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Better Energy Efficiency Planning for Russia? Let the Multiple Criteria Decision Analysis Help

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Abstract

Decision making in the energy sector in Russia is complex due to multiple policy objectives, conflicting interests and a lack of available data. We investigated the decision problem of planning for energy efficiency in the industry-a policy proposed by the Moscow City Government. We applied multiple criteria decision analysis (MCDA). We adapted PROMETHEE method and expert survey to evaluate policy alternatives. We described adjustment of an evaluation tool to institutional structure, discussed stakeholders participation, policy objectives, options, criteria. The analysis led to a ranking of policy alternatives and recommended partial subsidization of energy service contracts. As limited studies exist of the MCDA application in Russia, none – for regional energy systems, this paper bridges the gap and provides a novel solution for public management. Importantly we demonstrated the usefulness of MCDA for Russia - its wide application is expected to improve public planning at regional and federal levels.

Keywords: Multiple criteria decision analysis, energy, industry, developing country, Russian regions

1. Introduction

Russia is one of the most energy-intensive economies among the former USSR republics (WB and IFC,2008)with the highest energy intensity ratio (0.42 kgoe[1] per USD dollar of GDP) of the ten highest energy consuming countries in the World. At the same time, Russia has outstanding national energy efficiency potential of nearly half primary energy use (Trudeau and Murray, 2011). To realize its potential, Russia introduced a national energy efficiency goal. It targeted a 40% decrease in energy intensity by 2020 in comparison with 2007 across all sectors in the national economy (GRF, 2010), although later the target was reduced to 13.5% (GRF, 2014a).

The national energy efficiency target requires modernization of the whole energy system in the country which can only be achieved with active participation, both administrative and financial, of Russian regions and business organizations (Kiseleva et al.,2012). The ambitious national goal was taken up by Russian regions with subsequent regional energy efficiency targets, programs and policies (RF,2009; GRF,2014b). Regional governments, therefore, faced a complex planning problem of allocating limited public resources to improve energy efficiency across sectors and policies within the economy.

Moscow was one of the first regions in the country to initiate the energy efficiency program (MCG,2011a) addressing the 40%-reduction goal by means of regulatory and financial stimulation of energy efficiency across the economy (DFERM, 2011). A comprehensive regional program combined 15 prioritized public initiatives targeting improvement in engineering and utilities infrastructure and energy conservation (MCG, 2014). The proposed funding of the program over 2014-2018 exceeded 787 billion RUR with over 70% of the expense to be covered by private investors (MCG, 2014).

One of the key pillars of the whole-economy energy efficiency is energy efficiency in industry. It is responsible for approximately 25% of total energy consumption in Russia. Energy efficiency improvement potential in Russian industry is estimated at 38% of current energy use (WB and IFC, 2008).

Although in Moscow industrial production has mostly been reallocated from the central business area to the outer suburbs (Erin and

[1] Kgoe - kilograms of oil equivalent.

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Bratanova, 2012), the sector use of energy in the region remains substantial(MCG 2011;MCG 2011).

The Moscow regional government recognized the need for a strong policy to realize energy efficiency potential in industry. Therefore in 2012 the regional government declared a need to develop a public policy to stimulate efficiency improvement in the industry and help to achieve state goals (MCG, 2011a; CCAM, 2012; MCG, 2011b). The policy was drafted in 2013 and required economic evaluation. The policy developers and economists faced the complex challenge of multiple policy objectives, conflicting interest groups and lack of quantitative data for analysis(NISSE, 2012).We suggested the state government to apply multiple criteria decision analysis (MCDA) as a decision support tool as economic literature demonstrates the ability of MCDA to assist decision making for the complex problems in energy sector (Tsoutsos et al.,2009; Wang et al.,2009; San Cristóbal Mateo,2012; Diakoulaki and Karangelis,2007).This paper presents the results of the economic evaluation of this policy. The economic evaluation was made a part of the pilot project of regulatory impact assessment in Moscow (Kolegov, 2013). It was a novel solution and one of the first cases of MCDA application for Russian regional policy evaluation in energy.

In general, economic evaluation is rarely used to support decision making at the regional level in Russia(Bratanova, 2012; Bratanova and Belyaev, 2013; Bratanova, 2013; Kolegov, 2008; Kolegov, 2009). A review of the literature demonstrates a gap in the adoption of economic evaluation in the former USSR countries(Furubo et al., 2002).Only few studies to date applied MCDA to the Russian energy sector. One example is the study by Voropai and Ivanova (2002). They developed an MCDA to address a complex problem of electric power system expansion. They provided a case study for the Russian United Electric Power System (UEPS). However, their study is focused on a theoretical MCDA model for an energy system planning problem not addressed in this research. Their analysis is based on simulated rather than empirical data and generic expert preferences. To date no empirical studies have been found with MCDA undertaken for the regional energy sector in Russia.

In this paper we undertake an economic evaluation via MCDA and develop recommendations for the regional government on the preferred policy to stimulate energy efficiency in industry. We also test the tolerance of MCDA to the current institutional system in Russia. We provide recommendations on the integration of MCDA into the public program development and energy projects evaluation. This paper contributes to the body of the literature by providing an empirical application of MCDA to the real life Russian regional conditions to address an important decision problem.

The next section provides background information on the decision problem under consideration and establishes the research methodology including the major components for the MCDA adopted for the case study. It also describes the application of the research methodology to the regional case study. The results of this application, together with a discussion and acknowledgement of the limitations of the study are provided in section 3. The final section provides conclusions and discusses policy implications.

2. Materials and methods

2.1. Multiple criteria decision analysis

The family of decision support techniques based on MCDA principles has grown substantially since the 1960s and has become widely used to support decision making for international, national and regional projects (El-Swaify and Yakowitz,1996; DCLG,2009; Prabhu et al.,1999; Wang et al.,2009; Zopounidis et al., 2015) including those in the fields of energy and environmental management(Huang et al., 1995; Zopounidis et al., 2015; Bottero et al., 2015; Kowalski et al., 2009; Maxim, 2014).Zhou *et al*. (2006) showed that the number of studies has doubled every ten years since 1975.

Methodologically, MCDA accommodates a comparison of policy alternatives by their performance against multiple criteria and taking into

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account the relative importance of the criteria. Methods developed within the MCDA family vary significantly in terms of analytical purpose, use of underlying models and software utilization (DCLG, 2009).

