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1 **The need for integrated valuation tools to support decision-making – the**
2 **case of cultural ecosystem services sourced from geothermal areas**

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4 David Cook (corresponding author), Faculty of Economics and Faculty of Environment and
5 Life Sciences, University of Iceland, Gimli, Sæmundargötu 2, 101 Reykjavík, Iceland, email:
6 dac3@hi.is, tel: +354 525 4211.

7

8 Reza Fazeli, School of Engineering and Natural Sciences, University of Iceland, Gimli,
9 Sæmundargötu 2, 101 Reykjavík, Iceland, email: rfazeli@hi.is

10

11 Brynhildur Davíðsdóttir, Environment and Natural Resources, School of Engineering and
12 Natural Sciences, University of Iceland, Oddi, Sæmundargötu 2, 101 Reykjavík, Iceland, email:
13 bdavids@hi.is.

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32 Developing geothermal power projects may lead to trade-offs, whereby the economic and social
33 benefits of the venture are difficult to compare with its cultural consequences, which include
34 impacts to ES such as aesthetics, spiritual enrichment and inspiration. The socio-cultural rather
35 than monetary character of such impacts reinforce the importance of a pluralist approach to
36 valuation, in order to ensure that all human well-being impacts linked to the development of
37 geothermal power projects are accounted for in appropriate decision-support tools, which can
38 successfully integrate diverse values concerning the environment. In this short communication,
39 this paper considers the various impacts to cultural ecosystem services that are associated with
40 the development of geothermal power projects, and a literature review is conducted concerning
41 the extent to which cultural impacts have been included within Multi-Criteria Decision Analysis
42 (MCDA). Using the Search, Appraisal, Synthesis and Analysis, and snowballing methods, eight
43 studies are identified. This review finds, with one exception, a lack of focus on cultural impacts
44 and limited stakeholder consultation. This issue could potentially be of particular concern in
45 relation to geothermal power projects impacting indigenous communities, whereby decision-
46 making is frequently conducted according to the notion of the national good, with local interests
47 relegated in importance.

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50 **Keywords:** decision-making; valuation; geothermal energy; environmental impacts; ecosystem
51 services

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71 1. Introduction

72 Environmental conflicts often originate from a failure to reconcile trade-offs between values
73 (Bark et al., 2016; Jacobs et al., 2016, Mueller et al., 2016; Egli et al., 2017; Jacobs et al., 2018),
74 and this is especially important in relation to the energy sector (Phelan and Jacobs, 2016). It is
75 widely acknowledged in the ecosystem services (ES) literature that one of the major ongoing
76 research lines is to develop methodologies which successfully integrate multiple and often
77 conflicting values about the environment, including from the ecological, socio-cultural and
78 monetary domains (Liu et al., 2010; Escobedo et al., 2011; Martín-López et al., 2014; Jacobs et

79 al., 2016; Saarikoski, et al., 2016b; Wam et al., 2016; Costanza et al., 2017). In recent years, a
80 body of academic research has emerged endorsing the value pluralism perspective, arguing for
81 its adoption as a fundamental principle in all ecosystem services assessments (Pascual et al.,
82 2010; Chan et al., 2012; Jax et al., 2013; Martín-López et al., 2014; Baral et al., 2015; Saarikoski
83 et al., 2016a; Saarikoski et al., 2016b). It necessitates a transdisciplinary approach, as well as
84 the adoption of decision-support tools such as Multi-Criteria Decision Analysis (MCDA) that
85 can satisfactorily combine quantitative and qualitative information (Saarikoski et al., 2016b).

86
87 Recently, the work of Hastik et al. (2015) on the ES impacts of renewable energy technologies
88 was further advanced through Cook et al.'s thematic assessment of the effects of developing
89 geothermal power plants (Cook et al. 2017). This study determined that the majority of the ES
90 impacts linked to the development of high-temperature geothermal areas belonged to the
91 cultural typology (Cook et al., 2017). Cook et al. (2017) also highlighted several examples
92 whereby individuals could hold different types of values concerning a geothermal area, leading
93 to trade-offs with the economic and social objectives of such projects. One person may wish to
94 enjoy recreational experiences, business leaders may be motivated via profit-making
95 opportunities involving electricity generation, while indigenous peoples may have no economic
96 motive, instead viewing geothermal phenomena as fundamental to their way of life. Although
97 acknowledging the importance of value pluralism in the process of valuing the cultural ES of
98 geothermal areas, the paper by Cook et al. (2017) did not consider the ensuing decision-making
99 complexities involved in evaluating simultaneous impacts with non-material consequences for
100 human well-being.

