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Willingness to Pay for the Preservation of Geothermal Areas in Iceland

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ABSTRACT

Academic knowledge concerning preferences and willingness to pay for the preservation of geothermal areas is currently very limited. This paper seeks to increase understanding, using the contingent valuation method to estimate willingness to pay for the preservation of two high-temperature geothermal fields likely to be developed in the near future: Eldvörp and Hverahlíð. Both study sites are located in Iceland, a nation that has been the recipient of repeated calls by the OECD to commence accounting for environmental impacts in cost-benefit analyses, particularly those associated with power projects. We applied interval regression using log-transformation to estimate WTP for the preservation of the high-temperature Eldvörp and Hverahlíð fields. The estimated mean WTP was 8,333 and 7,122 ISK for Eldvörp and Hverahlíð respectively. Scaled up to the Icelandic population of national taxpayers, this equates to estimated total economic value of 2.10 and 1.77 billion ISK respectively. These results reinforce arguments in favour of accounting for environmental impacts of Iceland's future geothermal power projects as a mandatory component of the decision-making process. In Iceland and further afield, more research is necessary to develop understanding of the economic value of impacts to recreational amenity and other ecosystem services resulting from geothermal power projects.

1. INTRODUCTION

The approval of energy projects with significant environmental impacts implies that the economic costs of the affected environmental resources must be less than the financial benefits, but such irreversible decisions are frequently made without ever attempting to estimate the monetary value of the losses (Reilly, 2012; Mattmann et al., 2016). Consequently, an inequality in decision-making may occur, as Ruhl (2007, p. 761) describes: *"failure to refine our understanding of their economic values, and the consequent inability to account for those values in regulatory and market settings and, more importantly, in the public mind, is unlikely to promote the preservation of natural systems."*

Until this paper, academic knowledge concerning preferences and willingness to pay for the preservation of geothermal areas has, for over three decades, been limited to the results published in a single paper, the contingent valuation study by Thayer (1981). Thayer applied the contingent valuation method to estimate willingness to pay to preserve the Santa Fe National Forest in New Mexico, which was a diverse, scenically attractive and popular recreational area blessed with hot springs, but potentially subject to development in order to provide energy for a geothermal power project. This study was illustrative of the land-management complexities commonly associated with harnessing geothermal resources for power projects, whereby all stages of the fuel cycle are located at the production site and a multitude of ecosystem services may have to be sacrificed through the development and operation of plant infrastructure and transmission lines (Thayer, 1981; Hastik et al., 2015).

In this paper, the total economic value of preserving two of Iceland's geothermal areas – Eldvörp and Hverahlíð – is estimated using the contingent valuation method (CVM). In the case of Eldvörp, the impacts are related to further exploratory drilling, which may or may not eventually lead to an application for a production license; for Hverahlíð, the contingent valuation scenario relates to impacts deriving from a proposed geothermal power plant. These study sites have been chosen as case studies for two main reasons: (a) they are characterised by a range of geomorphological features, contrasting levels of pre-existing human intervention on their landscape in pursuit of geothermal power and recreational pursuits, and their development will lead to environmental and social impacts which vary in type and degree; and (b) they are both listed as approved for development by the Iceland Master Plan for Nature Protection and Energy Utilisation[1], the nation's legally binding strategic tool for identifying suitable energy projects. They thus represent credible scenarios for survey participants to respond to.

The outcomes from these studies are potentially of interest to anyone interested in decision-making connected to the development of geothermal power, and particularly practitioners of cost-benefit analysis. However, in the case of Iceland, there is also a decidedly practical relevance in terms of advancing the decision-making apparatus. All three of the OECD's Environmental Performance Reviews of Iceland have advocated the nation strengthening its use of economic analysis in decision-making (OECD, 1993; OECD, 2001; OECD, 2014). In particular, the OECD's 2014 assessment emphasised that it was important for Iceland to *"develop some cost-benefit analysis process which gives appropriate consideration to all dimensions of power development (environment, tourism, social and regional development, project profitability)"*(OECD, 2014, p.115). In addition, Working Group 4, currently responsible for progressing the economic knowledge base underpinning the next iteration of Iceland's Master Plan for Nature Protection and Energy Utilisation, has argued that the macroeconomic impact of the nation's future energy projects can only be properly evaluated based on knowledge of all costs and benefits of projects, and these must include the economic value of their environmental impacts (Rammaáætlun, 2016).

[1] Also referred to as the *Master Plan for Hydro and Geothermal Energy Resources* in Cook et al. (2016; 2017)

In recent years there has been heated debate in Iceland concerning the trade-off between environmental goods and power projects, most notably in the case of the multiple and long-lasting impacts to flora and fauna (Landsvirkjun, 2003) associated with the controversial 690 MW Kárahnjúkar Hydropower Plant in eastern Iceland, which has been used since 2007 to supply electricity to Alcoa's Fjardaál aluminium smelter in Reyðarfjördur. However, to date, cost-benefit assessments for Icelandic energy projects have been undertaken without conducting total economic valuations to guide decision-making, ensuring that the monetary value of socially desirable goods, such as the qualities of an undisturbed landscape in a preserved geothermal area, have been overlooked (Cook et al., 2016; Cook et al. 2017). Moreover, only a very few academic studies have been undertaken in Iceland involving the utilisation of non-market valuation techniques, and just two related to energy project, both contingent valuation studies on the Kárahnjúkar Hydropower Plant (Bothe, 2003; Lienhoop and MacMillan, 2007).

