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ECONOMIC BENEFITS OF GEOTHERMAL SPACE HEATING FROM THE PERSPECTIVE OF ICELANDIC CONSUMERS

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ABSTRACT

Geothermal resources provide a low-cost option for heating Icelandic buildings. This is evident when the cost of geothermal space heating is compared to the cost of heating with imported oil and domestic electricity, both of which are used by residents of areas where geothermal resources are not to be found. The comparison reveals annual savings that amount to 1.1-4.3% of the total income from employment in 2005. A comparison of district heating prices in Europe shows that Icelandic consumers pay the lowest price per energy unit.

1. INTRODUCTION

Over the course of one century, geothermal space heating has grown from being non-existent in Iceland to reaching 90% of the population. The first farm was connected to a hot spring in 1908 and the first geothermal district heating system was established in Reykjavik in 1930, in times when coal was the main heating fuel. In the following decades, the district heating system was expanded, but oil gradually became the heating fuel of choice for those inhabitants of the capital area who did not have the benefit of a geothermal connection. By 1960, oil had mostly taken over from coal and by the early 1970s, the district heating system had expanded to reach nearly all the inhabitants of Reykjavik. However, oil continued to be used for heating in the countryside. This was felt heavily by the Icelandic economy during the oil crises of the 1970s and early 1980s, which served to motivate the Icelandic Government to encourage further development of geothermal resources for space heating through policies and attractive loans. The resulting expansion of geothermal heating over this period is evident in Figure 1. While the lowest hanging fruit were harvested first, the Government and municipalities have continued to encourage the exploration and use of geothermal resources for space heating in areas of lesser population density and/or inferior resource quality, resulting in gradual increase in geothermal space heating from the mid-1980s up to the present.

Although geothermal resources are widely spread in Iceland, there are parts of the country where they are hard to find or non-existent. In those areas, electrical heating has mostly taken over from oil (Figure 1). In 2011, the electricity mix consisted of hydro (72.7%) and geothermal (27.3%) (Baldvinsdóttir et al., 2013).

Such wide access to geothermal resources for space heating in a cold country that needs year-round heating is of great benefit to the national economy and to consumers. The aim of this paper is to describe these benefits to Icelandic consumers, and to this end, the cost of geothermal space heating is compared to the following scenarios:

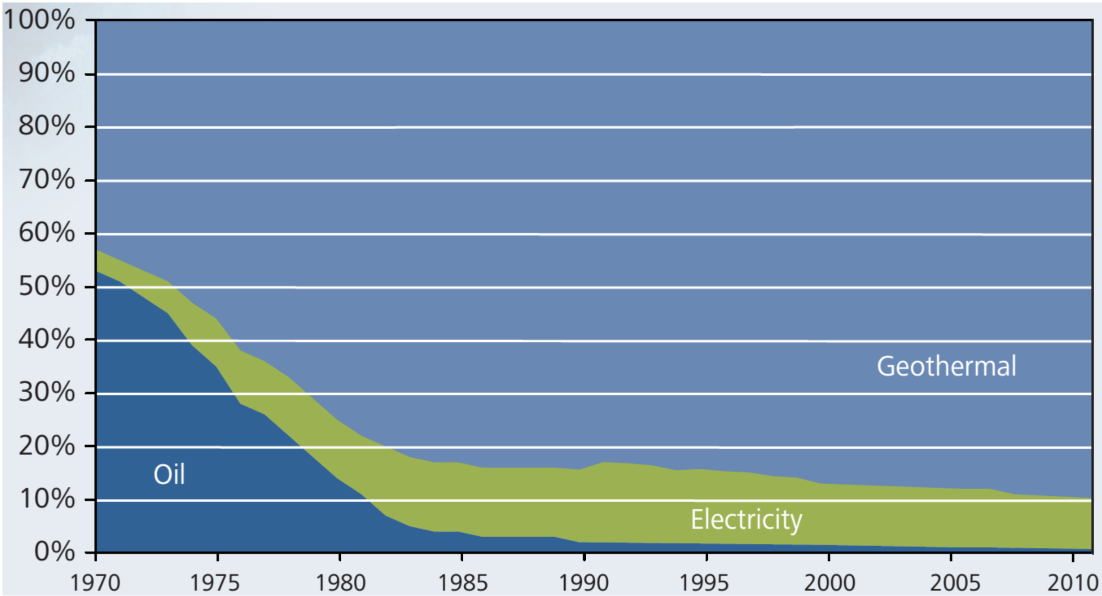

FIGURE 1: Space heating in Iceland by energy source 1970-2011 (Baldvinsdóttir et al., 2013)

1. The cost of heating by oil, as done in previous decades;
2. The cost of electrical heating, as done by close to 9% of the population; and
3. The cost of heating in neighboring countries.