101
102 The aims of this short communication are: (a) to summarise the impacts to cultural ES occurring
103 due to the pursuit of geothermal power projects, and provided specific examples of socio-
104 cultural impacts, and (b) conduct a literature review of the extent to which MCDA¹ studies
105 focused on geothermal power projects have evaluated cultural impacts.

106
107 Section 2 summarises the main cultural ES impacts linked to the development of geothermal
108 power projects. Cases of socio-cultural impacts are outlined and a brief summary detailed of
109 the merits of MCDA as a decision-support tool in an energy and ecosystem services assessment
110 context. Section 3 details the paper's methodology with regards to the selection of MCDA
111 literature. Section 4 summarises the results from the review of MCDA studies and discusses the
112 main decision-making implications. Section 5 provides a conclusion.

113 114 115 **2 Cultural ES of geothermal areas, MCDA and integrated valuation**

116 117 **2.1 Value domains and the cultural ES of geothermal areas**

118
119 Human beings can hold multiple values concerning the environment, including ecological,
120 economic, social, cultural, spiritual, symbolic, therapeutic, insurance and place values (Chan et
121 al., 2012; Martín-López et al., 2014). Although their boundaries are invariably blurred and
122 overlapping, these have been further categorised as monetary, socio-cultural and ecological
123 value-domains (Castro et al., 2014; Martín-López et al., 2014).

¹ It is noted that there are other integrated valuation tools which could be applied, however, none have yet been applied in a geothermal cultural ES context. Therefore, the review focuses solely on applicable MCDA studies in the published literature.

125 Based on the list of cultural ES typical² of geothermal areas identified in Cook et al. (2017),
126 several can derive from the socio-cultural domain, including spiritual enrichment, aesthetics,
127 inspiration, heritage, non-use value and recreation. With the exception perhaps of recreation,
128 such values are poorly captured using monetary metrics, payment vehicles and non-market
129 valuation techniques.

130

131 2.2 Cultural ES pertaining to the socio-cultural value domain and the impacts of geothermal
132 power projects

133

134 Preferences for cultural ES, such as spiritual enrichment, are often formed collectively based
135 on Traditional Knowledge (Martín-López et al., 2014), involve interactions with formal and
136 informal governance institutions (CAFF, 2015), and occur through direct relationships with an
137 environment rather than instrumental or intrinsic associations (Chan et al., 2016). In these cases,
138 which are often common in indigenous communities where notions of the sacredness of land
139 are important, willingness to pay for a particular service is likely to be zero, yet these individuals
140 will still hold a value in socio-cultural terms (Cooper, 2009; Zeppel, 2009; Martín-López et al.,
141 2014). Potential impacts to the cultural ES of spiritual enrichment in a geothermal context
142 highlight the decision-making challenges when resource situations involve multiple
143 stakeholders and diverse values about the environment. In cases such as these, a choice-
144 informing judgement about the effects of different development scenarios cannot be formed
145 through a monetary value alone (Altman et al., 2014; Ishizaka and Nemery, 2013; Raymond et
146 al., 2014).

147

148 American Indian land currently comprises approximately 5% of US land, yet holds an estimated
149 10% of its energy resources (Farhar and Dunlevy, 2003). Nothing illustrates the character of
150 value incommensurability more than a comparison between the economic benefits of
151 developing geothermal resources on Native American land in States such as Arizona and
152 Nevada, some of which would likely accrue to the indigenous population, and deep, resonant
153 socio-cultural traditions. These tribes define themselves and honour spiritual values with
154 respect to their land, which many traditional elders believe they hold sovereignty over and must
155 ensure remains undisturbed as a form of ancestral right (Farhar, 2002; Lund, 2006).
156 Furthermore, decision-making within Native American peoples, such as the Hopi Tribe, is a
157 private and collective process, which can take a long time to resolve due to the presence of two
158 types of leadership – the traditional and tribal councils – and frequent changes to leadership
159 personnel.

