A Multi-stakeholder Approach to Energy Transition Policy Formation in Jordan

Mats Danielson[1,2], Love Ekenberg[1,2(✉)], and Nadejda Komendantova[2,3]

[1] Department of Computer and Systems Sciences, Stockholm University, Postbox 7003, 164 07 Kista, Sweden
mats.danielson@su.se

[2] International Institute for Applied Systems Analysis, IIASA, Schlossplatz 1, 2361 Laxenburg, Austria
{ekenberg, komendan}@iiasa.ac.at

[3] Department of Environmental Systems Science, Institute for Environmental Decisions (ETH), Zurich, Switzerland

Abstract. We present the method used in an ongoing project in Jordan for a multi-stakeholder, multi-criteria problem of formulating a nationwide energy strategy for the country for the next decades. The Jordanian government has recognized the need for energy transition and the main goal of the energy strategy is to provide a reliable energy supply by increasing the share of local energy resources in the energy mix, while reducing dependency on imported fossil fuels, by diversifying energy resources, also including renewable energy sources, nuclear and shale oil, and by enhancing environmental protection. There were strong incentives for a collaborative approach, since the ways in which different stakeholder groups subjectively attach meanings to electricity generation technologies are recognized as important issues shaping the attainment of energy planning objectives. To understand the meaning of these constructs, we are using a multi-stakeholder multi-criteria decision analysis (MCDA) approach to elicit criteria weights and valuations.

Keywords: Energy policies · Multi-stakeholder workshops
Multi-criteria decision analysis · Surrogate criteria weights · Robustness

1 Introduction

Energy transition is a complex process which has political, social, economic and technical dimensions, requiring holistic, inclusive and comprehensive governance approach… The process of introducing energy sources and technologies can result in major socio-technical changes which might lead to frictions and conflicts. Thus, these processes will not only lead to technological changes but will also lead to socio-technological transition processes, combined with shifts in generation and distribution technologies, business models, governance structures, consumption patterns,

---

The original version of this chapter was revised: The spelling of the third author's name was corrected. The correction to this chapter is available at https://doi.org/10.1007/978-3-319-92874-6_16

Y. Chen et al. (Eds.): GDN 2018, LNBIP 315, pp. 190–202, 2018.
https://doi.org/10.1007/978-3-319-92874-6_15

values and world views. For sustainable implementations of these processes, new forms of governance are needed based on compromise solutions.

Energy transition could be seen as action fields or arenas where different individual or organized stakeholders are competing for legitimization of their actions and organizational survival in the future [18]. For instance, the energy sector in Jordan is well established with an existence of large providers, most often owned by the state, which generate, transmit and distribute electricity to consumers. Electricity providers, such as coal, oil and gas companies, are regarded as incumbents, i.e. actors, who have a disproportionate influence, and whose views and interests often are reflected in a dominant organization of the strategic action field, which might be entirely shaped by the worldviews, interests and positions of these incumbents. Thus, the appearance of new technologies or governance modes may heavily challenge the power distribution within the sector.

Furthermore, the dependency on imported energy sources is a heavy burden for the socio-economic and energy security of Jordan. During the last decades, energy supply to Jordan has been very volatile, also because of a number of external political shocks and setbacks. For example, an increase in the prices of crude oil, which happened during the Arab Spring in Egypt, significantly affected Jordan (being dependent on energy imports from Egypt). The interruption of Egyptian gas supply forced Jordan to switch to much more expensive heavy fuels, creating a large burden on the Jordanian national budget and significantly increased the already existing budget deficit. Also, to handle the difference between imported energy and affordability in the local market, the Jordanian government needed to heavily subsidize energy imports, which further increased its national deficit.

Several reports on energy transition in Jordan have been written, with the focus on economic and technological factors. Following evidence as well as national and international advice, Jordan has been developing a legal and regulatory framework to attract investments in renewable energy expansion but also in new technologies such as shale oil and nuclear power. However, the discussions about an energy transition and a transformation of the Jordanian society, which might be caused by large-scale deployment of new technology, as well as socio-economic consequences of the transformation of the energy system, have been limited. Furthermore, the process of learning from other regions and from technology transfer, which goes beyond single projects, but includes regional models of energy transitions and transformation of society, should be considered with caution. There are several examples and good practices in Europe, such as “Energiewende” in Germany or energy transition through climate and energy models in Austria. However, a plan for an energy transition in the MENA region should consider completely different energy market structures, stakeholders’ networks and societal aspirations regarding energy, climate and environmental policies [22].