A review of the literature indicates that no single MCDA approach has yet been suggested as offering a uniform solution suitable for application for all situations. Each approach has limitations and perspectives (Ishizaka and Nemery, 2013).The specific features which influence the choice include data availability, analysis objectives, personnel skills and availability, financial and time constraints of decision makers and analysts, and field of its application(Ishizaka and Nemery,2013; Guitouni et al.,1999). Although the literature shows no general preference toward application of particular MCDA approaches to studies in the energy sector, Munier (2011), based on a survey of 66 projects evaluated using MCDA, demonstrates that there was an abundance of cases which used analytic hierarchy process (AHP) and outranking methods for environmental projects. The same conclusion is reached in the review of MCDA studies in energy planning by Pohekar and Ramachandran (2004).

This study applies PROMETHEE I and II ('Preference Ranking Organization METHod for Enriched Evaluation') techniques which gained popularity in research applications after being first introduced by Brans (Brans, 1982; Brans et al., 1986) and extended by French school of MCDA (Macharis et al., 2004; Brans and Mareschal, 1994). The method is believed to match the properties of the case study under consideration and provide an analysis of results satisfying transparency, consistency as well as ease to use requirements(Behzadian et al.,2010; Brans and Mareschal,2005). The method also allowed for communication between decision maker and the model during the construction of the performance matrix (DCLG,2009)which was important for the Russian regional case study. The method is also reported to have been broadly applied to facilitate decision making in the field of energy management although more often for the energy generation and exploitation topics (Behzadian et al., 2010)

The underlying principles of the PROMETHEE method is elimination of policy options dominated by others according to their performance against the criteria, taking into account the relative weights of the criteria(DCLG,2009). The outranking approach is based on pair wise comparison of options against criteria and can be described as follows.
Given options *a* and *b*, the difference between scores $f_j(a)$ and $f_j(b)$ against criterion *j* is $d_j(a,b)$:

$$d_j(a,b) = f_j(a) - f_j(b). \tag{1}$$

The obtained value for this difference is processed with a preference function P_j to obtain a multi-criteria preference index $\pi(a,b)$ such that the following holds:

$$0 \le P_j(d_j(a,b)) \le 1, \tag{2}$$

$$\pi(a,b) = \sum_{j=1}^{k} w_j \times P_j(d_j(a,b)). \tag{3}$$

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Where $P_j(d_j(a,b))$ is a preference function value obtained when option a is compared with option b against criterion j; and, w_j is the weight applied to criterion j. When $\pi(a,b)=0$, option a is not preferred to option b on any criteria. On the contrary, when $\pi(a,b)=1$, option a is preferred to option b on all criteria(Mareschal, 2013):
The weights are normalized such that the following holds:

$$\sum_{j=1}^{k} w_j = 1, \qquad 0 \le w_j \le 1. \tag{4}$$

The ranking of options is executed in PROMETHEE with the help of two indexes also referred to as “preference flows”, positive and negative, and a resulting net flow index. The indexes are outlined in Table 1.

The preference indexes are used to construct two types of ranking in the PROMETHEE framework: partial and complete ranking as defined in Table 2.

Preference functions are utilized to reflect decision makers' perception about the scaling used for criteria(Mareschal,2013). Although the preference functions help to fully define decision makers' preferences, their selection is associated with some level of subjectivity. The assumptions for the choice of a preference function for each of the criteria in this study are discussed in Determination of policy options.

Table 1.PROMETHEE preference flow description

Preference flow	**Description**	**Function**
Positive	Measures relative preference of one option (a) to all others	$\phi^{+}(a)=\frac{1}{n-1}\sum_{a\neq b}\pi(a,b)$ $a,b\in A,\ a\neq b$
Negative	Measures relative preference of all other options to the one option (a)	$\phi^{-}(a)=\frac{1}{n-1}\sum_{a\neq b}\pi(b,a)$ $a,b\in A,\ a\neq b$
Net	Aggregated value of flows	$\phi(a)=\phi^{+}(a)-\phi^{-}(a)$

Source:(Mareschal, 2013)

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Table 2.PROMETHEE partial and complete ranking

Ranking	Function
Partial	a is preferred to $b$iff $\phi^+(a) \geq \phi^+(b)$ *and* $\phi^-(a) < \phi^-(b)$ *or* $\phi^+(a) > \phi^+(b)$ *and* $\phi^-(a) \leq \phi^-(b)$
Complete	a is preferred to $b$iff $\phi(a) > \phi(b)$

Source: (Mareschal, 2013)

Having outlined the research methodology, the next section describes features of the MCDA developed for the case study.The data collection has been organized to mimic the decision-making process in the regional government and government procedures currently in place in Moscow to ensure the evaluation tool can be integrated and effectively used to support decision making in Russian regions.

2.2. Moscow regional case study: policy evaluation

Determination of state policy objectives

Establishment of clear objectives for the policy is an essential part of the decision making process using MCDA(DCLG,2009). Difficulties in the objective determination are frequently associated with the need to incorporate political, economic and social aims of the policy as well as to ensure that the interests of all stakeholder groups are accommodated.

For the Russian regional case study multiple iterations and broad discussion with government representatives facilitated an agreement on the following objectives for the proposed policy:

- Create incentives for the regional industry organizations to improve energy efficiency;
- Stimulate industry development in Moscow;
- Stimulate growth of investment and technological development in the regional industrial sector;
- Improve ecological situation in the region.

Discussion with the stakeholder groups showed that the ecological objectives were mostly treated as complementary to the other objectives. Investment growth in industry and technological development were also declared to be secondary with respect to the stimulation of energy efficiency improvement. These objectives were removed from the front line, such that industry support targeting energy efficiency improvements were made the most important objective of the policy.

Stakeholder and expert groups: data collection

A wide representation of stakeholders was required to undertake the MCDA. Five stakeholder groups were identified whose interests are potentially impacted by the proposed regulation as described in table 3.Equal weights (20%) were assigned to each stakeholder group.

Self-assessment was used to analyze the aptitude of each expert to represent the stakeholder group interests. The analysis revealed no contradictions between the self-reported field of expertise and the area of interest of the expert and stakeholder group represented. Therefore none of the surveys from experts were excluded from the analysis.