160

161 Similar conflicts and trade-offs have emerged in recent years in New Zealand connected to
162 potential geothermal developments on Maori land (Hikuroa et al., 2010). These have been
163 resolved, at least in part, through the Maori's receipt of dividends and revenue from power
164 plants on sacrificed indigenous lands, a process facilitated through recognition in New Zealand
165 law that the Maori owned the resources mined from their land (Mwanza, 2018). This legal
166 entitlement has not applied in the case of Olkaria, Kenya, where sub-surface geothermal
167 resources are owned by the state rather than the Maasai tribes who use their surface
168 manifestations for cooking, heating and traditional rituals. Conflicts emerged linked to the
169 relocation of more than 100 Maasai families by Kenya Electricity Generating Company
170 (KenGen), the state-run geothermal operator. A report by the World Bank found adverse
171 impacts on those affected, partly due to the limited suitability of the new land for traditional

² This is not an exhaustive list of the cultural ES that might be applicable to geothermal areas. In addition, less significant ES, such as cognitive development, education, and peace, are not considered in this illustrative analysis. In addition, the term recreation is considered to be inclusive of recreational tourism.

172 spiritual practices compared to Olkaria (World Bank, 2015). More recently, a revenue-sharing
173 bill has been tabled in the Kenyan Parliament to try and ensure adequate economic
174 compensation for indigenous communities. This would ensure that 2.5% of KenGen's revenue
175 from Olkaria plants would be directed to a special fund. Of this, 75% would return to national
176 government, with 20% and 5% directed to local governments and affected communities
177 respectively (Mwanza, 2018).

178
179 With regards to aesthetics, inspiration and heritage, these three ES are considered as a bundle
180 together due to their role as intermediate services contributing to recreation in geothermal areas
181 (Dowling 2013; Borović and Marković, 2015; Liu and Chen, 2015), as well as non-use value
182 (Cook et al., 2018). Peaceful surroundings and the presence of multi-coloured and geo-diverse
183 environments in geothermal areas generate rare aesthetics. As well as forming a motivation for
184 undertaking recreational activities (e.g. hiking and bathing), geothermal environments can often
185 be inspiring for artists due to their diversity and uniqueness (Gray, 2012). Due to their age,
186 aesthetic diversity and rarity, geothermal areas can also constitute feelings of nostalgia, tradition
187 and history. For sites such as the geysers in Yellowstone National Park, heritage can be
188 considered to be an intermediate benefit contributing to demand for recreation in the form of
189 tourism activities. In addition, although geothermal areas are generally sparsely populated, they
190 can sometimes include valued archaeological remains (Borović and Marković, 2015). Cook et
191 al. (2017) discuss how noise emissions and visual blight caused during the construction,
192 operation and decommissioning phases of geothermal power plants can contribute to negative
193 impacts to the aesthetics of surrounding landscapes, which may lead to trade-offs in terms of
194 the quality of the recreational experience. These were the findings of a cultural impact study by
195 Edelstein and Kleese (1995) investigating native Hawaiian opposition to geothermal power
196 projects.

197 198 2.3 MCDA and integrated valuation of ES

199
200 A decision-making apparatus that has gained some traction in recent years is MCDA, an
201 overarching term and framework describing approaches which attempt to account for multiple
202 criteria and stakeholder objectives in decision-making. MCDA methods enable information to
203 be integrated from non-market valuation studies (monetary value domain) and the outcomes
204 from deliberative research (socio-cultural value domain) (Chan et al., 2012). Given these
205 advantages, MCDA has become increasingly popular in energy project planning, as its
206 processes and outputs can assist decision-makers in identifying applicable objectives and trade-
207 off criteria linked to affected stakeholders, and making appropriate decisions as per determined
208 priorities (Kumar et al., 2017).

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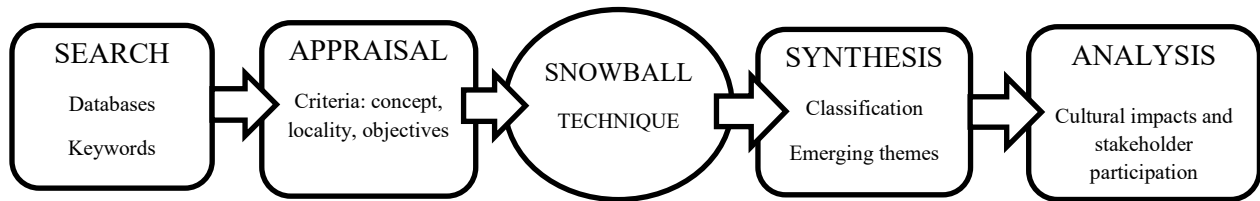
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213 **3 Methodology**

