see Stagl and Garmendia, 2006). It showed that social learning was a strong component of the local process. Concerning the evaluation results, they were accepted by the stakeholders on both levels, but only seen as directly implementable actions on the local level, which was a contribution to bridge the gap between science and policy, one aim of transdisciplinary research. However, having direct implementable results was not the target of the national process. The applied evaluation process was flexible and adaptive by making a redesign of the scenarios and criteria possible and thus allowing for feedback loops.
To conclude, we found that the use of weights reveals a better founded display of social preferences, compared to a direct ranking of the alternative scenarios by stakeholders; this helps to avoid strategic behaviour of stakeholders and allows for a more complex assessment of alternative options than a mere presentation or description of the impacts of the options. But there are still methodological challenges ahead for a sound combination with analytical tools!

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Appendix

Table I: Local impact matrix including weights and preference functions

	Unit	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Weight
Climate change impact	t/TJ EE	31.9	15.7	33.3	15.5	9.5
Energy input	GJ/TJ EE	2,587.2	1,274.1	2,793.7	1,310.9	2.9
Material input	kg/TJ EE	55,823.3	15,167.5	49,883	11,864.3	2.9
Sealed land	m²	8,100	0	8,900	100	2.9
SO2-equivalents	kg/TJ EE	295.9	181.9	326.7	193.2	1.9
Stratospheric ozone	kg/TJ EE	406.2	360.7	456.5	369.8	2.85
Dust	kg/TJ EE	94.4	120.8	263.8	143.1	4.75
Noise	Qualitative	Low	None/Hardly	Moderate	None/Hardly	0.97
Smell	Qualitative	Moderate	None	Moderate	None	0.97
Influence of water habitats	Qualitative	Moderate	None	No	None	0.97
Influence of soil habitats	Qualitative	Moderate	None	Moderate	None	0.97
Empowerment	Qualitative	Low	Moderate	Low	High	0.69
Social justice	Qualitative	Low	Low	High	Moderate	1.49
Regional social cohesion	Qualitative	Low	Moderate	Moderate	High	5.49
Costs	€ / TJ EE	25,113	28,664	21,447	28,777	4.69
Regional economic development	Qualitative	High	Low	High	Moderate	10.3
Employment	Employed	4.82	4.3	5.45	5.8	9.5
Diversity	Qualitative	High	Moderate	Low	Moderate	8.7
Adaptability	Qualitative	Moderate	High	Moderate	High	3.09
Import dependency	%	64	67	81	74	7.89
Quality of landscape	Qualitative	Low	Moderate	Moderate	None	7.89
Security of supply	Qualitative	Good	Good	Good	Good	8.7

Table II: National impact matrix including weights

	Unit	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Weight Range (in %)
Climate change impact							
CO_2 equivalents	*(t/ TJ)*	18	16	17	21	18	7,77- 12,74
Air quality							
SO_2 equivalents	*(kg/ TJ)*	276	236	179	289	265	1- 3,53
TOPP	*(kg/ TJ)*	359	312	240	399	353	1- 3,53
Particulate matter	*(kg/ TJ)*	94	78	69	124	72	1- 3,53
Rational resource use							
Cum. energy effort	*(GJ/ TJ)*	2,365	2,099	1,822	2,444	2,274	1,56- 6,37
Cum. material effort	*(kg/ TJ)*	81,441	83,182	105,203	78,311	75,468	1,56- 6,37
Water quality							
Phosphorus	*(mg/ TJ)*	30	31	56	77	33	0,6- 2,03
Nitrogen	*(g/ TJ)*	4	4	5	6	5	0,6- 2,03
AOX	*(mg/ TJ)*	25	24	22	20	33	0,6- 2,03
CSB	*(kg/ TJ)*	33	36	51	92	31	0,6- 2,03
BSB	*(g/ TJ)*	967	1,040	1,467	2,598	899	0,6- 2,03
Costs	*E3 €/ TJ*	43	41	51	40	46	2,59- 12,5
(Reg.) Self determinacy	*Qualitative*	Rather low	Low	Rather high	Medium	High	0,79- 7,81
Social cohesion	*Qualitative*	Rather low	Rather low	Medium	Medium	Rather high	0,79- 10,6
Diversity of technologies	*Qualitative*	Rather low	Medium	Medium	Low	Medium	1,27- 9,75

Employment	*Qualitative*	Rather low	Rather low	Medium	Medium	Rather high	0,79- 8,43
Effect on public budget	*Qualitative*	Low	Rather low	Rather high	Rather low	Medium	0,79- 18,56
Import dependency	*Qualitative*	Medium	Medium	Low	Medium	Medium	0,93- 12,74
Quality of the land-scape	*Qualitative*	Low	High	High	Medium	High	1,01- 7,77
Noise	*Qualitative*	Medium	Low	Low	High	Low	0,79- 7,77
Social justice	*Qualitative*	Medium	Medium	Medium	Medium	Medium	0,59- 10,24
Technological leader-ship	*Qualitative*	Low	Medium	High	Low	Low	0,79- 8,75
Ecological justice	*Qualitative*	Low	Medium	Rather high	Low	Medium	0,79- 10,06
Security of supply	*Qualitative*	Low	Low	Medium	Medium	High	2,96- 15,72