The experts representing ecological funds, environment protection organizations, industrial ecologists and other organizations in this field were combined into one stakeholder group with representatives of social development and protection organizations. Although they could have been separated, experts from each field of interest ranked themselves as representing both positions sharing the interests of environmental protection and social security and development. Therefore a single stakeholder group, group 4, was formed for the analysis.

Table 3.Stakeholder groups, description and representation

Stakeholder group		Description
1	Regional and municipal governments, other authorities	Government departments, municipal authorities
2	Energy generating companies	Companies operating in the electricity and heat generation industry
3	Energy management and energy service companies	Firms operating in the emerging market of energy management and energy service for industry, business and residential construction management
4	Social development and environment protection groups	Organizations working with international, national and regional programs and initiatives for social-economic development of Russia and regions, community support and social security
		Environment management companies, independent experts (environmental engineers) qualified and experienced in energy management and pollution control in industry
5	Industrial production companies	National and regional associations of business organizations and producers. Small and medium sized companies operating in the production sector in Moscow

Source: Expert survey results

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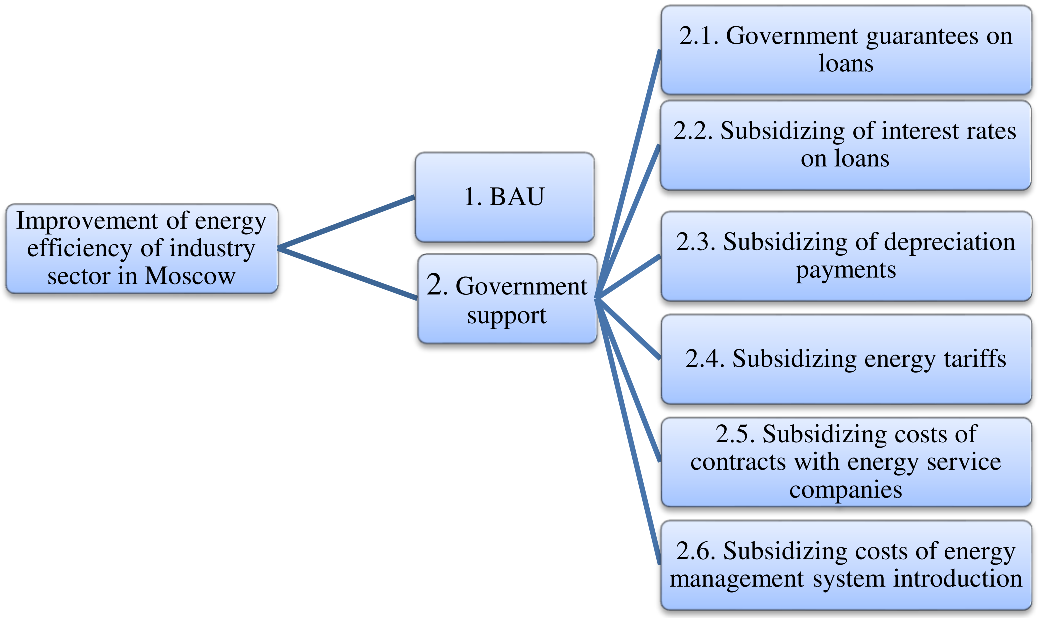
Determination of policy options

MCDA as a decision support tool is frequently used to provide a structured and systematic approach for the identification of policy options or alternatives (DCLG, 2009; Haldi et al., 2002). Determination of the policy options for this study required several stages with a number of iterations. At the first stage, the initial set of options with broad definitions was developed based on the policy proposal and objectives. However, as a result of the focus group discussion some of the shortlisted options were considered unfeasible and removed from the option list. The final list of options is defined in table 4 and illustrated in a hierarchy diagram (Figure 1).



Source: Focus group discussion outcomes

Figure 1Final set of policy options

Determination of criteria for analysis

Criteria play a crucial role in MCDA application since they are the parameters against which the options' performance is measured (DCLG,2009; Janssen,1991;El-Swaify and Yakowitz,1996). Systematic determination of criteria therefore is especially important for the analysis.

An initial broad set of criteria was developed to reflect the policy objectives, however as a result of a discussion with stakeholder representatives a few criteria were excluded as being redundant. After several iterations, a final set of criteria was formed as provided in Table 5 and in the criteria diagram (Figure 2).

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Table 4.Policy options

Options		Description
1	BAU	Maintain business as usual, regulation and policy are unchanged
2	Provision of government support	Government providing support to the industrial organizations to improve energy efficiency in one of the following forms:
2.1	Government guarantees on loans	Government guarantees are to be provided to eligible industrial organizations to support their applications for bank loans to undertake energy efficiency improvement projects
2.2	Subsidizing of interest rates on loans	Partial subsidizing interest rates on loans to undertake industrial programs of modernization for energy efficiency improvement (including generating capacity and transmission lines modernization)
2.3	Subsidizing of depreciation payments	Partial subsidizing of depreciation payments for assets purchased, renewed or repaired for the purposes of energy efficiency improvement or/and as a part of energy efficiency projects
2.4	Subsidizing energy tariffs	Partial subsidizing of energy tariffs for organizations in case they undertake modernization programs for energy efficiency improvement
2.5	Subsidizing costs of contracts with energy service companies	Partial subsidizing costs for industrial companies entering into contracts with energy service companies. Eligible companies will be allowed to apply together with eligible energy service companies
2.6	Subsidizing costs of energy management system introduction	Provision of subsidies to partly cover costs of energy management system development and implementation including educational and training activities in energy efficiency and energy conservation

Source: Focus group discussion

Interestingly, the criterion 4.2 “Propensity for corruption” was added to the criteria set as it was suggested that the preferred policy option should have minimal opportunity to create a corruption situation. Since corruption reduction is one of the major national goals (President of the Russian Federation,2012; MFRF, 2012), current legislation sets procedures for anti-corruption evaluation of proposed regulation, anti-corruption measures are required to be undertaken by all federal and regional authorities. The criterion was added to the investment group of criteria to reflect the position

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expressed by the experts, who identified corruption as one of the major barriers for an increase in external investment inflow to the industrial sector of Moscow.