214

215 A literature review was conducted on the application of MCDA for geothermal power projects.
216 The Search, Appraisal, Synthesis and Analysis (SALSA) framework was applied (Cronin et al.,
217 2008; Grant & Booth, 2009) (see Figure 1), which applies an organised and replicable approach
218 to find, select, and analyse published academic research (Tranfield et al., 2003, Jones, 2004).
219 The SALSA framework was first applied in health sciences but its simplicity and rational order
220 of stages means that it has increasingly been applied in ES research (Mastrangelo et al., 2015;

221 Yang et al., 2018; Malinauskaite et al., 2019). In addition, in line with the approach of
 222 Malinauskaite et al. (2019), as there were only a small number of identified relevant scientific
 223 articles, it was decided to also apply the ‘snowballing’ technique (Greenhalgh & Peacock, 2005;
 224 Creswell, 2007; Malinauskaite et al., 2019) between the Appraisal and Synthesis stages to
 225 expand the list of relevant publications.
 226



227 **Fig. 1. The combined SALSA and snowballing framework used for the literature review**
 228 (Source: Adapted from Malinauskaite et al., 2019)
 229

230 The main stages of the method were as follows:

- 231 1) Step 1: Search
 - 232 • Search for terms ‘Geothermal’, ‘Multi-criteria Decision Analysis’ and
 - 233 ‘ecosystem services’ in Science Direct, Scopus, Web of Science and Google
 - 234 Scholar databases; use of additional search terms added to narrow down the
 - 235 search.
- 236 2) Step 2: Appraisal
 - 237 • Read abstracts to determine suitability of publications for the review according
 - 238 to two criteria: use of ES concept, consideration of multiple criteria.
 - 239 • Selected publications read in full.
- 240 3) Additional Step 3: Snowballing Technique
 - 241 • Apply snowballing technique to identify more relevant articles.
- 242 4) Step 4: Synthesis
 - 243 • Review the main aims and objectives of the publications, classifying these
 - 244 according to topic and scope.
- 245 5) Step 5: Analysis
 - 246 • Analyse literature based on (a) evaluative scope, and (b) levels and type of
 - 247 stakeholder participation
 - 248 • Focus of (a) was particularly on whether cultural impacts were included

249
 250 The literature search was done in July 2018, to select studies published in any year that
 251 contained the following terms in the title, abstract or keywords: (“Multi-criteria*” OR
 252 “Multicriteria*”) AND “ecosystem service*”, AND Geothermal. All of the results from Scopus
 253 (n=73), Web of Science (n=11), Science Direct (n=14) and Google Scholar (n=42), were
 254 reviewed, while additional search words (“power plant” and “decision making”) were used to
 255 remove a total of 77 articles that were deemed not relevant for this literature review, leaving six
 256 articles. Then, ‘Snowballing technique’ was applied, resulting in an additional two publications.
 257 In total, eight publications were then analysed.
 258
 259

260 4 Results and discussion

261
 262 Table 1 provides a summary of the existing MCDA studies for geothermal energy projects,
 263 including details of the authors and year of publication, study location, scale, levels of
 264 stakeholder participation, and scope of evaluative criteria. Stakeholder analysis is essential in

265 order to ensure that an ecosystem services perspective has the potential to become embedded
266 into decision-making processes. Of equal importance is the use of a wide range of criteria in
267 evaluation processes, otherwise different values and perspectives will be omitted from the
268 MCDA tool.