This paper has four main aims: (1) to enhance the currently scant academic literature concerning preferences and willingness to pay for the preservation of geothermal areas; (2) to provide a comparison of WTP to preserve high-temperature for geothermal areas of varying scale, environmental characteristics and impacts; (3) to begin to satisfy the OECD's oft-repeated call for the introduction of a suitable environmental accounting method for use within the cost-benefit assessments of future energy projects in Iceland; and (4) to communicate in detail a best practice case study of the CVM for future practitioners in Iceland to follow.

The structure of this paper is as follows. Section 2 of this paper begins by briefly summarising details about the regulative background and study locations for Eldvörp and Hverahlíð, before outlining the anticipated environmental and social impacts of their development. Section 3 sets out a detailed description of this paper's methodology, including the survey design and mode of statistical analysis. Section 4 outlines the results and discusses the main implications of the outcomes.

2. LEGISLATIVE BACKGROUND AND PROJECT IMPACTS

2.1 Legislative and regulatory background

The Iceland Master Plan for Nature Protection and Energy Utilisation began to be forged in the late 1990s. Its ambition was to provide a national strategic guide to aide decision-making concerning energy projects (Rammaáætlun, 2011). Closely akin to Strategic Environmental Assessment in terms of its land use planning objectives, its aim was to evaluate the suitability of various potential geothermal and hydro power projects, ranking and classifying these according to their environmental, socio-cultural and economic impacts (Thórhallsdóttir, 2007a, 2007b; Cook et al., 2016). Enshrined in law in 2013[2], the Master Plan approved by the Icelandic Parliament segregated sixteen projects (2 hydro power, 14 geothermal) into the category of 'suitable for development', twenty (11 hydro power, 9 geothermal) as 'protected', and the remaining thirty-one (22 hydro power, 9 geothermal) as 'under consideration' pending further data and review (Rammaáætlun, 2011). The geothermal areas of Eldvörp and Hverahlíð were bracketed within the fourteen geothermal projects deemed 'suitable for development'.

2.2 Study site background and project proposals – Eldvörp and Hverahlíð

Eldvörp is a high-temperature field of 1,007 ha, located on the Reykjanes peninsula, approximately 50 km south-west of the capital city of Reykjavík. Eldvörp is currently owned by the energy company, HS Orka, who have estimated the productive capacity of the area to be in the region of 50 MW_e (Rammaáætlun, 2011). Base on the results from a test well in 1983, HS Orka consider the field to have a productive capacity in the region of 50 MW_e. HS Orka have planning permission to carry out further exploratory research, involving the drilling of shallow and deep test wells. They intend to conduct shallow and deep drill testing on up to five further boreholes (VSO Consulting, 2013).

Hverahlíð is a high-temperature field of 320 ha, located approximately 25 km to the east of Reykjavík and 2 km south-east of the existing 303 MW Hellisheiði Power Plant. Owned by Reykjavík Energy, Hverahlíð is estimated to have a productive capacity in the region of 90 MW_e (Rammaáætlun, 2011). Reykjavík Energy currently holds a fifteen-year exploration license for the Hverahlíð area. Their project proposals include two 45 MW turbines, 18 production wells, with estimated steam consumption of around 80-85 kg/sec each, and 9 re-injection wells. The main project components would also include the steam utility, freshwater utility, power plant, cooling towers, drainage utility, roads and tracks to connect to the nearby main highway, quarrying of material, facilities for contractors, and a connection with the transmission system (VSO Consulting, 2008).

2.3 Summary of environmental and social impacts – Eldvörp and Hverahlíð

An Environmental Impact Assessment, based on HS Orka's proposals for further exploratory research, was completed by VSO Consulting in 2013. A brief summary of the likely environmental impacts is provided as follows:

- Noise impacts will be local and potentially impact negatively on the visitor experience. They are very likely to be in breach of regulations 724/2008 and 1000/2005, which state that noise in quiet rural areas should not exceed 40 dB (A). These effects will be reversible over time, although their duration will depend on the length of the testing phase.
- There are no plans to disturb the crater row itself, only surrounding lava fields. The project's proposals are, however, in breach of Article 37 of Iceland's Nature Conservation Act (no. 44/1999), as they will lead to irreversible damage to lava fields formed during the past 10,000 years.
- The current landscape contains multiple geological features, which contribute to the recreational and educational value of the area. The introduction of geothermal power projects in the area, even research ventures, will lead to uncertain impacts on the quality of the future visitor experience – for those seeking evidence of geothermal energy, it may be positive; for those preferring quiet natural environments largely devoid of human interventions, it may be very negative.