MCDM methods have been used during the last decades to select between different energy system solutions, most often on a regional scale, for example [2, 24, 34], or smaller scale [29], or for non-specific discussions on energy system solutions [25] or policies [16]. Some have had a national scope targeting a specific technology, for example [36]. This current project, however, deals with a national energy policy based on input information from large sets of stakeholders. The required methodology to deal with it is a multi-stakeholder, multi-criteria decision analysis method suitable for discussions and negotiations in different settings and with different background data.

In this article, we discuss, an ongoing project for the multi-stakeholder, multi-criteria problem of formulating an energy strategy for Jordan for the next decades.

2 Problem Setup

This section describes the process of selecting a relevant energy policy and makes this process more transparent. It also identifies a set of optimal solutions out of a set of technologies of the prevailing realistic options.

2.1 Identification of Available Technologies

The collection of data for establishing the performance characteristics for each technology was based on different sources and methods encompassing both quantitative and qualitative data. Primary quantitative data sources involved remote sensing data and Geographical Information System (GIS) maps as well as data available from national statistics databases. Secondary quantitative data sources included a total of more than 200 regionally specific and international peer-reviewed articles, official policy reports, industry reports, Environmental and Social Impact Assessments (ESIAs), and real project case studies. Additionally, experts were surveyed to obtain qualitative indicators on criteria where no quantitative data could be found or developed, such as the perceptions of capacity of national authorities to control the risks involved. A purposeful sampling was applied in order to consult a balanced diversity of experts from different fields of expertise and roles in society. The identification and selection of individuals was influenced by practical considerations, such as the availability, willingness to participate, or opportunities that emerged during the research process [26]. Overall, 52 experts were asked to take part in the survey of whom 31 responded. The identification of the technologies resulted in the following set of options:

- **Utility-Scale Photovoltaic** (PV), which uses direct and diffused solar radiation and converts it into electricity by using a photovoltaic effect.
- **Concentrated Solar Power** (CSP), which, with the help of different kinds of mirrors, concentrates solar radiation onto a receiver and then converts it into thermal energy inside the receiver. Then thermal energy is transformed into mechanical energy with the help of a steam turbine and converted to electricity with the help of a generator.
- **Onshore Wind**, which with the aid of wind turbines harnesses kinetic energy of the wind and converts it first into mechanical energy and then electricity.
- **Utility Hydro-Electric** uses water to turn a turbine that provides mechanical energy and drivers a generator.
- **Nuclear Power**, which uses the thermal energy released by uranium fission reactions.
- **Lignite Coal**, when the coal-fired power plant converts the chemical energy from coal into heat in the process of combustion. The heat is then used to generate steam which drives a turbine to produce electricity.

- **Natural Gas**, when kinetic energy from the motion of flowing gas is utilized to generate electricity with the help of a gas turbine.
- **Heavy Fuel Oil**, when the oil-fired power plant uses the chemical energy of oil to generate electricity with the help of different kinds of steam systems.

These technologies were identified before consultations with the stakeholder groups and were presented for comments, after which the stakeholders added shale oil to the set of options.

2.2 Criteria Selection

All technologies were assessed against a set of 11 criteria, with a corresponding total of 20 indicators. Out of these, 9 indicators are quantitative and 11 are qualitative. The criteria were selected in a threefold, iterative process. The first step of the selection process was based on an extensive literature review of scientific publications that developed criteria relevant to assessing the performance of energy systems and electricity technologies (e.g., [1, 11, 12, 19–21, 23, 35]). Thereafter, the national policy framework was supplemented with a criterion set with nationally relevant development criteria. Each criterion was then evaluated according to its relevance for the decision-making problem at hand ("high", "medium", or "low"). This process included several interactions and iterations, through which the number of criteria was eventually narrowed down from 32 to the final set of 11 criteria in a three-level criteria with tree comprising a total of 24 sub-criteria, see Fig. 1.

2.3 Stakeholder Groups

At the core of the study was a series of seven one-day stakeholder workshops. Each of the first six workshops included groups of stakeholders from the same backgrounds, whereas the participants in the final workshop comprised a heterogeneous stakeholder group to which an equal number of previous participants from each of the previous workshops (i.e. stakeholder groups) were invited.