Table 1. Application of MCDA for geothermal power projects

Publication	Study location	Scale	Stakeholder participation	Scope of evaluative criteria
De Jesus, (1997)	Mount Apo Project (Philippines) Ngawha and Rotokawa Projcers (New Zealand)	Local	Public project proponent, the host community, the concerned agencies, government leaders, and institutional leaders from the religious, academic, and other concerned NGO sectors.	Environmental soundness and social acceptability
Goumas et al., (1999)	Nea Kessani, Northern Greece	Local	Limited (claimed to have occurred but undefined)	Energy use; return on investment; new jobs
Goumas and Lygerou, (2000)	Nea Kessani, Northern Greece	Local	Limited (claimed to have occurred but undefined)	Net present value of the investment; new jobs; energy consumed; risk index.
Haralambopoulos and Polatidis, (2003)	The island of Chios, Greece	Region	Local authorities, potential investors, central government, and public pressure groups (NGOs and local media).	Conventional energy saved; return of investment; number of jobs created; environmental pressure index and entrepreneurial risk of investment
Rammaáætlu (2010)	Iceland's potential geothermal and hydro power projects	National	Various workshops involving a wide range of stakeholders from government, private sector and NGOs	Environmental impacts; cultural impacts; recreation and land use impacts; regional and economic consequences; energy capacity and project costs
Borzoni et al., (2014)	Tuscany, Italy	Regional	Not conducted	Electricity production; profitability; municipality revenues; direct heat uses; avoided GHG emissions; H2S emissions; Hg emissions; NH3 emissions; As emissions; impact of aquifer; visual impact.
Polatidis et al., (2015)	The island of Chios, Greece	Region	Broad but based on secondary data (focused on investors and local stakeholders, including the mayor, members of municipal councils, NGOs, local development companies and regional authorities, but taken from an earlier study 11 years previously)	Annual energy saved; return on the investment; new jobs; environment; risk index.
Mohammadzadeh Bina et al., (2017)	Sabalan, Iran	Local	Not conducted	Energy efficiency; exergy efficiency; net power output; production cost; and total cost rate

4.1 Main review outcomes

Three main features emerge from the results of the literature review: (1) a tendency for current studies to be derived from limited or undefined levels of public participation; (2) a predominant focus on economic and technical efficiency objectives and omission of cultural impacts; and (3) a tendency for studies not to be used in decision-making protocols. With regards to the second observation, this is likely a direct consequence of the first. None of the eight studies reviewed in this paper were specific in valuing impacts to cultural ES, although Rammaáætlun (2010) did so without directly referring to the concept. Economic, energy efficiency and design optimisation objectives were the most common evaluative criteria, with much more limited focus on the environmental and social acceptability of proposals, and, in four of the eight papers, limited (undefined in two cases) or zero levels of stakeholder participation. The studies by De Jesus (1997) and Borzoni et al. (2004) were more extensive in terms of their objectives, encompassing social and environmental criteria, but they were still demonstrative of either zero stakeholder consultation or a lack of transparency concerning the degree to which they integrated insights from stakeholder consultation, which entails the risk that the full links between the impacts of developing geothermal power and human well-being are poorly understood.

With the exception of Rammaáætlun (2010) and as far as we are aware, all of the studies in Table 1 represent purely academic analyses, which were not used in practice by decision-makers. Rammaáætlun (2010) has been enshrined in Icelandic law since 2013, as a means of determining the strategic suitability of Iceland's potential energy projects, including geothermal and hydro power sites. An overarching Steering Committee was responsible for co-ordinating four separate working groups³ to assess the many impacts of geothermal power projects. The first evaluated environmental impacts and cultural heritage (Thórhallsdóttir, 2007; Ketilsson et al., 2015; Cook et al., 2016). The expert working group focused on environmental impacts and cultural heritage applied a three step procedure to the evaluation of cultural impacts from potential geothermal and hydro power developments, as follows: (1) assessment of the site values; (2) assessment of developmental impacts; and (3) ranking of projects from worst to best. Values for sites were assessed in expert panel workshops using numeric scales ranging from 1-10 in relation to the severity of their impacts in relation to, the following attributes: richness and diversity; rarity; size; and information value. Although not explicit in terms of embedding the ecosystem services perspective into its evaluative processes, the general approach of Rammaáætlun (2010), with its deliberative evaluation of the socio-cultural consequences of power projects, implies the inclusion of diverse values and benefits in its assessment processes, and that these have become informative to decision-making through the platform's enshrining in Icelandic law.

Another geothermal MCDA study with well-defined and extensive levels of stakeholder consultations was the publication of Haralambopoulos and Polatidis (2003). To develop a group decision-making framework, the authors recognised four groups of decision makers: local authorities, potential investors, central government, and public pressure groups (NGOs and the local media). However, since the project was in its preliminary stage, it was not possible to engage these various entities into a formal procedure for extracting preferences regarding weight attributes for the MCDA objectives.