Due to the complex interplay of various factors and the hypothetical nature of reference cases, the outcome of such an undertaking will be suggestive rather than concrete.

2. COMPARISON TO HEATING BY OIL

In 2010, Orkustofnun – the National Energy Authority of Iceland (NEA), published a report on the benefits to the Icelandic national economy of using geothermal resources for space heating in place of oil over the period 1970-2009 (Haraldsson et al., 2010). Figure 2 shows that during this period, the retail price of imported heating oil has at all times been higher than the price of geothermal energy per unit of deliverable heat energy (65% conversion efficiency is assumed for the oil). For some years, the use of oil for heating was "only" 2 times as expensive as heating by geothermal, but in 1979 (Iranian revolution) and 2008 (overheated world economy), it became almost 10 times as expensive. The accumulated savings to Icelandic geothermal district heating customers over this 40 year period amount to 9,510 million USD (adjusted for inflation to February 2014 based on the annual average consumer price index and the average exchange rate (114.1 ISK/USD) for the same month (Central Bank of Iceland, 2014)). By comparison, the total income from employment in 2005 was 7,845 million USD (Iceland Statistics, 2014) (total income is not available for later years from Iceland Statistics; same method of inflation adjustment and conversion to USD as before). Although the consumer group of geothermal district space heating services includes the commercial, industrial and agricultural sectors, the residential sector has a large share in the overall utilization. This suggests that the savings of an average residential customer of a geothermal district heating service in Iceland who subscribed in 1970 amounted to a sizable share of a year's salary over a 40 year period compared to a person who heated their identical home with oil at retail prices. For the year 2005 in particular, when oil was 4 times as expensive as geothermal (which also happens to be the average ratio between the two energy sources over the 40 year period), the total savings of geothermal customers amounted to 341 million USD, which is 4.3% of total income from employment in that year.

In reality, the very small fraction of homes that are still heated by oil in Iceland get a subsidy from the Government that is intended as a measure towards equalizing energy prices. This subsidy is substantial, although it does not suffice to bring oil heating prices down to the level of geothermal district heating (Figure 3). As a result, the largest part of the price difference between geothermal and oil heating is covered by the Government, although the consumer does take part. In this case, geothermal heating is a boon to taxpayers.

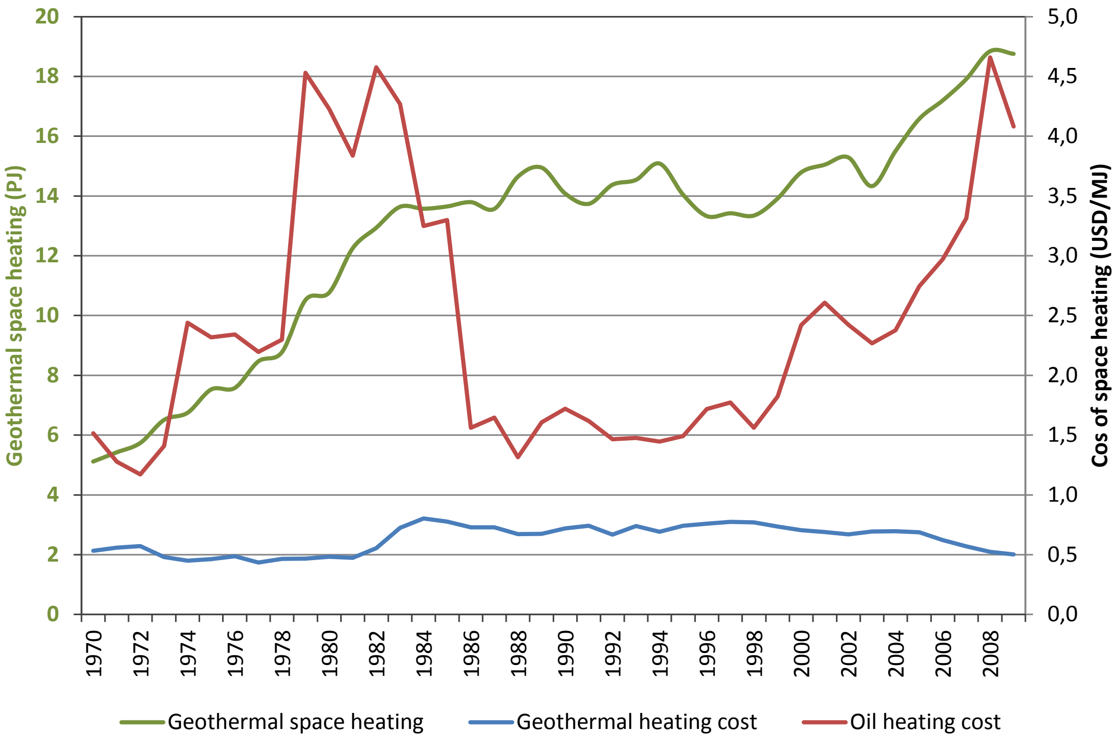

FIGURE 2: Geothermal utilization for space heating and real term energy prices (based on the annual average consumer price index and ISK/USD exchange rate in February 2014) in Iceland over the period 1970-2009 (modified from Haraldsson et al, 2010)