In line with different scholars [3, 30, 31, 34], who recommend the inclusion of political, economic, scientific, and socio-cultural actors in electricity planning, six stakeholder groups of different backgrounds were selected to participate in this research. The participants were identified based on a comprehensive stakeholder analysis and according to their positions and interest in Jordan's energy decision-making and also based on the extent to which they are impacted by electricity installations. The stakeholder analysis was conducted by the research team in cooperation with the local partners. In the first step, broad stakeholder categories, for example "Policy-makers", "Young Leaders", etc. in line with the above mentioned different backgrounds were established. In the second step, these categories were broken down into more concrete sub-groups of these categories, e.g., for the category "Finance and Industry", small and medium-sized enterprises or national banks.

In the final step, the representatives of the sub-groups were determined. As a result, the following stakeholder groups were identified.

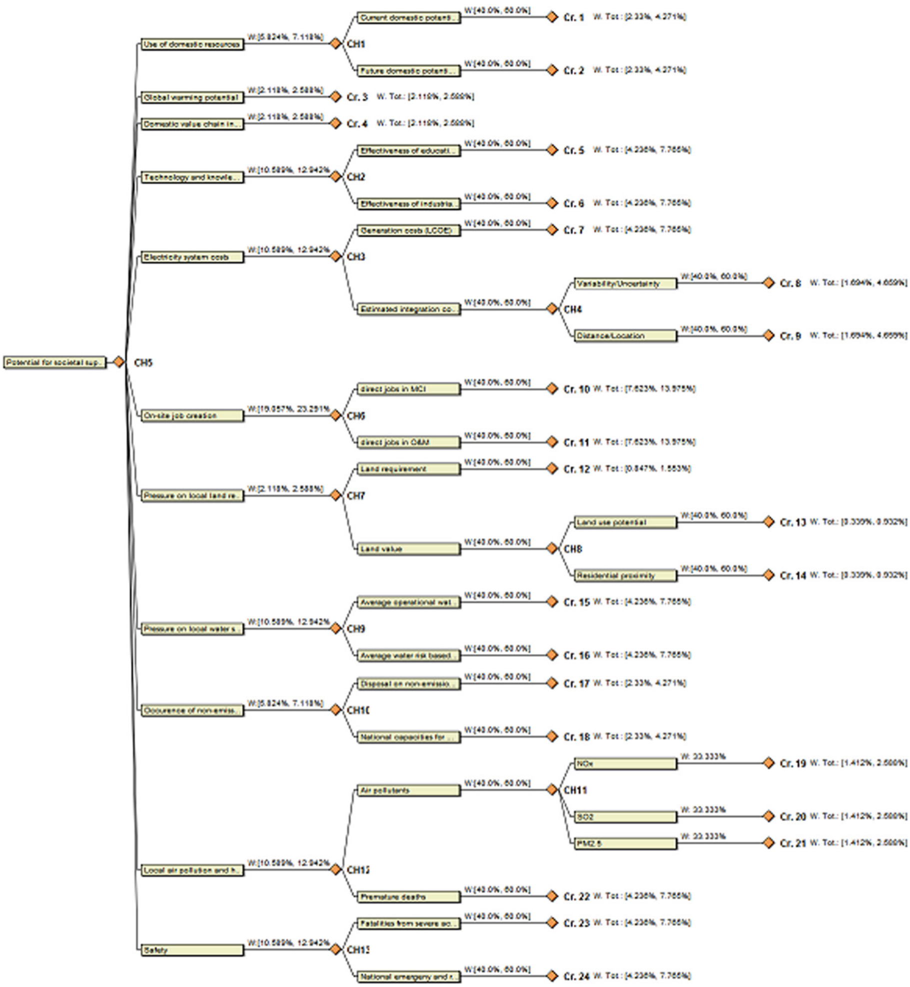

Fig. 1. Final criteria tree in the tool DecideIT.

- **Policy-makers:** stakeholders who are directly involved in electricity planning including generation and distribution;
- **Finance and Industry:** stakeholders who are characterized by high electrical power end-use and are directly involved in the implementation and financing of power generation capacities;
- **Academia:** stakeholders who are scientifically interested and involved in the research and development of electricity systems, e.g., universities, research institutions, and think tanks;
- **Young Leaders:** stakeholders who can be regarded as future decision-makers or opinion-leaders and have a strong interest in national energy planning due to their professional background, public engagement, and networks;

- **National NGOs:** stakeholders who have a strong interest in national energy planning and are involved in national NGOs working on environmental protection, social justice, and human development;
- **Local Communities:** stakeholders who live in close proximity to electricity generation technologies and are thus directly affected by national electricity planning;

The involvement of different stakeholder groups, in an intensive, discussion-oriented, and participatory process, allowed a wide array of multidimensional perspectives on Jordan's energy future to be elicited. During the workshops, attention had to be focused on creating a climate that welcomed discussion, where different stakeholder views were respected and equally validated, while at the same time room for mutual learning and new information was provided. This was in particular the case for the final workshop where equally legitimate opinions and perspectives as well as mutual learning experiences had to be safeguarded by the moderators in order to allow for a balanced representation of all stakeholder groups during the often heated debates among participants.