Table 5.MCDA criteria

Criterion		Qualitative/ quantitative	Description of the criteria or question to be asked to measure the performance of options
1.1.	Budget expenditure	Quantitative	Amount of budget funds required to implement the option, counted per one company over five year period
1.2.	Costs for Moscow industrial organizations		A period of time required to recover costs of the energy efficiency project implementation for accompany given it obtains the government support
2.1.	Energy efficiency improvement[a]	Qualitative	Will the implementation of the option reduce energy use per unit of production or result in improvement of energy efficiency?
2.2.	Decrease of emissions level[a]		Will the implementation of the option result in improvement in the environmental situation in the region by reducing emissions by industrial enterprises?
3.1.	Decrease of production costs and goods prices		Will the implementation of the option result in reduction of production costs of goods produced by regional industrial enterprises?
3.2.	Creation of jobs in industry sector		Will the implementation of the option generate new jobs for the residents of the region?
4.1.	Increase of investments into assets renovation		Will the implementation of the option increase investment activity of enterprises and use of funds for replacement, renovation or modernization of fixed assets?
4.2.	Propensity for corruption		Will the implementation of the option lead to an emergence of a corruption situation?

[a]although these criteria can technically be estimated quantitatively, at the time of research no adequate estimates were available and agreed upon by the stakeholders, therefore qualitative measures were used as requested by the decision maker.

Source: Focus group discussion

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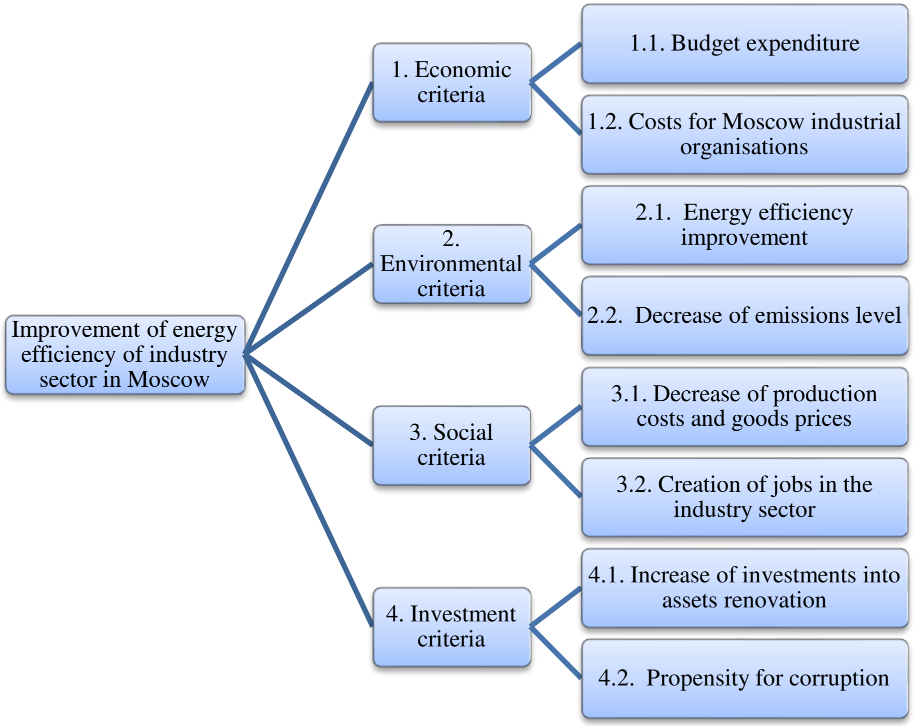

Figure 2MCDAcriteria
Source: Focus group discussion

The listed criteria and options formed the performance matrices which were distributed to stakeholder representatives to collect qualitative data to score the performance of options against criteria. Experts were asked to estimate options' performance against criteria based on a scale of one to five. The interpretation of the scale is presented in Table 6.

Another important step for the MCDA is criteria weighting. To ensure transparency of the analysis, a simple way to allocate weights was applied-experts were asked to attach a percentage weight to each criterion reflecting its importance for the policy such that the sum of the weights equals 100%. Similarly averages were used to aggregate weights across stakeholder groups.

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Table 6.Interpretation of scores for qualitative criteria

Score	Interpretation	Answer to the associated questions
1	no performance against a criterion, no change from the existing situation is expected	"no, will not result in change"
2	low performance against a criterion, existing situation is expected to be changed slightly	"will result in slight change"
3	medium performance against a criterion, existing situation is expected to be changed to a medium scale	"will result in change to a moderate extent"
4	good performance against a criterion, existing situation is expected to be changed	"yes, will result in change to a substantial extent"
5	excellent or outstanding performance against a criterion, existing situation is expected to be substantially changed	"yes, will change to a large extent"

As discussed in Material and methods, the PROMETHEE approach requires specification of the preference function for every criterion. A trade-off exists between complexity of the preference function which is expected to reflect the performance of the option against the criteria and transparency of the analysis. As transparency is a high priority in the analysis undertaken for this regional case study, simple preference functions are applied for the analysis. Specifically, a "usual" preference function (Munier 2011) is applied to all qualitative criteria since they were evaluated on a five scale qualitative basis (Table 6) and it is believed that the difference between the qualitative scores (for example, between "good" and "very good"; "bad" and "good") is consistent for application to all qualitative criteria. A linear preference function is utilized for quantitative criteria namely costs to the budget and business (criteria 1.1 and 1.2).

3. Results and discussion

This section first discusses the weights applied to the criteria by the survey respondents. We continue with a discussion about the MCDA results from an overall perspective. The weights assigned by stakeholder groups are illustrated in Figure 3.