[2] Law number 48/2011: http://www.althingi.is/lagas/141b/2011048.html

- Although Eldvörp includes human remains, the research proposals are not likely to directly affect the archaeological heritage of the area. The only negative impacts might relate to a reduction in the quality of the visitor experience due to the introduction of nearby boreholes.
- Impacts on the quality and availability of local groundwater resources are considered to be negligible.
- There are few birds living in the area so any impacts to these or other fauna are likely to be zero or negligible.
- The project will lead to disturbance of generally common moss vegetation where structures will be built, but given their nationwide abundance, the overall impacts are considered to be insubstantial. (VSO Consulting, 2013)

In 2008, VSO Consulting prepared an Environmental Impact Assessment based on Reykjavík Energy's proposals for a future power plant at Hverahlíð. The likely impacts are summarised as follows:

- Calculations show that a noise level exceeding 45 dB will be audible at a distance of 1,000 to 1,400m from the steam chimneys, which is more than is commonly found at other outdoor recreational sites in Iceland.
- Insubstantial but very uncertain impacts to the sustainability of the geothermal reservoir at Hverahlíð.
- Insubstantial impacts on local geological formations – the hot springs formed in the last 10,000 years in the area will be protected in accordance with Article 37 of Iceland's Nature Conservation Act, number 44/1999.
- Landscape impacts may vary in degree between insubstantial and considerable – the proposals will lead to small reductions in the size of young lava fields and impinge on old trodden routes; the general visual impact of the proposals is likely to be quite high, as they affect previously untouched areas. A number of hikers, skiers and horse riders use the Hverahlíð area, and thus the value of the area for those enjoying these recreational pursuits will likely deteriorate for an irreversible period of several decades.
- Mitigating measures will be adopted in accordance with The National Heritage Act (107/2001) to ensure that the impact on three archaeological remains at Hverahlíð is insubstantial.
- Increased but insubstantial concentrations of hydrogen sulphide and greenhouse gas emissions.
- Insubstantial hydrological effects are anticipated, including groundwater resources – groundwater holes in Hverahlíð will provide a source of freshwater for the project and reinjection will be used to maintain the sustainability of these supplies.
- Insubstantial but uncertain impacts will occur on local fauna – there are few birds in the area but it is possible that micro-organisms living in the hot springs may be disturbed.
- The project will lead to disturbance of vegetation where structures will be built, but such plants and mosses are abundant nationwide and thus the overall impacts are considered to be insubstantial. (VSO Consulting, 2008)

3. METHODOLOGY

3.1 Survey administration and design

Various instruments have been used to conduct contingent valuation surveys, including mail surveys, telephone surveys, face-to-face interviews, and mixtures of the aforementioned (Carson and Hanemann, 2005). Different survey instruments come with various pros and cons in terms of costs, biases and participation rates (Mitchell and Carson, 1989; Carson, Flores and Meade, 2001; Marta-Pedroso, Freitas and Domingos, 2007). Although the National Oceanic and Atmospheric Administration (NOAA) panel advocated the use of face-to-face interviews (Arrow et al., 1993), in recent times web-based formats have become very popular (Lindhjem and Navrud, 2011; Bonnichsen and Olsen, 2016; Menegaki et al., 2016). Even though use of the internet to administer surveys is a relatively recent advancement, evidence has been found in the literature in support of the method in terms of statistically insignificant differences in mean and median WTP compared to other survey instruments (Lindhjem and Navrud, 2011; Mozumder et al., 2011; Nielsen, 2011).

This study adopted a web-based format for two main reasons. It was a cost-effective means of obtaining a large sample – in 2015, the most recent year of data availability, 96% of the Icelandic population had access to the internet (Statistics Iceland, 2016). The web-based survey format also provided considerable opportunities and advantages in terms of design. As well as communicating a straight-forward, interactive and visually amenable style of presentation, participants were not able to browse through the surveys and answer questions in the wrong order. The surveys were interactive and branched to a considerable extent, so that participants did not have to respond to questions that were irrelevant to them based on their previous answers. In addition, the use of a web-based survey was particularly useful for randomising the bid offers in a manner which ensured that no participants were aware of this underlying process.

The surveys were implemented by the University of Iceland's Social Science Research Institute, who possess an internet panel of over 11,000 participants. These individuals are selected at random from the national registry to ensure they are representative of the Icelandic population and to prevent self-selection. Prior to implementation, the surveys were tested through two small pilot studies of fifty participants. Next two separate draws from the internet panel were undertaken, ensuring that participants completed either the Eldvörp or Hverahlíð survey, never both. The surveys were open for four weeks during April 2016. In this period, those who had not participated within a few days of an initial email were sent a reminder. A total of 474 and 448 responses were attained for the Eldvörp or Hverahlíð surveys respectively. These samples were found to be highly representative of the Icelandic population in terms of gender balance, age, number of children, marital status, and income, with comparable proportions to those identified within the most recent Icelandic Census, held in 2011.

The contingent valuation component of the web survey was designed with the objective of being in accordance with the various best practice guidelines set out by Arrow et al., (1993), Carson (2000), Carson, Flores and Meade (2001), Carson and Groves (2007), Kling, Phaneuf and Zhao (2012), and Haab et al. (2013). The web survey included three sections.

In the first section, participants were asked a series of attitudinal questions concerning the environment and society in Iceland. Participants were asked to select from a list of nine options the issues they considered to be the most and least pressing for Icelandic

society to address. Next, they were asked to state their degree of agreement[3] with nine clearly defined statements. These covered attitudes relating to the national importance of economic diversification; economic growth; harnessing untapped renewable energy resources; protecting areas of environmental value; paying monetarily for the preservation of environmentally valuable areas and evaluating monetarily the impacts of developments in such areas; and whether recreational amenity must always be sacrificed following construction of a geothermal power plant. Finally, the first section concluded by asking participants to select from a list of 15 options (including 'other') the activities they had carried out during outdoor excursions in Iceland over the past year.