During the stakeholder workshops the participants were given 45 min to develop their individual vision on what they, as representatives of their specific stakeholder group, would like Jordan to be in the year 2050. The participants were provided with a set of cards and asked to write down either a short sentence or an attribute for their vision in three areas: the economy, the society, and the environment. Then, all cards were discussed on flipcharts and clustered in common themes, where agreement was reached, as well as where perspectives diverged. The aim here was not to be comprehensive but rather to identify the top priorities with respect to how different stakeholder groups imagine a desirable future for Jordan.

Following the vision development phase, the participants were given 60 min to express their aspirations and concerns in regard to the question of how the deployment of new electricity generation technologies in Jordan could enable or hamper the fulfilment of their vision financially, socially, and environmentally. To facilitate this task, short vignettes for each technology were distributed to provide as far as possible unbiased, non-technical information on the basic functions and performance of the technologies under examination. After discussing the specifics of the different technologies, the participants were again provided with a set of cards and asked to formulate their thoughts as representatives of their specific stakeholder groups. Afterwards, all cards were clustered around the main issues that emerged during the vision development and discussed openly.

3 Criteria Ranking

Simos proposed a procedure, using a set of cards, for determining numerical values for criteria weights suitable for negotiation settings [32, 33]. In its standard form, a group of decision-makers are provided with a set of coloured cards with the criteria names written on them. Furthermore, the decision-makers are provided with a set of white (blank) cards. Thereafter, the non-blank cards are ranked from the least important to the most important, where criteria of equal importance are grouped together. Furthermore, the decision-makers are asked to place the white cards in between the coloured cards to express preference strengths. Figueira and Roy [17] have suggested a modified version, where the decision-makers state how many times the most important criterion or criteria group is compared to the least important. A variation of the Simos method was used in this project for elicitation purposes. The card ranking part was employed as the original but the evaluation part differs significantly from the Simos method. The criteria were at this point well-known by the participants from the previous sections of the workshops.

Each criterion was written on a coloured card and arranged horizontally on a table. Then each of the participants successively ranked the cards from the least important to the most important by moving the cards to a vertical arrangement, where the highest ranked criteria was put on top and so forth. If two criteria were considered to be of equal importance, they were put on the same level. This process lasted for four rounds, where the number of moves for each round was 8, 5, 3 and 2 respectively. Furthermore, the first and third round was concluded by an open discussion before the following round commenced.

The ranking procedure lasted for 120 min or until a final ranking was obtained that the participants found acceptable. Needless to say, the decreasing number can be disputed and is a weak point of the method (and thus an open research question needs to be addressed in subsequent projects), since it encourages the participants to act strategically in relation to the information they received during the process. So when applying this method, the potential conflicts must be lifted and handled. In some cases, working with a set of final ranking in the evaluations, showed whether or not the differences are of importance.

When this first ordinal ranking was finalised, the participants were asked to introduce preference strengths in the ranking by introducing the blank cards during three additional rounds (with 3, 2 and 1 moves respectively). The number of white cards (i.e. the strength of the rankings between criteria) was also given a verbal interpretation as shown in Table 1.

Table 1. Verbal interpretation of card placements

Equal level of cards	Equally important
No blank card	Slightly more important
One blank card	More important (clearly more important)
Two blank cards	Much more important
Three blank cards	Very much more important

The final rankings of the six workshops were handed to the representatives of each stakeholder group during the final workshop two months later, when the exercise was repeated also for this compiled cross-sectional multi-stakeholder group. At the final workshop, they could present each ranking and its rationales to the other participants during an introductory presentation round.