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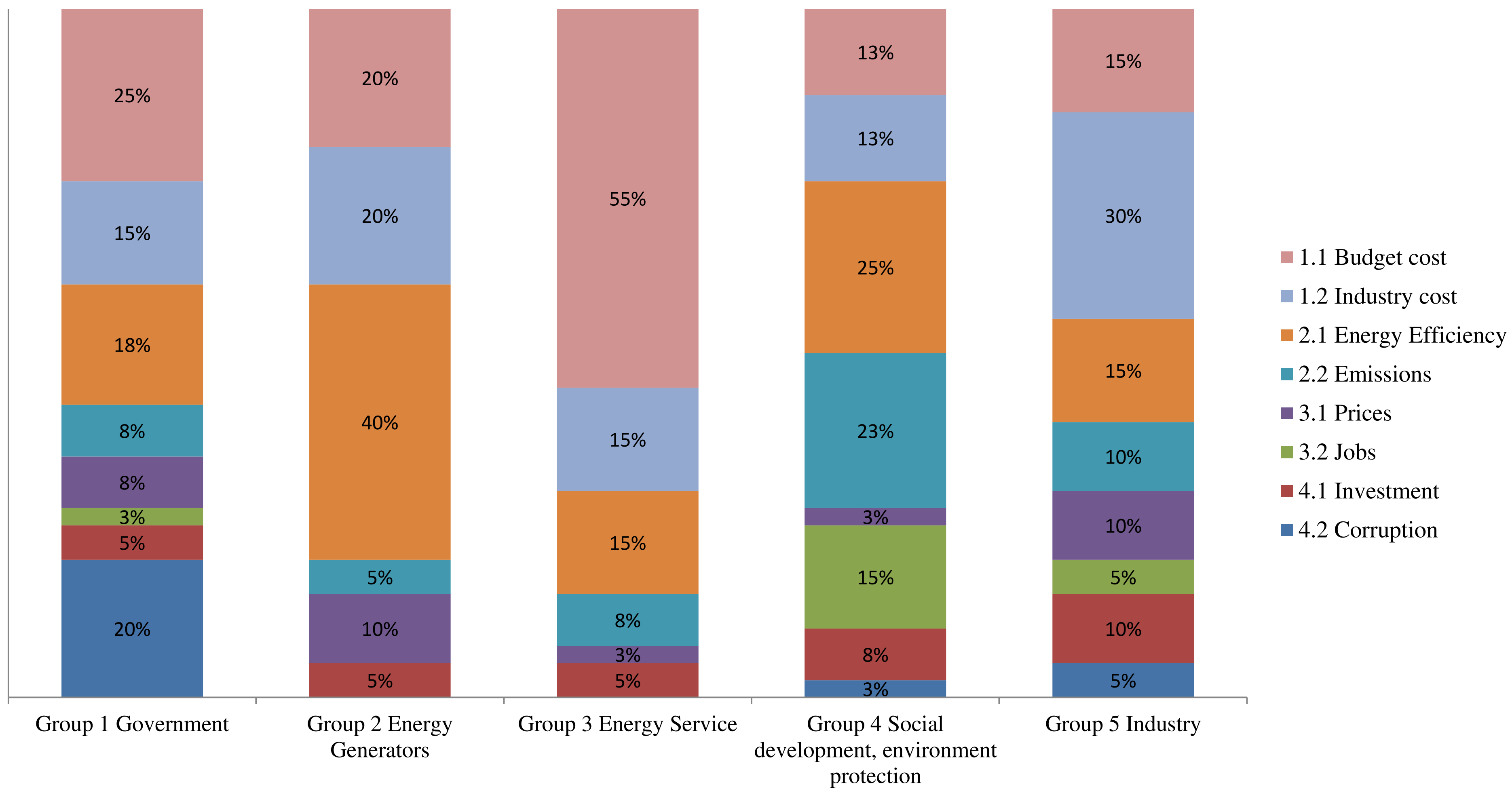
Figure3 Weights allocated by stakeholder groups



Source: Survey results

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The analysis shows that the criteria weighting reflects the positions and interests of the stakeholder groups. Specifically, group 5, representing the industry stakeholder group, stresses the importance of criterion 1.2 (costs to business) above any other criteria. The social and environmental group (group 4) ranks the criterion of jobs creation (criterion 3.2) higher than representatives of other stakeholder groups. They also emphasize the importance of emissions reduction as the policy objective by assigning a weight of 22.5% to criterion 2.2.

Interestingly, the criterion of increasing investment activity of industrial enterprises (criterion 4.1), designed to reflect the regional policy objective to stimulate modernization and renewal of assets and production technology in the industry, is estimated as marginally significant by the survey respondents with an assigned weight of 5-10%. At the same time criterion 4.2 "Propensity for corruption" is ranked very low by all the stakeholder groups except for the representatives of public authorities who assigned it a weight of 20%.

Analysis of the weighs assigned to criteria by the experts allows us to comment on important differences in policy preferences across stakeholder groups. In many cases the weights show clear bias towards the interests of individual groups suggesting strategic behavior. Analysis of the performance matrices of individual stakeholder groups confirms this conclusion.

MCDA results

Integration of the stakeholder groups' positions has been facilitated by the embedded *Visual PROMETHEE* scenario analysis tool -*Balance of Power* analysis. The resulting ranking for policy options is presented in Table 7 and Figure 4.

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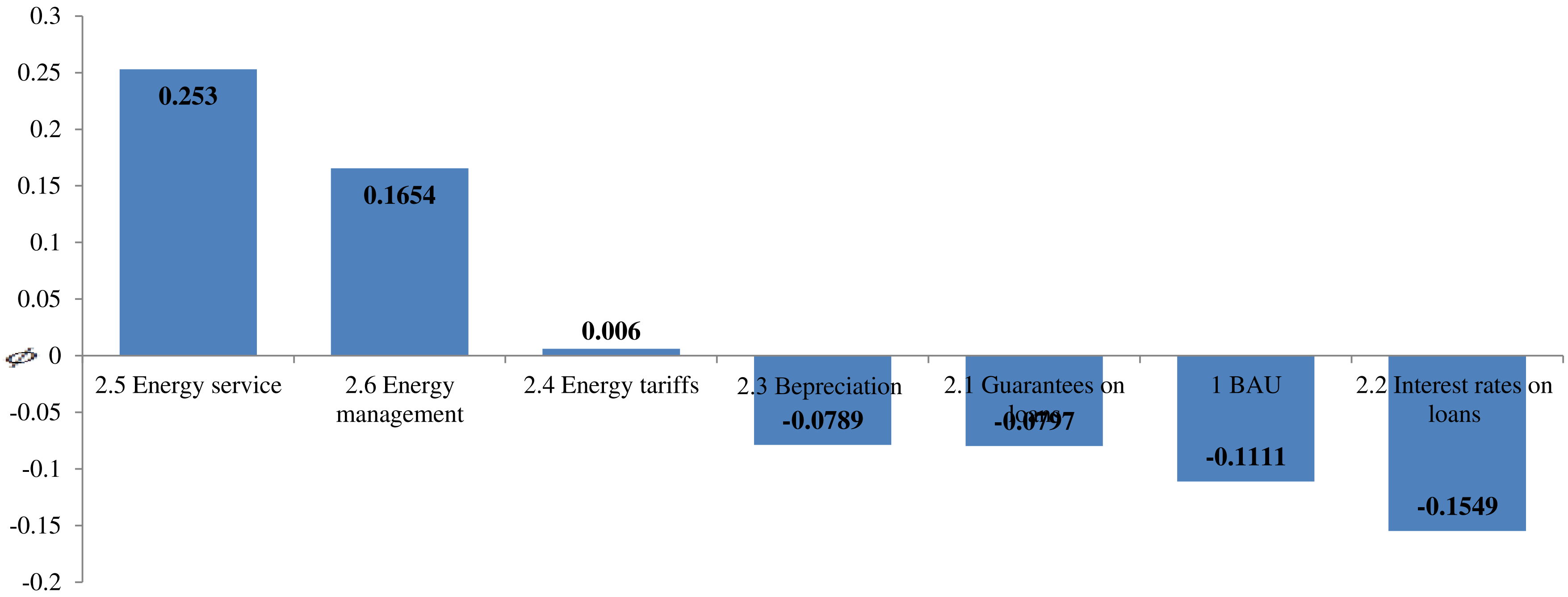