The second section questioned participants about their familiarity with Eldvörp or Hverahlíð. They were asked if they had ever visited the study sites and, based on that answer, they either received a question about their activities or if they intended to visit in the future. Participants were then provided with the respective contingent valuation scenarios for the study sites, which included details of the likely environmental impacts of the project proposals. Following this, participants were reminded about their budget constraint and asked whether they were for or against the preservation of their study site, much like the approach in referendum voting (Kling, Phaneuf and Zhao, 2012). Individuals expressing a preference for preservation were presented with double-bounded WTP questions and validity checks afterwards to assimilate their understanding of their scenario. Individuals who were against preservation of their study site were forwarded to questions designed to sort protest voters from those with a pure preference against preservation.

The third and final part of the survey, as is customary, was comprised of socio-economic questions in order to ascertain factors influencing WTP. These questions were issued at the very end of the survey since they have the potential to stimulate a state of objection amongst participants, leading to non-responses (Carson, Flores and Meade, 2001).

3.2 Scenario description and payment vehicle

In contrast to normal opinion polls, contingent valuation surveys include a detailed description of a scenario that essentially constructs a hypothetical market for participants (Carson, 2000). However, it is vital that the hypothetical market is kept as real (Cummings and Taylor, 1998) and consequential (Carson and Groves, 2007) as possible to limit the effects of bias on welfare estimates. As these studies were based on pre-existing designs and their likely environmental impacts had already been determined, the risk of hypothetical bias was much reduced compared to a purely theoretical scenario. Participants were carefully reminded that Eldvörp and Hverahlíð have both been deemed potentially suitable for development by the Iceland Master Plan for Nature Protection and Energy Utilisation. Both surveys provided participants with a detailed description about the study sites, their ownership in terms of current licensing arrangements, environmental characteristics, likely developments in pursuit of geothermal power, and the environmental impacts pertaining to these proposals. Environmental impacts were described in accordance with the content in Section 2.3 of this paper and summarised using non-technical language to maximise the likely understanding of participants. In order to alleviate potential land management conflicts between utilisation and preservation desires, the scenarios proposed that national legislation could potentially be enacted to ensure that the areas were preserved. However, participants were informed that due to the forgone future economic benefits suffered by the license holders, a financial payment would be required to secure the sites' preservation.

In recent years, considerable focus has been allocated to the overall valuation process, with due recognition that WTP estimates are strongly influenced by the procedures through which the resource is provided and how the payment is made (Cummings et al., 1986; Mitchell and Carson, 1989; Morrison, Blamey and Bennett, 2000). A realistic and neutral choice of payment vehicle can be incentive compatible (Mitchell and Carson, 1989; Carson, 1997; Carson, Flores and Meade, 2001; Grammatikopoulou and Olsen, 2013). In this study, the chosen payment vehicle was an additional lump-sum tax, payable only once and charged to all taxpayers aged over 18 years in Iceland irrespective of income. This choice was made due to its incentive compatibility compared to voluntary arrangements and the technical infeasibility of charging entrance fees. Its design was very similar to other lump-sum taxes in Iceland, such as the annual fixed levy towards the state television and radio production[4]. Assuming that participants believed in the survey's scenario, the design of the tax and knowledge that it would be levied irrespective of income minimised the risk of strategic bias influencing the welfare estimates.

Based on the results from the pilot studies and recent focus groups concerning the significance of these study sites, the affected population for the surveys was considered to be the entire nation. Since the payment vehicle used to elicit WTP was an additional lump-sum tax, the affected population became all taxpayers in Iceland.

3.3 Elicitation of WTP

There are many different ways of eliciting WTP estimates using contingent valuation surveys. A variety of methods have been advocated in previous studies: open-ended questions (Bateman et al., 1995), payment cards (Olsen and Donaldson, 1998), dichotomous choice (single, one and a half, or double bounded) (Arrow et al., 1993; Cooper, Hanemann and Signorello, 2002; Afroz and Masud, 2011; Tilahun et al., 2012), iterative bidding games (Van Minh et al., 2013) and referendums (Dutta et al., 2007). Dichotomous choice has proven to be a very widely adopted elicitation formation, mainly due to its simplicity of use in data collection (Antony and Rao, 2010). In this study, we adopted the double bounded model due to its greater statistical efficiency and reduced coefficient variance compared to the single bounded version (Hanemann, Loomis and Kanninen, 1991). In the double bounded approach, participants with WTP are asked a closed-ended question twice in relation to bid offers. If the answer to the first question was 'no' then the second question offered a lower bid$\left(t_i^L\right)$; if the answer to the first question was 'yes' then a higher bid was communicated $\left(t_i^U\right)$ (Hanemann, Loomis and Kanninen, 1991).

[3] On a scale of 1-5, with 1 = strongly agree; 2 = somewhat agree; 3 = neither agree nor disagree; 4 = somewhat disagree; and 5 = strongly disagree

[4] The levy for broadcasting services was 16,400 ISK for the 2015 tax year and was required to be paid by all individuals of at least 18 years of age with taxable income (Invest in Iceland, 2014).