4 Selection of Analysis Method

One well-known class of multi-criteria decision analytic methods is the SMART family, where [13–15] proposed a method to assess criteria weights. The criteria are ranked and then 10 points are assigned to the weight of the least important criterion (w_N). Then, the remaining weights (w_{N-1} through w_1) are given points according to the decision-maker's preferences. The overall value $E(a_j)$ of an alternative a_j is then the weighted average of the values v_{ij} associated with a_j (Eq. 1):

$$E(a_j) = \frac{\sum_{i=1}^{N} w_i v_{ij}}{\sum_{i=1}^{N} w_i} \tag{1}$$

The most utilised processes for converting ordinal input to cardinal use automated procedures and yield exact numeric weights. For instance, [13] proposed the SMARTER method for eliciting ordinal information on importance before converting it to numbers, thus relaxing information input demands on the decision-maker. An initial analysis is carried out where the weights are ordered, such as $w_1 > w_2 > \ldots > w_N$, and then subsequently transformed to numerical weights using ROC weights after which SMARTER continues in the same manner as the ordinary SMART method.

The best known ratio scoring method is the Analytic Hierarchy Process (AHP). The basic idea in AHP [27, 28] is to evaluate a set of alternatives under a criteria tree by pairwise comparisons. The process requires the same pairwise comparisons regardless of scale type. For each criterion, the decision-maker should first find the ordering of the alternatives from best to worst. Next, he or she should find the strength of the ordering by considering pairwise ratios (pairwise relations) between the alternatives using the integers 1, 3, 5, 7, and 9 to express their relative strengths, indicating that one alternative is equally good as another (strength = 1) or three, five, seven, or nine times as good. It is also allowed to use the even integers 2, 4, 6, and 8 as intermediate values, but using only odd integers is more common.

As discussed in [5], a viable alternative to these, when cardinal information is present, is the Cardinal Ranking (CAR) method and it has been demonstrated that the latter is more robust and efficient than the methods from the SMART family and AHP. Providing only ordinal rankings of criteria seems to avoid some of the difficulties associated with the elicitation of exact numbers. It puts fewer demands on decision-makers and is thus, in a sense, effort-saving. Furthermore, there are techniques for handling ordinal rankings with various successes. A limitation of this approach is that decision-makers, not least in multi-stakeholder settings, usually have more knowledge of the decision situation than a pure criteria ordering is able to capture, often in the sense that they have an idea regarding the importance of relation information containing strengths. In such cases, the ordinal rankings are often an unnecessarily weak representation, leading to a need for extending the methods to accommodate information regarding relational strengths as well, while still preserving the property of being less demanding and more practically useful than other types of methods such as SMARTS or AHP. In line with the results in [9], the CAR method was selected for the evaluation phase in the project.

5 Evaluations

The analytical part of the evaluation in the project consists of translating the rankings to surrogate weights, evaluating them by applying the CAR method, and then using these values in the software DecideIT which is designed for solving this type of problem under uncertainty. Thereby, the information loss is limited [8]. The idea is the following:

- Assign an ordinal number to each importance scale position, starting with the most important position as number 1.
- Let the total number of importance scale positions be Q. Each criterion i has the position $p(i) \in \{1, \ldots, Q\}$ on this importance scale, such that for every two adjacent criteria c_i and c_{i+1}, whenever $c_i >_{s_i} c_{i+1}$, $s_i = |p(i+1) - p(i)|$. The position $p(i)$ then denotes the importance as stated by the decision-maker. Thus, Q is equal to $\sum s_i + 1$, where $i = 1, \ldots, N - 1$ for N criteria.

In [9, 10], several cardinal weight methods are derived, discussed, and evaluated. The best method for cardinal rankings with properties similar to Simos cards was shown to be CSR weights, expressed as

$$w_i^{\text{CSR}} = \frac{1/p(i) + \frac{Q+1-p(i)}{Q}}{\sum_{j=1}^{N}\left(1/p(j) + \frac{Q+1-p(j)}{Q}\right)} \tag{2}$$

which are consequently employed in this study. Based on the weightings of each stakeholder group, expressed as CSR weights, and observations made during the workshops, the analysis of potential conflict lines and commonalities between the different stakeholder preferences was facilitated through negotiation.

5.1 Encoding of Criteria Weights

As mentioned above, one of the problems with most models for criteria ranking is that numerically precise information is seldom available. This is partially solved by introducing surrogate weights in the way that was done before, but this is only a part of the solution since the elicitation can still be uncertain and the surrogate weights might not be a totally adequate representation of the preferences involved, which is of course a risk with all kinds of aggregations. To allow for a more thorough robustness analysis, we also introduce intervals around the derived weights as well as around the values of the technology options. Thus, in this elicitation problem, the possibly incomplete information is handled by allowing the use of ranges of possible values (cf., e.g., [4, 6, 7]).

There are thus several approaches to elicitation in MCDM problems and one partitioning of the methods into categories is how they handle imprecision in weights (or values).