Table 3: Stability intervals for the aggregation on the local level with the group weights

Stability Intervals

Stability Level: 4 first actions

	Weight	Interval		% Weight	% Interval	
		Min	Max		Min	Max
CO2-Äquivalent	9.5000	3.0316	Infinity	9.50%	3.24%	100.00%
Energy input	2.9000	0.0000	Infinity	2.90%	0.00%	100.00%
Material input	2.9000	0.0000	9.3883	2.90%	0.00%	8.81%
sealed land	2.9000	0.0000	Infinity	2.90%	0.00%	100.00%
SO2 equivalents	1.9000	0.0000	Infinity	1.90%	0.00%	100.00%
stratospheric ozo	2.8500	0.0000	Infinity	2.85%	0.00%	100.00%
Dust	4.7500	2.5872	17.6868	4.75%	2.64%	15.66%
Noise	0.9725	0.0000	Infinity	0.97%	0.00%	100.00%
Smell	0.9725	0.0000	Infinity	0.97%	0.00%	100.00%
Influence of wate	0.9725	0.0000	4.2167	0.97%	0.00%	4.08%
Influence of soil h	0.9725	0.0000	Infinity	0.97%	0.00%	100.00%
Empowerment	0.6900	0.0000	Infinity	0.69%	0.00%	100.00%
Social justice	1.4900	0.0000	4.0853	1.49%	0.00%	3.98%
Regional social cc	5.4900	0.0000	9.8155	5.49%	0.00%	9.41%
Gestehungskoste	4.6900	0.0000	10.9939	4.69%	0.00%	10.34%
Regional economi	10.3000	0.0000	15.4747	10.30%	0.00%	14.71%
Employment	9.5000	0.0000	22.4368	9.50%	0.00%	19.86%
Diversity	8.7000	6.5372	17.3245	8.70%	6.68%	15.95%
Adaptability	3.0900	0.0000	Infinity	3.09%	0.00%	100.00%
Import dependenc	7.8900	0.0000	10.2073	7.89%	0.00%	9.97%
Landscape quality	7.8900	1.4017	Infinity	7.89%	1.50%	100.00%
Supply security	8.7000	0.0000	Infinity	8.70%	0.00%	100.00%

Table 4: Stability intervals of the ranking of national ARTEMIS scenarios with equal weights

Stability Intervals

Stability Level: 5 first actions ☑ AutoLev

	Weight	Interval		% Weight	% Interval	
		Min	Max		Min	Max
CO2 equivalents	1.0000	0.0000	2.1255	4.17%	0.00%	8.46%
SO2 equivalents	1.0000	0.1325	2.4069	4.17%	0.57%	9.47%
TOPP	1.0000	0.0000	2.8759	4.17%	0.00%	11.11%
Particulate matter	1.0000	0.0000	Infinity	4.17%	0.00%	100.00%
Cum. energy effort	1.0000	0.0000	3.8138	4.17%	0.00%	14.22%
Cum. material effort	1.0000	0.0000	2.0410	4.17%	0.00%	8.15%
Phosphorus/Water quality	1.0000	0.0000	2.0410	4.17%	0.00%	8.15%
Nitrogen/Water quality	1.0000	0.0000	6.6277	4.17%	0.00%	22.37%
AOX	1.0000	0.0000	3.8138	4.17%	0.00%	14.22%
CSB	1.0000	0.0000	2.7349	4.17%	0.00%	10.63%
BSB	1.0000	0.0000	2.7349	4.17%	0.00%	10.63%
Costs	1.0000	0.0000	3.1142	4.17%	0.00%	11.93%
Self determinancy	1.0000	0.0621	4.9036	4.17%	0.27%	17.57%
Social cohesion	1.0000	0.1960	2.7349	4.17%	0.85%	10.63%
Diversity of technology	1.0000	0.0000	Infinity	4.17%	0.00%	100.00%
Employment	1.0000	0.1960	2.7349	4.17%	0.85%	10.63%
Effect on public budget	1.0000	0.0000	2.8759	4.17%	0.00%	11.11%
Import dependency	1.0000	0.0000	Infinity	4.17%	0.00%	100.00%
Quality of landscape	1.0000	0.0000	9.7889	4.17%	0.00%	29.85%
Noise	1.0000	0.0000	Infinity	4.17%	0.00%	100.00%
Social justice	1.0000	0.0000	Infinity	4.17%	0.00%	100.00%
Technological leadership	1.0000	0.1325	2.4069	4.17%	0.57%	9.47%
Ecological justice	1.0000	0.0000	Infinity	4.17%	0.00%	100.00%
Security of supply	1.0000	0.1960	2.7349	4.17%	0.85%	10.63%