4. RESULTS AND DISCUSSION

4.1 Responses to attitudinal questions and outdoor activities in Iceland

For the purposes of the first section of the surveys only, focused on attitudes and outdoor behaviour, the results are combined (n = 922) since these questions did not relate specifically to either study site. The issues of improving healthcare (39.15%) and securing affordable housing to rent or buy (20.82%) stood out as being by far the most pressing societal concerns. Protecting important natural areas, their habitats and wildlife (12.26%) was of third greatest concern. The selection of the least pressing issue appeared dominated by uncertainty, with 16.16% of participants selecting the 'don't know' response and a further 4.66% opting not to answer. Of those who selected a pre-defined option, waste management (16.16%), economic growth (15.15%) and economic diversification (11.17%) were deemed the least pressing societal concerns. Few members of the sample considered improving healthcare (3.25%) or protecting important natural areas, their habitats and wildlife (4.01%) to be their least pressing issue.

More specific insight into societal attitudes was obtained through responses to nine statements focused generally on conflicts between further economic development and environmental preservation, particularly related to the further deployment of Iceland's renewable energy resources and associated decision-making processes. These are displayed in Table 2, with percentages provided in parentheses.

Although not considered to be the most pressing issues for Icelandic society to address, there was consensus that economic diversification and economic growth were still important issues, with 77.65% and 74.52% of the sample voicing either strong or slight agreement. Studies have shown that Iceland's economic growth has been intrinsically linked to the utilisation of its renewable energy resources (Bhattacharya et al., 2016; Iceland Chamber of Commerce, 2016), yet opinion was mixed concerning whether the harnessing of untapped sources of renewable energy was important, with 41.44% and 32.21% of the sample strongly agreeing / slightly agreeing and strongly disagreeing / slightly disagreeing respectively. Almost half of the sample (48.58%) were in strong agreement with the statement that Iceland's environmentally valuable resources should be protected from development. Moreover, only 17.46% strongly or somewhat agreed (51.84% somewhat or slightly disagreed) with the notion that the economic benefits of harnessing Iceland's geothermal and hydro power resources are of greater importance than the protection of natural areas. There was broad agreement about the importance of the National Energy Authority (Orkustofnun) evaluating the environmental impacts of energy projects in terms of their economic value, with almost 80.80% of the sample voicing some level of agreement with this statement, although the subject matter of this survey may have influenced this outcome. In terms of paying for the protection of natural areas in Iceland, less than half the sample (48.08%) either strongly or slightly agreed with the notion that they should pay for the protection of natural areas that they have visited and consider valuable.

Finally, in Section 1, participants stated the activities they have carried out during outdoor excursions in Iceland over the past year. The five most commonly listed activities were hiking (782/922), swimming (536/922), mountaineering (433/922), cycling (396/922), and berry picking (377/922).

4.2 Visitor data for Eldvörp and Hverahlíð

A total of 146 (30.80%) and 202 (45.09%) participants stated that they had visited Eldvörp and Hverahlíð respectively. The proximity of Hverahlíð to Iceland's Route 1, the island's main highway, probably explains the higher frequentation associated with this site. Of the 328 participants who had not visited Eldvörp, a further 224 (47.26%) asserted that they were likely to in the future. For Hverahlíð, 149 (33.26%) of participants stated that they planned to visit the site in the future. Similar proportions of the samples claimed to have no intention to visit the sites in the future – 98 (20.68%) and 94 (20.98%) for Eldvörp and Hverahlíð respectively. Nine participants across the two samples were unclear about their future intentions.

The sub-sample of participants who had visited the study sites were asked to tick the various activities they had enjoyed. In the case of Eldvörp, the most commonly stated activities were hiking (126 participants, 86.30%) and photography (108 participants, 73.97%). Hiking was also a popular pursuit at Hverahlíð, enjoyed by 150 (74.26%) participants, whilst cycling and skiing were both listed by 44 (21.78%) members of the sub-sample.

4.3 Willingness to pay for preservation of Eldvörp and Hverahlíð

Following the scenario description, all participants were asked if they were prepared to pay a one-time lump sum tax to preserve Eldvörp or Hverahlíð. Table 1 sets out the responses, with percentages in parentheses. Compared to the Hverahlíð study, 8.60% more participants from Eldvörp's sample expressed WTP.

Table 1: Willingness to pay for preservation of Eldvörp or Hverahlíð

WTP Tax	Eldvörp	Hverahlíð
Yes	264 (55.70)	211 (47.10)
No	210 (44.30)	237 (52.90)
Total	**474 (100.00)**	**448 (100.00)**

Of the sub-sample of 264 participants who were WTP for Eldvörp's preservation, 89 (33.71%) had visited the site previously, whilst a further 136 (51.52%) intended to in the future. Only 36 (13.64%) participants expressed WTP and had neither visited Eldvörp nor intended to in the future. For Hverahlíð, 94 (44.55%) of the 211 participants with WTP had visited the site, and a further 87 members (41.23%) were likely to do so in the future. The remaining 30 participants (14.22%) were willing to pay, but had neither visited Hverahlíð nor stated that they were likely to do so in the future.