Figure4MCDA complete ranking results
Source: PROMETHEE analysis

The analysis of stakeholder groups' responses doesn't identify a unique solution for the decision maker. It shows that no option is preferred to all others in absolute terms. However, the complete ranking results (Figure 4) allow us to separate several groups of policy alternatives. The leading options are 2.5 and 2.6 which represent energy management and energy service development policy alternatives. The next best option in the ranking is option 2.4 - tariff subsidizing, which obtained an overall ϕ score of 0.006(Table 7).

Partial ranking of the aggregated data (Table 7) shows that only option 2.5 (subsidizing costs of energy service companies) shows positive values for both parameters under consideration – ϕ^+ and ϕ^-. That indicates that weighted sum of preferences in favour of the option outscores those against it. Consequently, option 2.5 outperforms the others with the given performance matrix scores and criteria weights. However, performance of option 2.6 (subsidizing costs of energy management system introduction) is close to the highest ranked option.

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The remainder of the policy alternatives obtained negative ϕ values (Figure 4). The worst ranked option is option 2.2. (interest rate subsidizing), which was slightly outperformed by the BAU (option 1).

Table 7.MCDA policy options ranking

Rank	Policy option		Score		
			ϕ	ϕ^-	ϕ^+
1	2.5	Subsidizing costs of contracts with energy service companies	0.2530	0.2525	0.5055
2	2.6	Subsidizing costs of energy management system introduction	0.1654	0.1663	0.3317
3	2.4	Subsidizing energy tariffs	0.0060	0.3832	0.3893
4	2.3	Subsidizing of depreciation payments	-0.0789	0.4088	0.3299
5	2.1	Government guarantees on loans	-0.0797	0.4239	0.3442
6	1	BAU	-0.1111	0.4303	0.3193
7	2.2	Subsidizing of interest rates on loans	-0.1549	0.4713	0.3164

Source: PROMETHEE analysis

It is noted that the BAU option, which assumes continuation of the current situation in the industry with no government support to be provided, falls in the negative range of the results as one of the lowest ranked alternative. This can be interpreted as recognition of the need for change in the functioning of the current system.
Overall, the MCDA analysis revealed the following results;

1. The policy alternative ranked highest is option 2.5 “Subsidizing costs of energy service companies”.
2. The second ranked alternative is option 2.6 “Subsidizing costs of energy management system introduction”, although it is not clearly compatible to most of the other policy options.
3. Tariff subsidizing (option 2.4) is ranked the third best policy alternative.

These results are further discussed from the perspective of policy implications in the Conclusions.

Sensitivity analysis

A sensitivity analysis of the results determined the robustness of the model and the responsiveness of the rankings to change in the weights assigned to the criteria and stakeholder groups.

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The sensitivity analysis demonstrates that the two highest ranked options, 2.5 and 2.6, do not change their rank as a result of the change in weights. The three options with the worst performance also remain poorly ranked for all the sensitivity scenarios. This supports the conclusion that the MCDA provides a robust ranking of the options. Importantly, MCDA as an evaluation tool is frequently criticized in the literature for subjectivity of the results which in turn is attributed to the weighting of criteria. The case study shows that the ranking of the policy options and hence the recommendations provided to decision makers can be regarded as robust with respect to the criteria weighting. The outcome of the sensitivity analysis is provided in more detail in the Appendix.

Limitations of the analysis

There are a number of limitations of the analysis. These are discussed below.

-The options are assumed not to be implemented simultaneously.

This assumption was crucial to collate qualitative data, complete the performance matrix and was a limiting factor of the software. However, it can be argued that a combination of options could be expected to produce a synergic effect and overall better results than any single option.

-Limited communication with experts.

Focus group meetings took place in December, 2012 – January, 2013 in Moscow. No opportunities were available for further meetings with the participants.This limited communication opportunities. Follow-up interviews would have been valuable for discussion about the results, for testing the robustness of the results and to receive and provide feedback to participants. At the same time it limited the transparency of the analysis since it has not been possible to determine if all the experts fully understood all the options and criteria.
However, taking into account that the objective of the research is to develop a practical tool for analysis and decision making which can be integrated into the current decision making procedures, this approach is acceptable given that written communication is prescribed in government communication and all the acceptance procedures for government papers assume written comments and communication.

-Identification of options and criteria

The identification of options and criteria was undertaken with limited specification of their scope or detail. Although this limits the transparency and objectivity of the analysis, this approach reflects the objective of the policy proposal which required evaluation. MCDA has played an important role in the identification of options considered by experts as worth further development and exclusion of options which are not expected to meet the strategic objectives for improving energy efficiency.
Although some criteria might be seen as dependent (e.g. energy efficiency and emissions), consultations with stakeholders suggested that they reflect on different aspects of the proposed policy and need to be included in the criteria set separately. To ensure analysis process is transparent, aggregation of weights for criteria and across stakeholders is done using simple averaging, however more sophisticated approaches could have been technically applied (Zhou et al., 2010).