- Weights (or values) can only be estimated as fixed numbers.
- Weights (or values) can be estimated as comparative statements converted into fixed numbers representing the relations between the weights.

- Weights (or values) can be estimated as comparative statements converted into inequalities between interval-valued variables.
- Weights (or values) can be estimated as interval statements.

Needless to say, there are advantages and disadvantages of the different methods. Methods based on categories 1 and 2 yield computationally simpler evaluations because of the weights and values being numbers, while categories 3 and 4 yield systems of constraints in the form of equations and inequalities that need to be solved using optimisation techniques. If the expressive power of the analysis method only permits fixed numbers (category 1), we usually get a limited model that might affect the decision quality severely. If intervals are allowed (categories 3 and 4), imprecision is normally handled by allowing variables, where each y_i is interpreted as an interval such that $w_i \in [y_i - a_i,\ y_i + b_i]$, where $0 < a_i \leq 1$ and $0 < b_i \leq 1$ are proportional imprecision constants. Similarly, comparative statements are represented as $w_i \geq w_j$. However, we might encounter an unnecessary information loss using only an ordinal ranking. When using both intervals and ordinal information, we obtain some rather elaborate computational problems. Despite the fact that they can be solved, when sufficiently restricting the statements involved (cf. [7]), there is still a problem with user acceptance and these methods have turned out to be perceived as too difficult to accept by many decision-makers. Expressive power in the form of intervals and comparative statements leads to complex computations and loss of transparency on the part of the user. This should be kept in mind here as always when working with aggregation methods of whatever kind.

5.2 Results from the Final Workshop

The performance of different electricity generation technologies was estimated based on a large expert survey. Together with the surrogate weights, they provided the decision base for the multi-criteria analysis. Using the aggregation principle in (2), the multiple criteria and stakeholder preferences could be combined with the valuation of the different technology options under the criteria surrogate weights.

The results of the evaluations are (i) a detailed analysis of the performance of each technology compared with the other technologies, and (ii) a sensitivity analysis to test the robustness of the result. Figure 2 shows part of the results of the final workshop.

In the figure, it can be seen that alternative 1 (Utility-Scale Photovoltaic) is the preferred alternative, meaning that solar radiation converted into electricity by the photovoltaic effect was the collective stakeholders' preference. As the runner-up, alternative 2 (Concentrated Solar Power) was selected, which concentrates solar radiation onto a receiver and then converts it into thermal energy. Especially the preference of alternative 1 was very pronounced in the standings after the final stakeholder summit. Thus, it became the recommendation from the summit (the final workshop).