Participants who were not willing to pay were asked to state their reason to determine whether they were protest voters, who needed to be dropped from the results, or had a genuine WTP of zero. Protest voters were identified if their reasoning related to objections

about paying higher taxes in Iceland or if they voiced strong discontentment concerning energy development in their study area. A genuine WTP of zero was determined on the basis of either insufficient disposable income to pay the tax (but otherwise an intention to preserve) or a clearly stated indifference between the preservation of the site and scenario of energy development. In these surveys, the number of protest voters was fairly high, corresponding to 151 of 210 participants (71.90%) in the case of Eldvörp and 175 of 237 participants (73.84%) for Hverahlíð. The majority of protest voters (65.33% of participants across the two samples) were against the paying of higher taxes for the preservation of these sites. The high number of protest voters was likely exaggerated by the political turmoil occurring during the launch of the surveys in April 2016, which involved considerable anti-government sentiment. At this time, the largest political protests in Icelandic history were occurring in connection to various financial irregularities revealed by the Panama Papers expose, which ultimately led to the resignation of the prime minister. There were 57 and 55 instances of genuine zero WTP for Eldvörp and Hverahlíð respectively, and these participants were accounted for using the spike model.

4.4 Bid elicitation responses

All participants expressing WTP were moved on to the bid elicitation stage. The first bid offers were randomly allocated to participants from the following options: 1,000 ISK; 2,000 ISK; 3,000 ISK; 4,000 ISK; or 5,000 ISK. If a participant answered 'yes' to the first binary question, then their second bid was higher and one of the following: 2,000 ISK; 4,000 ISK; 6,000 ISK; 8,000 ISK; or 10,000 ISK. Participants answering 'no' to the first binary question received lower bid offers from this pool: 500 ISK; 1,500 ISK; 2,500 ISK; 3,500 ISK; or 4,500 ISK. 76.43% of participants in the Eldvörp survey answered 'yes' to the first bid, but slightly under half (49.75%) of these individuals were subsequently affirmative of the second bid. Proportionally, 23.57% of the Eldvörp sample rejected the first bid and 12.17% answered 'no' to both bid offers. Broadly similar patterns were evident in the case of the Hverahlíð survey, with marginally higher (by 3.31%) and lower (by 2.22%) percentages accepting or rejecting both bid offers respectively.

4.5 Summary of predictor information used in regression model

For each predictor variable, the mean outcome is provided with standard deviations in parentheses. The socio-demographic and user variables were coded as per Table 2:

Table 2: Predictor variables and coding

Predictor variable	Explanation of coding
Gender	A dummy variable, with 0 = female and 1 = male.
Age	Age was the stated age based on participants' date of birth.
Residence	A dummy variable, with 0 = a person living outside of a 100 km radius surrounding Reykjavik and 1 = a person living inside this boundary. The 100 km demarcation was determined to establish the influence on WTP of a person living within reasonable day-trip travelling distance of the sites.
Education	A dummy variable, with 0 = no form of degree education and 1 = a participant having completed at least an undergraduate programme.
Job market participation	A dummy variable, with 0 = a participant not actively involved in the labour market and 1 = an active participant. Those not actively involved encompassed students, the retired, sick or disabled individuals, carers, people on maternity/paternity leave, and the unemployed. Active participants included all employed and self-employed individuals, irrespective of whether these duties were part or full-time.
Number of children	Coded on a scale of 0-6 and related to the participant's number of children aged under 18.
Number in household	Coded on a scale of 0-7 and related to how many people lived in the participant's home, including themselves.
Marital status	A dummy variable, with 0 = not married, cohabitating or in a relationship, and 1 = married, cohabitating or in a relationship.
Disposable income	Classified according to five separate dummy variables. This was because response omissions were particularly evident in connection to the question about disposable income, and in order to maintain as many respondents in the sample used for the regression model, dummy variables were established for each of the income categories – Income dummy 1 = 200,000 ISK or less; Income dummy 2 = 201,000-300,000 ISK; Income dummy 3 = 301,000-400,000 ISK; Income dummy 4 = 401,000-600,000 ISK; and Income dummy 5 = more than 600,000 ISK. For all five dummy variables, a value of 0 = not applicable and 1 = applicable.

4.6 Interval regression models

The results from the two interval regression models are shown in Table 3. Standard errors are shown in parentheses. Due to a small number of cases (24 across both samples) whereby participants failed to answer the socio-demographic questions, the eventual sample numbers were 247 and 203 for Eldvörp and Hverahlíð respectively.

Table 3: Interval regression results – Eldvörp and Hverahlíð

Variables	Eldvörp	Hverahlíð
Socio-demographic:		
Gender	0.312 (0.157)**	0.133 (0.180)
Age groups	0.044 (0.079)	-0.036 (0.103)
Residence	0.129 (0.154)	0.344 (0.185)*
Education	0.341 (0.161)**	0.351 (0.191)*
Job market participation	0.152 (0.187)	0.000 (0.207)
Number of children	0.074 (0.123)	-0.011 (0.123)
Number in household	-0.035 (0.100)	0.028 (0.102)
Marital status	-0.189 (0.188)	-0.038 (0.225)
Income dummy 1	0.129 (0.280)	-0.122 (0.343)
Income dummy 2	0.183 (0.262)	0.219 (0.309)
Income dummy 3	0.460 (0.263)*	0.093 (0.315)
Income dummy 4	0.484 (0.259)*	0.215 (0.317)
Income dummy 5	0.826 (0.324)**	0.279 (0.384)
User:		
Visitor	0.074 (0.154)	0.419 (0.182)**
Constant	7.861 (0.448)***	8.022 (0.522)***
σ	0.964 (0.069)	1.023 (0.084)
N	247	203
Log-likelihood	-277.946	-231.76
LR Chi^2	36.95	22.95
Prob > Chi^2	0.0007	0.0611

*** indicates significance at the 1% level, ** significance at the 5% level, and * significance at the 10% level.

Relatively few predictor variables were statistically significant in either model. Gender, education and income dummy 5 (>600,000 ISK) were significant at the 5% level in the Eldvörp model, whilst being a visitor was the only predictor with this level of significance in the Hverahlíð study. Other variables significant at the 10% level were two of Eldvörp's income dummy variables (3 and 4), and residence and education in the Hverahlíð model.