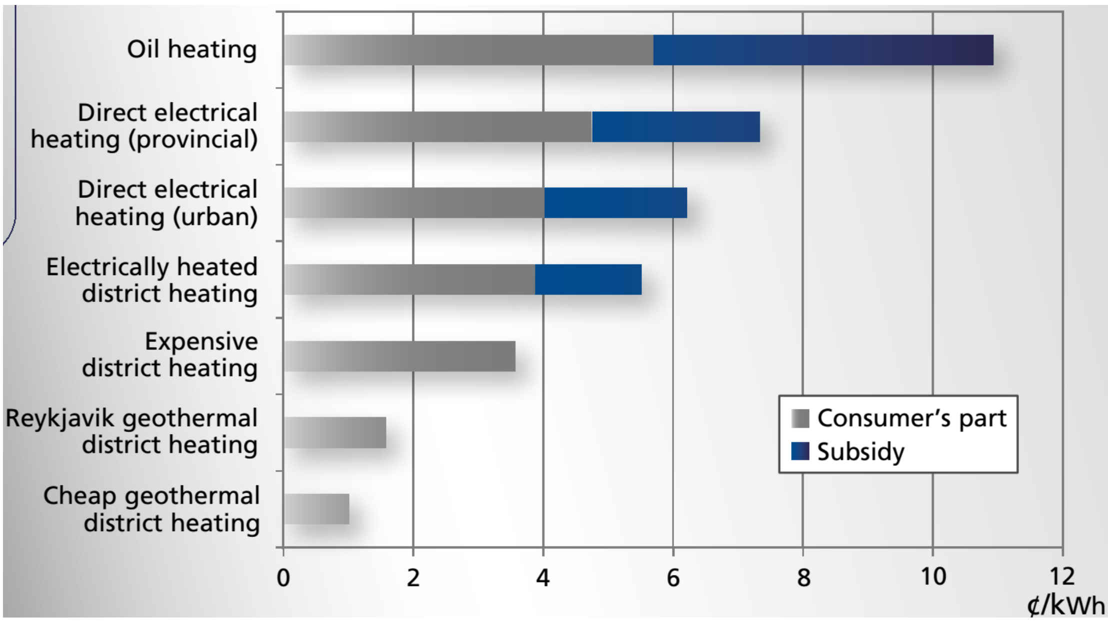

FIGURE 3: Comparison of energy prices for residential heating in Iceland in mid-2009 (Eggertsson et al., 2009)

It is worth noting in this comparison that consumer / State savings translate to foreign currency savings for the national economy at large, and it is sheltered from world market price fluctuations through the use of a stable domestic resource (Figure 2).

3. COMPARISON TO ELECTRICAL HEATING

If geothermal resources were not found in Iceland, but the country and climate would otherwise be the same, it must be seen as a more likely scenario that homes were heated by electricity generated by the country's bountiful hydropower resources than with imported oil. This is supported by Figure 3, which shows average prices for electrical district heating (water heated by electricity in central heating stations), as well as direct electrical heating for urban and rural areas. A conservative approach is taken for this scenario, and it is assumed that urban areas would be serviced with electrical district heating systems, whereas rural dwellers would heat their homes directly.

It is assumed that the heat delivery networks in urban areas would be similar to geothermal district heating networks and that infrastructure requirements would therefore be similar. Two years are selected for the comparison: 2005 is singled out as a year for which data on total income from employment are available and 2009 is selected as the last year reviewed in NEA's report from 2010, mentioned in the previous section. Table 1 summarizes the givens, assumptions and results.