-Sticks and carrots in the stimulation of energy efficiency improvement

The listed policy options clearly represent only incentive-based mechanisms for government intervention, none of the proposed policy alternatives are obligatory. It can be argued that introduction of energy saving norms or

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energy efficiency requirements for equipment in the industry might result in better outcomes for the region as a whole targeting energy efficiency improvement. However, it needs to be acknowledged that Russian regional authorities have limited jurisdiction in regulation of industry operations. Industry regulation development and enforcement is mostly under the jurisdiction of the Federal Government and the State Duma of the Russian Federation. This limits the policy options available for regional governments.

-Timeframe for the analysis

A five year period was selected as a timeframe to consider the effects of the options. This appears reasonable as it matches the regional budgetary arrangements. However, it needs to be acknowledged that the flow-on consequences from energy efficiency improvements would be expected to exceed the selected timeframe.

-Subjectivity

Criteria weighting is often associated with subjectivity which is the main argument of MCDA opponents. However, for the purposes of this research subjectivity in the weighting of the identified criteria reflects the strategic behaviour of stakeholder groups and is considered a positive feature in the analysis, rather than a disadvantage. Strategic behaviour of stakeholders is a characteristic of public decision making and public management. Decision making in the energy sector in Russia is complex and involves multiple parties with potentially conflicting interests, consequently strategic behaviour is anticipated. Therefore MCDA as an evaluation technique should acknowledge, consider, and be capable of including and managing the strategic behaviour of involved parties.

At the same time it is necessary to acknowledge that the selected way of assigning weights across stakeholder groups also limits the research results.

-Business as usual option

The BAU option assumes nothing changes over the period from when the proposed policy is put in place. However, changes might be expected to occur in the energy efficiency of industrial organisations regardless of the proposed policy. However, these changes are independent of the decision to be made regarding the selection of the regulatory option for the regional government and cannot be reasonably predicted and incorporated into the analysis. Consequently it has been assumed that any change to the current situation, beyond the scope of the potential effect of the proposed policy, will affect all the options. This allows us to define the BAU option as the scenario with no foreseeable changes in the future with respect to the current situation.

4. Conclusions

Based on this analysis, it is recommended that the regional government develops a p objectives of the policy–namely, energy efficiency improvement in industry in the Moscow region.

By partially subsidizing the costs of energy management in industry regional authorities can utilize the potential of the next highest ranked option to facilitate achievement of the policy objectives.

Subsidizing energy tariffs, although ranked closely behind the two highest ranked options, is not recommended to the government. Subsidizing depreciation payments cannot be recommended for implementation either, as it showed a poor performance against the criteria and is not expected to facilitate improvement in the existing regional energy efficiency.

An important result of the analysis is the ranking of the BAU policy option. The result shows that the BAU option is ranked among the two least preferred options. This suggests that stakeholders share a positive expectation of a change to the existing situation which could result from

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implementation of the proposed policy. Hence if the regional government develops and implements the policy under consideration, it is expected to go some way towards improving energy efficiency in industry, stimulating technological development in Moscow and investment in-flow as well as facilitating an improvement in the ecological situation in the region.

However, analysis of the ranking for each of the stakeholder groups also identified important differences across the groups which can be partly explained by the strategic behavior of respondents. In the situation under investigation strategic behavior is important to identify and acknowledge. Identification of strategic behavior by stakeholder groups in the weighting of criteria and scoring the performance matrix helps to understand the positions and interests of each of the stakeholder groups. It is a valuable outcome from the analysis-the decision maker needs to be aware of the stakeholder group interests when formulating and implementing the energy efficiency policy. Specifically, budget cost and achieving energy efficiency were priority criteria for the energy services and energy generators respectively.

However, it is acknowledged that the efficacy of implementation of each policy option under consideration will, to a great extent, depend on the way the option is implemented, managed and monitored. There are other options, not considered in this analysis, which might perform an important role for improving energy efficiency. For example, education can be effective if educational programs are properly designed, planned, implemented and monitored. On the other hand, options with a high ranking as a result of the analysis but poorly implemented, could be ineffective. A good example of this situation is government subsidies to install energy measuring devices. If the subsidy targets installation of devices only there is a risk that the devices will not be used, monitored and supported after the subsidy is received. A similar situation was widely discussed in the literature when federal legislation introduced a requirement for industrial organisations to undertake an energy assessment and to submit energy efficiency passports (GRF, 2011; MCG, 2011a). Audits were undertaken and passports submitted by the majority of large enterprises to avoid fines, but the recommended measures for energy efficiency improvements were mostly not implemented (CCAM, 2012). Consequently it is reasonable to assume that any option requires suitable implementation, monitoring and control and sufficient resources to achieve the policy objectives.

The results lead to the conclusion that MCDA can be recommended for decision support along with the development of relevant databases to be incorporated into policy and program development procedures at the regional level in Russia. It should be used at the level of strategic planning and to facilitate policy option development and selection for the energy sector. MCDA facilitates the inclusion of a broad range of stakeholder representatives into development and discussion about policy alternatives and represents an improvement from the qualitative and descriptive practice which is currently in place to undertake analysis with pre-defined policy options. Consequently, this study contributes to filling this gap by establishing an MCDA framework which has demonstrated its capability of integration into current decision making procedures in Russia.

Given the concluding comments from this study, MCDA, with a demonstrated applicability to support decision making and future planning in the Russian regional energy sector, can also be adapted to a broad range of decision problems in energy management and other public utilities. The potential of MCDA as a decision aid tool therefore spans all Russian regions and public policies.

Appendix

Sensitivity analysis of the MCDA results

Sensitivity analysis to change in criteria weights

For the purposes of the sensitivity analysis to the change of criteria weights each of the weights is changed by 5% at a time. An increase of 5% for one of

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the criteria resulted in a subsequent proportional decrease of weights assigned to other criteria. For illustrative purposes a case of equal weights for all criteria was also considered. Consequently, ten scenarios of weights allocation (WS) were developed for sensitivity analysis:

-WS1: initial weights for MCDA;

- WS2: equal weights assigned to every criterion (approximately 12%);

- WS3-WS10: weights increased by 5% for individual criteria with a subsequent proportional decrease of weight for all other criteria.