4.7 Mean and total WTP estimates

Building on the results of the models and incorporating the spike model, the mean results for Eldvörp and Hverahlíð are set out in Table 4. Table 5 provides an estimate of the total economic value of the Eldvörp and Hverahlíð by up-scaling the mean values by the deemed affected population, the total number of Icelandic tax payers. The total economic values are 2.10 and 1.77 billion ISK for Eldvörp and Hverahlíð respectively.

These values have been formed in response to the specific scenarios of environmental impact described in Section 2.3. As some environmental impacts were deemed to be uncertain in the respective EIAs, the WTP responses and scaled-up outcomes occur in the light of this unpredictability. WTP responses would likely have varied given alternative survey formats and scenarios of environmental change. Indeed, the communication of different project design parameters, environmental impacts and mitigation measures might have led to markedly different outcomes. Furthermore, the extent to which members of the public, often not well-versed about environmental issues, understood the consequences of simultaneous environmental consequences, some short and others long-term, is not known. Nor do these outcomes provide information about the environmental impacts which participants classed to be the most severe.

Table 4: Mean WTP for the preservation of Eldvörp and Hverahlíð

	Mean WTP (ISK)	Standard deviation (ISK)	95% confidence interval (ISK)	
Eldvörp (n=304)	8,433	6,246	7,728	9,138
Hverahlíð (n=258)	7,122	7,270	6,231	8,013

Table 5: Total WTP for the preservation of Eldvörp and Hverahlíð

	Mean WTP (ISK)	Population of taxpayers (2015)	Total WTP (ISK)
Eldvörp	8,433	249,094	2.10 billion
Hverahlíð	7,122	249,094	1.77 billion

4.8 Economic valuation and Icelandic decision-making

As the OECD have repeatedly advised and Working Group 4 of Iceland's Master Plan recently requested, Iceland should commence an accounting process that enables traditional cost-benefit analyses to be extended to account for the full cost of proposed power projects. In this paper, a methodology has been delineated to fulfil these calls and two pilot contingent valuation studies conducted on likely forthcoming projects, expanding national and international knowledge of the total economic value of geothermal areas. The total economic value of the Eldvörp and Hverahlíð geothermal areas is considerable. To place these estimated costs into some sort of context and scale, 2.10 and 1.77 billion ISK are approximate to 2% of the estimated total construction costs of US $ 800,000,000 for Iceland's largest geothermal power plant at Hellisheiði (Gunnlaugsson, 2012). They are thus of sufficient scale to provide ballast to the OECD and Working Group 4's respective calls for these values to be included within cost-benefit analyses.

As knowledge increases, a further challenge is apparent in the form of embedding accounting procedures into Iceland's decision-making processes. A considerable layer of discretion remains in Icelandic decision-making related to all development projects, and particularly those involving energy resources. Currently, in order for Icelandic energy projects to be granted licenses for exploration or production, they must be approved by the Master Plan and Orkustofnun, the National Energy Authority, needs to be satisfied that the proposals are compliant with regards to various legislation, including the Planning and Building Act (73/1997), Nature Conservation Act (44/1999) and Environmental Impact Assessment Act (106/2000) (Ketilsson et al., 2015; Cook et al., 2016). With regards to the latter, developers are required to undertake a comprehensive evaluation of an energy project's likely environmental and social impacts. The administration of this Act is conducted by Skipulagsstofnun, the National Planning Agency, who then issue a non-binding legal opinion on the project for Orkustofnun to consider. Cook et al. (2016) contend that this approach risks the formation of a 'regulatory gap', whereby a project's negative environmental and social impacts, which are entirely qualitative in nature, are afforded insufficient arbitrage in decision-making. The authors cite the example of the Kárahnjúkar Hydropower Plant[5], using this example to argue that *"failure to also quantify these impacts in monetary terms can therefore lead to project approvals that undermine social welfare"* and thus it is important *"to ensure standardisation of all costs and benefits related to projects"* (Cook et al., 2016, p. 110).

A policy agenda is already in place to encourage the sustainable utilisation of Iceland's renewable energy resources – in 2013, the Master Plan was enshrined in law, and since 1994 all energy projects have been required to carry out Environmental Impact Assessments. As this study has communicated, the environmental impacts associated with geothermal power projects approved by the Master Plan may appear relatively inconsequential when outlined in qualitative terms, but considerable when translated into economic values. Failure to standardise the environmental impacts of geothermal power may leave such costs insufficiently represented and the true social welfare implications of projects undetermined.

4.9 Valuing the ecosystem services of geothermal areas, challenges and future research

As per the inaugural study by Thayer (1981), in estimating the total economic value of preserved geothermal areas, this paper has not explored the economic value of the individual ecosystem services deriving from such environments. This paper has not delved into the constitutional components of total economic value and the economic impacts of changes in their provisioned quantity or quality. In so doing, it has been assumed that participants can assimilate all of the impacts to ecosystem services described within the respective Environmental Impact Assessments for the study sites to arrive at a single estimate of economic value for preservation. This may be a straight-forward consideration for disturbances to popular features of recreational value such as caves, ancient lava fields or footpaths, but is perhaps less easy when the estimate must also reflect impacts to the more intangible cultural ecosystem services associated with geothermal areas, such as landscape aesthetics. Furthermore, in some cases the impacts described in the Environmental Impact Assessments were set out in uncertain terms, leading to a lack of clarity concerning the degree of qualitative change.