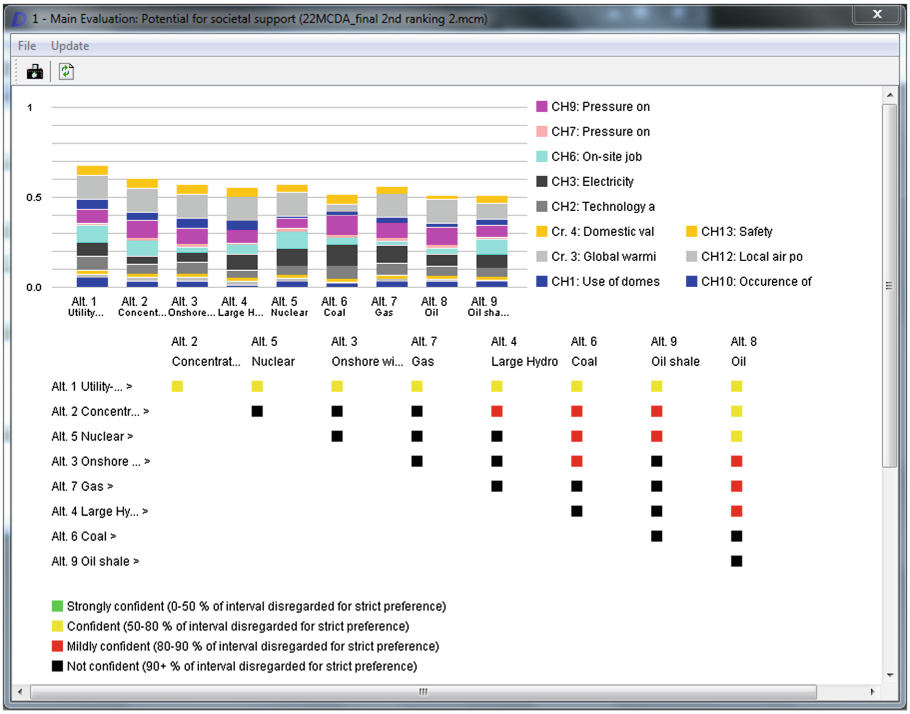

Fig. 2. Rankings of the options for future energy strategies

6 Concluding Remarks

We have presented the method of an ongoing project in Jordan for a multi-stakeholder, multi-criteria problem of formulating an energy strategy for Jordan for the next decades. We used a multi-stakeholder MCDM approach with ordinal or imprecise importance information and suggested a method for how to incorporate various stakeholders' views on energy technologies and their valuation under several criteria. The implementation of MCDM in Jordan was based first on stakeholder workshops with each of a set of groups of stakeholders and then also applied within a final concluding workshop with mixed groups of stakeholders. Our experience of the implementation of the MCDM methodology showed that the local process in Jordan could benefit from a series of workshops with the same mixed group of stakeholders. Such a process would also contribute to the identification of compromise solutions and the facilitation of discussions among stakeholders with different views and perceptions on the importance of different technology relevant criteria. We also followed up with a survey in which stakeholders were asked to rank their results again, but this time individually and not as a group, and to assess their degree of satisfaction with the results from the final workshop. This current article deals with the methodological issues in the project and we have thus omitted a discussion on the final outcome of this analysis, but this will be the subject of a forthcoming article.

Acknowledgements. This research was partly funded by the project Middle East North Africa Sustainable Electricity Trajectories (MENA-SELECT) and partly by the strategic grants from the Swedish government within ICT – The Next Generation.

References

1. Afgan, N.H., Carvalho, M.G.: Multi-criteria assessment of new and renewable energy power plants. Energy **27**, 739–755 (2002)
2. Beccali, M., Cellura, M., Mistretta, M.: Decision-making in energy planning. Application of the Electre method at regional level for the diffusion of renewable energy technology. Renew. Energy **28**, 2063–2087 (2003)
3. Bidwell, D.: Thinking through participation in renewable energy decisions. Nat. Energy **1**, 16051 (2016)
4. Danielson, M., Ekenberg, L.: A framework for analysing decisions under risk. Eur. J. Oper. Res. **104**(3), 474–484 (1998)
5. Danielson, M., Ekenberg, L.: A robustness study of state-of-the-art surrogate weights for MCDM. Group Decis. Negot. **7** (2016). https://doi.org/10.1007/s10726–016-9494-6
6. Danielson, M., Ekenberg, L., He, Y.: Augmenting ordinal methods of attribute weight approximation. Decis. Anal. **11**(1), 21–26 (2014)
7. Danielson, M., Ekenberg, L.: Computing upper and lower bounds in interval decision trees. Eur. J. Oper. Res. **181**(2), 808–816 (2007)
8. Danielson, M., Ekenberg, L.: Rank ordering methods for multi-criteria decisions. In: Zaraté, P., Kersten, G.E., Hernández, J.E. (eds.) GDN 2014. LNBIP, vol. 180, pp. 128–135. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-07179-4_14
9. Danielson, M., Ekenberg, L.: The CAR method for using preference strength in multi-criteria decision making. Group Decis. Negot. **25**(4), 775–797 (2016). https://doi.org/10.1007/s10726-015-9460-8
10. Danielson, M., Ekenberg, L.: Trade-offs for ordinal ranking methods in multi-criteria decisions. In: Bajwa, D., Koeszegi, S.T., Vetschera, R. (eds.) GDN 2016. LNBIP, vol. 274, pp. 16–27. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-52624-9_2
11. Del Rio, P., Burguillo, M.: Assessing the impact of renewable energy deployment on local sustainability: towards a theoretical framework. Renew. Sustain. Energy Rev. **12**, 1325–1344 (2008)
12. Del Rio, P., Burguillo, M.: An empirical analysis of the impact of renewable energy deployment on local sustainability. Renew. Sustain. Energy Rev. **13**, 1314–1325 (2009)
13. Edwards, W., Barron, F.: SMARTS and SMARTER: improved simple methods for multiattribute utility measurement. Organ. Behav. Hum. Decis. Process. **60**, 306–325 (1994)
14. Edwards, W.: How to use multiattribute utility measurement for social decisionmaking. IEEE Trans. Syst. Man Cybern. **7**(5), 326–340 (1977)
15. Edwards, W.: Social utilities. Eng. Econ. Summer Symp. Ser. **6**, 119–129 (1971)
16. Erol, Ö., Kilkis, B.: An energy source policy assessment using analytical hierarchy process. Energy Convers. Manag. **63**, 245–252 (2012)
17. Figueira, J., Roy, B.: Determining the weights of criteria in the ELECTRE type methods with a revised Simos' procedure. Eur. J. Oper. Res. **139**, 317–326 (2002)
18. Fligstein, N., McAdam, D.: A Theory of Fields. Oxford University Press, Oxford (2012)
19. Grafakos, S., Flamos, A., Enseñado, E.M.: Preferences matter: a constructive approach to incorporating local stakeholders' preferences in the sustainability evaluation of energy technologies. Sustainability **7**, 10922–10960 (2015)