The scenarios of weights allocation and the MCDA ranking of policy options for every scenario are provided in Table 8. The plus and minus signs in the table represent positive and negative positions of options on the ϕ scale.

Table 8 Sensitivity of MCDA results to the change of criteria weights

Parameter		Scenarios of weights allocation									
		WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8	WS9	WS10
Criteria	1.1	25	12	30	24	23	24	24	24	24	24
	1.2	16	12	15	21	15	16	16	16	16	16
	2.1	24	12	22	22	29	22	22	22	22	22
	2.2	11	12	11	11	11	16	11	11	11	11
	3.1	6	12	6	6	6	6	11	6	6	6
	3.2	7	12	6	6	6	6	6	12	6	6
	4.1	6	12	6	6	6	6	6	6	11	6
	4.2	5	12	5	5	5	5	5	5	5	10
		Option / ϕ parameter range									
Rank	1	2.5/+	2.5/+	2.5+	2.5/+	2.5+	2.5/+	2.5/+	2.5/+	2.5/+	2.5/+
	2	2.6/+	2.6/+	2.6/+	2.6/+	2.6+	2.6/+	2.6/+	2.6/+	2.6/+	2.6/+
	3	2.4/+	2.3/+	2.4/-	2.4/+	2.4+	2.4/+	2.4/+	2.4/+	2.4/+	2.4/-
	4	2.1/-	2.4/+	2.1/-	1/-	2.3-	2.3/-	2.3/-	2.3/-	2.1/-	1/-
	5	2.3/-	2.2/-	1/-	2.3/-	2.1-	2.1/-	2.1/-	2.1/-	2.3/-	2.3/-
	6	1/-	2.1/-	2.3/-	2.1/-	2.2-	2.2/-	2.2/-	2.2/-	2.2/-	2.1/-
	7	2.2/-	1	2.2/-	2.2/-	1-	1/-	1/-	1/-	1/-	2.2/-

Source: PROMETHEE analysis

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The sensitivity analysis shows that the MCDA results are robust and consistent in the ranking of the best performing policy alternatives. Across all of the scenarios tested, policy options 2.5 and 2.6 remain the two highest ranked options.

Option 2.4 (tariff subsidizing) showed only minimal sensitivity to the change in weights and retained the third highest rank in almost all the cases of weighting change.

Option 2.3 (depreciation subsidizing) retain fourth and fifth position in the overall ranking remaining in the negative part of the ϕ range (with the exception of the WS2 and WS3 cases). Although option 2.3 shows sensitivity to the weighting, it remains within the middle range of the ranking across scenarios, not improving better than third position in the ranking, but not falling below sixth position.

Options 2.1 and 2.2 remain at the end of the ranking for all the weighting scenarios. Option 2.1 outperformed option 2.2 in all but one weighting scenarios. However, both options remain in the negative range according to the ϕ parameter. This observation confirms the robustness of the MCDA results and hence ranking of options.

Important variability of ranking position with respect to change in weight is shown by the BAU option. It fluctuates from fourth to last position in the ranking across scenarios. However, as it mostly remains at the end of the ranking list, it supports the robustness of the earlier findings and the recommendation to reject this option is robust.

Sensitivity analysis to change in the weights for expert groups

The analysis has been undertaken assuming all the stakeholder groups have equal importance in this decision making process. The importance is reflected by the weights assigned to every expert group within stakeholder groups and used to weight each criterion in the construction of the aggregated performance matrix. The equal allocation of weights, however, can be questioned. Sensitivity analysis has been undertaken to test the responsiveness of the MCDA ranking results to the change in weights allocation among expert groups. As before, the *Balance of Power* tool embedded in the *VP* software has been applied to test the sensitivity of MCDA results. Nine scenarios (WS11-WS19) have been developed accordingly for the changed weights.

The results from the sensitivity analysis are presented in Table 9 for the weighting scenarios WS11-WS19. It shows that variation of weight for each of the expert groups in the allocation has not substantially changed the MCDA ranking. Option 2.5 preserves the highest rank across all the weighting scenarios followed by option 2.6. Option 2.4 remains third ranked. Option 2.2 shows the worst performance across the scenarios. It is outperformed by the BAU option, and options 2.3 and 2.1. The latter share fourth and fifth positions in the ranking.

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Table9 Sensitivity of MCDA results to the change of weights for expert groups

Parameter		Weighting scenario								
		WS11	WS12	WS13	WS14	WS15	WS16	WS17	WS18	WS19
Expert group	1	10	15	9	10	9	9	9	9	10
	2	10	10	15	9	9	9	10	9	9
	3	10	9	10	15	10	9	9	9	9
	4	10	9	10	9	15	9	9	10	9
	5	20	19	19	20	19	25	19	20	19
	6	10	9	9	9	10	9	15	9	10
	7	10	9	9	9	9	10	10	15	9
	8	20	20	19	19	19	20	19	19	25
		Option / ϕ parameter range								
Rank	1	2.5/+	2.5+	2.5+	2.5/+	2.5/+	2.5/+	2.5/+	2.5/+	2.5/+
	2	2.6/+	2.6/+	2.6/+	2.6/+	2.6/+	2.6/+	2.6/+	2.6/+	2.6/+
	3	2.4/+	2.4/-	2.4/-	2.4/-	2.4/-	2.4/+	2.4/+	2.4/+	2.4/+
	4	2.1/-	2.1/-	2.1/-	2.1/-	2.1/-	2.1/-	2.3/-	2.1/-	2.1/-
	5	2.3/-	1/-	1/-	2.3/-	2.3/-	2.3/-	2.1/-	2.3/-	2.3/-
	6	1/-	2.3/-	2.3/-	1/-	1/-	1/-	1/-	1/-	1/-
	7	2.2/-	2.2/-	2.2/-	2.2/-	2.2/-	2.2/-	2.2/-	2.2/-	2.2/-

Source: PROMETHEE analysis results

In conclusion, the MCDA ranking shows little sensitivity to the weights allocated across expert and stakeholder groups. It confirms that the final ranking of options to be recommended to decision makers is robust.

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