³ Note that a new version of the plan is under development, but not yet enshrined in Icelandic law as a replacement of Rammaáætlun (2011). This includes five rather than four impact groups, focused on: (i) environment (nature) and culture, (ii) recreation, agriculture and land, (iii) social, and (iv) economic.

4.2 Barriers, challenges and future uses of MCDA in a geothermal context

The general omission of cultural impacts from the MCDA studies could have been for many reasons, including a thematic or discipline-specific focus of the paper, limited public participation in terms of shaping study design, or alternatively it could have been because of the challenges inherent in conducting integrated valuation – these necessitate the use of multiple valuation techniques, both monetary and non-monetary, and the investment of considerable time and resources on the part of researchers (Martínez-Alier and Muradian, 2015; Jacobs et al., 2016; Pandeya et al., 2016; Villegas-Palacio, 2016; Jacobs et al., 2018). In practice, decision-making in a geothermal context needs to be undertaken through careful evaluation of the main value dimensions existing in a system, but must not overburden planning resources and processes, which are often very limited in developing countries where a significant proportion of untapped resources are located (Szabó et al., 2013).

Challenges also remain concerning the conflicting nature of the different value dimensions. MCDA approaches maintain the need for stakeholders to consider trade-offs linked to policy alternatives – where these relate to certain cultural ES of geothermal areas, such as spiritual enrichment, there may still be issues of categorical non-commensurability that cannot be satisfactorily resolved (Saarikoski et al., 2016a; Saarikoski et al., 2016b). In order to facilitate integrated valuation, it is essential that stakeholder consultation is embedded at the earliest stage, enabling a very broad array of policy alternatives to be considered, objectives to be determined, and weightings to be evaluated. This was the case in Rammaáætun (2010), which was forged and ultimately enshrined in law following more than a decade of consultation, stakeholder engagement and data collection.

4.3 Decision-making implications of results

This study has reinforced the importance of considering different value dimensions concerning the trade-offs of developing geothermal power projects. Moreover, this paper's results concerning existing MCDA studies communicate the need for more effective stakeholder engagement relating to planning and decision-making, and the need for academic analyses to be far broader in scope in order to facilitate relevant information provision to decision-makers. This is all the more important considering the indigenous and often marginalised character of affected communities, such as the Kenyan Maasai in Olkaria. This example typifies the afflictions that can occur when international and domestic legal frameworks are insufficient, leading to multiple cultural impacts with considerable associated implications in terms of human rights, gender equality and identity issues (Koissaba, 2017). Effective stakeholder consultation can only be facilitated through the provision of sufficient financing to support and develop community capacity in relation to entrepreneurial projects seeking to harness geothermal resources. Through financing of stakeholder consultation and deliberation on objectives, MCDA approaches can be helpful in terms of refining and embedding community needs into the goals of the projects. In so doing, MCDA studies are broadened in scope beyond a focus on technical feasibility and contribution to the national economic good, encompassing cultural ES impacts and an array of socio-economic evaluative criteria. In particular, MCDA approaches that place as an objective the extent to which geothermal power projects deliver benefit-sharing, regarding indigenous communities as co-owners, are likely to be more inclusive and equitable than those seeking to provide economic compensation for land losses.

5. Conclusion

Although the current pool of studies is limited, it is evident that MCDA approaches have potential as an integrative decision-support device in the context of geothermal resources. However, only one study embedded cultural impacts into its evaluative criteria and current studies have demonstrated limited stakeholder engagement, with objectives focused mainly on economic and technical criteria. A broadening of scope and standardisation of approaches to encompass the full array of cultural ES impacts is necessary, but does remain challenging in practice because of budgetary constraints and various economic agendas within research-design and decision-making protocols. The example of Rammáætlun provided an example of an applied MCDA work, which came to fruition after more than ten years of stakeholder engagement and analysis.

The next stages in this research project will focus on the non-monetary research techniques suitable for the elicitation of public preferences relating to cultural impacts in a geothermal context. The outcomes from such evaluations will then be used to develop an illustrative MCDA case study, highlighting best practice procedures, participation and the formation of informed project objectives, with impacts to cultural ES fully embedded into the platform's design. Future research also needs to focus more intently on how to ensure that MCDA studies in a geothermal context are not merely academic exercises, but can support decision-making in practice.

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