20. Grafakos, S., Gianoli, A., Tsatso, A.: Towards the development of an integrated sustainability and resilience benefits assessment framework of urban green growth interventions. Sustainability **8**, 461 (2016)
21. Hirschberg, S., Burgherr, P., Spiekerman, G., Dones, R.: Severe accidents in the Energy Sector. PSI Report No. 98-16, Villigen (1998)
22. Komendantova, N., Irshaid, J., Marashdeh, L., Al-Salaymeh, A., Ekenberg, L., Linnerooth-Bayer, J.: Country Fact Sheet Jordan: Energy and Development at a Glance 2017: Background Paper. Middle East North Africa Sustainable Electricity Trajectories (MENA-SELECT) Project Funded by the Federal Ministry for Economic Cooperation and Development (BMZ), 65 pp. (2017)
23. Kowalski, K., Stagl, S., Madlener, R., Omann, I.: Sustainable energy futures: Methodological challenges in combining scenarios and participatory multi-criteria analysis. Eur. J. Oper. Res. **197**, 1063–1074 (2009)
24. Latinopoulos, D., Kechagia, K.: A GIS-based multi-criteria evaluation for wind farm site selection. A regional scale application in Greece. Renew. Energy **78**, 550–560 (2015)
25. Oberschmidt, J., Geldermann, J., Ludwig, J., Schmehl, M.: Modified PROMETHEE approach for assessing energy technologies. Int. J. Energy Sect. Manag. **4**, 183–212 (2010)
26. Palinkas, L.A., Horwitz, S.M., Green, C.A., Wisdom, J.P., Duan, N., Hoagwood, K.: Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Adm. Policy Ment. Health Ment. Health Serv. Res. **42**, 533–544 (2015)
27. Saaty, T.L.: A scaling method for priorities in hierarchical structures. J. Math. Psychol. **15**, 234–281 (1977)
28. Saaty, T.L.: The Analytic Hierarchy Process. McGraw-Hill, New York (1980)
29. Simos, J.: Evaluer l'impact sur l'environnement: Une approche originale par l'analyse multicriteere et la negociation. Presses Polytechniques et Universitaires Romandes, Lausanne (1990)
30. Simos, J.: L'evaluation environnementale: Un processus cognitif neegociee. Theese de doctorat, DGF-EPFL, Lausanne (1990)
31. Schweizer, P.-J., Renn, O., Köck, W., Bovet, J., Benighaus, C., Scheel, O., Schröter, R.: Public participation for infrastructure planning in the context of the German "Energiewende". Utilities Policy (2014, in press)
32. Sánchez-Lozano, J.M., Henggeler Antunes, C., García-Cascales, M.S., Dias, L.C.: GIS-based photovoltaic solar farms site selection using ELECTRE-TRI: evaluating the case for Torre Pacheco, Murcia, Southeast of Spain. Renew. Energy **66**, 478–494 (2014)
33. Shortall, R., Davidsdottir, B., Axelsson, G.: Development of a sustainability assessment framework for geothermal energy projects. Energy. Sustain. Dev. **27**, 28–45 (2015)
34. Tsoutsos, T., Drandaki, M., Frantzeskaki, N., Iosifidis, E., Kiosses, I.: Sustainable energy planning by using multi-criteria analysis application in the island of Crete. Energy Policy **37**, 1587–1600 (2009)
35. Wang, J.-J., Jing, Y.-Y., Zhang, C.-F., Zhao, J.-H.: Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renew. Sustain. Energy Rev. **13**, 2263–2278 (2009)
36. Zangeneh, A., Jadid, S., Rahimi-Kian, A.: A hierarchical decision making model for the prioritization of distributed generation technologies: a case study for Iran. Energy Policy **37**, 5752–5763 (2009)