[5] This project was rejected in the opinion provided by Skipulagsstofnun on the grounds of its environmental impacts, but the project was approved by Orkustofnun. The impacts included the permanent loss of habitats suitable for the breeding and nesting of reindeer, pink-footed geese and harbour seals; widespread soil erosion; loss of vegetation with a high conservation value; fragmentation and disruption of one of the last wilderness areas in Europe; and loss of one of Iceland's most popular glacial canyons, Dimmugljufúr (Lansvirkjun, 2003).

The academic literature is devoid of any studies providing a holistic yet structured economic assessment of the impact of a geothermal power project on the provisioning of multiple ecosystem services (Cook et al. 2017). Similarly to other comprehensive valuation studies, the process of estimating the economic value of impacts to the ecosystem services of geothermal areas is important, but will likely be challenging in three ways: (1) establishing the scientific links between project proposals and the economic value of changes in the quantity and quality of provisioned services; (2) ensuring that double counting of welfare benefits from specific ecosystem services does not occur; and (3) assembling sufficient resources in terms of funding, personnel and time to simultaneously conduct multiple economic valuation studies.

One area of particular intrigue in the debate about geothermal power concerns impacts to recreational amenity. Looking back at the attitudinal questions posed in this study, 62.18% of the sample either strongly or somewhat agreed with the notion that it was possible for geothermal areas to provide the same or similar levels of recreational benefits after a power plant was constructed. Other anecdotal evidence also supports the possibility that geothermal power projects do not necessarily have to undermine long-term recreational amenity and may even have the opposite effect. One example is Iceland's Blue Lagoon spa. Formed in 1976 by waste waters emanating from the Svartsengi Power Plant, the geothermal spa continues to attract a burgeoning clientele of tourists keen to relax in its waters (Blue Lagoon, 2016). Another case relates to the Hellisheiði Power Plant, where the facilities include a popular interactive exhibition for educating tourists and locals (ON Power, 2016). Further economic valuation studies are needed to investigate the impacts of geothermal power projects on recreational amenity. The Eldvörp field perhaps represents a suitable starting point for this research, as the further exploratory research by HS Orka will impact on a number of popular hiking trails in the area. Initially there is merit in applying the travel cost method to establish an estimate of the recreational value of the area in its current form. However, in order to understand the impacts to recreational amenity of a geothermal power project, it would be necessary for researchers to combine stated and revealed preference methods. Participants taking part in a travel cost study would need to be asked how their frequentation of the area might vary in the light of power project proposals, with the change in consumer surplus between the total studies equating to the social welfare implications associated with qualitative changes to recreational amenity.

Other valuable insights into the economic impact of geothermal power projects could be sought via an *a priori* approach. Rather than assuming that project proposals are a given and determining the economic value of environmental impacts relating to these, there may be the potential for economic information to influence design. Discrete choice modelling could be carried out to analyse economic preferences for different design parameters, such as the location of pipes, visibility of plant infrastructure, installation of scrubbing equipment to remove hydrogen sulphide emissions, and the extent of vegetative disturbance.

5. CONCLUSION

This paper used the CVM to estimate the economic value of preserving two high-temperature geothermal fields in Iceland, both likely to be developed in the near future. The methodology applied in this paper could be adopted to satisfy the OECD's repeated calls for Iceland to account for environmental impacts of power projects in cost-benefit analyses, which would potentially reduce the risk of sub-optimal decision-making. Based on impact scenarios derived from Environmental Impact Assessments, which were based on design proposals for Eldvörp and Hverahlíð, the contingent valuation studies revealed estimated mean economic values of 8,433 and 7,122 ISK. Based on the affected population of Icelandic taxpayers, these equated to estimated total economic values of 2.11 and 1.78 billion ISK for Eldvörp and Hverahlíð respectively. These are not inconsiderable estimates, amounting to approximately 2% of the total lifetime construction costs of Iceland's largest geothermal plant, Hellisheiði. As such, they imply the need for further research focused on the economic value of the environmental costs associated with developing geothermal power projects in Iceland and beyond. In addition, their scale in itself provides an evidence base supporting the incorporation of utilitarian values of the environment into Icelandic decision-making processes. The results from these studies considerably advance academic knowledge concerning preferences and willingness to pay for the preservation of geothermal areas, which, until this study, had been limited to the contingent valuation study by Thayer (1981). However, considerable further research is necessary to understand the economic impacts to specific ecosystem services associated with the development of geothermal environments, particularly connected to changes in recreational amenity and landscape aesthetics. In so doing, it would be possible to gain greater comprehension of impacts to the various components of total economic value, leading to understanding of why the environmental costs associated with developing one geothermal field – in this case Eldvörp – may be perceived to be greater than another. At this stage, until further knowledge is acquired of the economic value of preserved geothermal fields and their respective ecosystem services, it is recommended that the results from these studies are considered indicative and not used in any studies reliant on benefit transfer methodology.

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