TABLE 1: Comparison between geothermal and electrical heating costs in 2005 and 2009

Year	**2005**	**2009**
Population	293,577 (31 Dec 2005)[1]	317,593 (1 Dec 2009)[2]
Proportion in rural areas	0.061 (1 Jan 2004)[3]	0.055 (1 Jan 2009)[3]
Proportion in urban areas	0.939	0.945
Av. price of electrical district heating	4.6 ISK/kWh[4+]*	8.4 ISK/kWh[5]*
Consumer part	N/A	5.9 ISK/kWh[5]*
Subsidy	N/A	2.5 ISK/kWh[5]*
Av. price of rural direct el. heating	11.4 ISK/kWh[4]*	11.2 ISK/kWh[5]*
Consumer part	6.6 ISK/kWh[4]*	7.3 ISK/kWh[5]*
Subsidy	4.8 ISK/kWh[4]*	3.9 ISK/kWh[5]*
Replaced geothermal heating	16.58 PJ[6]	18.76 PJ[6]
Geothermal heating cost	$13.0 \cdot 10^9$ ISK[6]*	$10.8 \cdot 10^9$ ISK[6]*
Av. price of geothermal heating	2.82 ISK/kWh*	2.06 ISK/kWh*
Av. price of geothermal heating USD¢	2.47 USD¢/kWh*	1.81 USD¢/kWh*
Cost of equivalent electrical heating	$23.1 \cdot 10^9$ ISK*	$44.6 \cdot 10^9$ ISK*
Electrical district heating	$19.9 \cdot 10^9$ ISK*	$41.4 \cdot 10^9$ ISK*
Electrical rural direct	$3.2 \cdot 10^9$ ISK*	$3.2 \cdot 10^9$ ISK*
Total savings	$10.1 \cdot 10^9$ ISK*	$33.8 \cdot 10^9$ ISK*
Total savings USD	**$88.5 \cdot 10^6$ USD**	**$296.2 \cdot 10^6$ USD**

1: (Statistics Iceland, 2006); 2: (Statistics Iceland, 2009a) ;3: (Statistics Iceland, 2009b)
4: (Pálsson and Jónasson, 2005); 5: (Eggertsson et al., 2009); 6: (Haraldsson et al., 2010)
[+]: No distinction made for rural and urban prices
*: Corrected for inflation to Feb 2014

Some of the items in the table warrant discussion:

- *Population*: Although population figures are available for the end of both of the selected years, the division into the urban and rural compartments is not available for 2005. Instead ratios for 2004 are used as an approximation for 2005.
- *Average price of electrical district heating*: The values are obtained from graphs published in the annual publication of NEA, *Energy statistics in Iceland*, as shown in Figure 3. There is a

possibility of a slight visual error in the reading of the numbers. It should be kept in mind that prices vary between heating energy providers, and the published graphs are based on averages. There is a very significant increase in the reported price for electrical district heating between 2005 and 2009 (both values corrected for inflation to February 2014), which is not seen in the price of rural direct electrical heating. The reported price for 2005 is slightly lower than the reported price of "expensive" district heating in the same year, whereas the latter is a considerably better option than electrical district heating in 2009, as displayed in Figure 3. The reason for this change is unclear, but the value for 2005 is assumed to produce a conservative result in the comparison between geothermal and electrical heating.

- *Replaced geothermal heating*: This term refers to the geothermal heating consumption, including space heating and direct water use (bathing etc.), in the two years under examination, as reported by NEA in 2010.
- *Geothermal heating cost*: These costs are obtained from NEA's 2010 report, although values have been adjusted to correct for inflation to February 2014.
- *Cost of equivalent electrical heating*: It is assumed that all geothermal heating is replaced by electrical heating, distributed equally over the population. Consequently, costs are divided between electrical district heating systems and direct electrical heating systems in proportion to urban and rural residents.

The calculated savings in 2005 amount to 88.5 million USD, which is considered a conservative estimate. Although not as big a number as the 341 million USD in savings calculated for the oil scenario, it is still 1.1% of the total income from employment in 2005. The calculated savings for 2009 amount to 296 million USD. Table 2 summarizes these numbers along with savings calculated for Scenario 1.

TABLE 2: Calculated total consumer savings due the use of geothermal resources for space heating compared to heating with oil or electricity

	2005		**2009**
	Savings	Share of total employment income	Savings
S1: Geothermal vs. oil	$341\cdot10^6$ USD	4.3%	$671\cdot10^6$ USD
S2: Geothermal vs. electricity	$88.5\cdot10^6$ USD	1.1%	$296\cdot10^6$ USD

These results suggest that out of three energy sources that can be utilized for space heating in Iceland, geothermal is the most cost attractive option and is of high economic significance to consumers.

4. COMPARISON TO NEIGHBORING COUNTRIES

Due to its diffusive nature, there are economic limits to the geographic transport of heat. As a result, the utilization of geothermal resources for direct applications is quite localized, as demonstrated by the fact that the longest geothermal transmission pipeline in the world, found in Iceland, is 64 km in total (Georgsson et al., 2010). In contrast, electricity can be transmitted thousands of kilometers and oil can be shipped around the globe. In Europe, gas is a common source of heat that can be transported in pipelines over thousands of kilometers. Nevertheless, local resources are commonly used where possible, which results in substantial differences in the energy mix between countries. Figure 4 shows this variation for heating in the Nordic countries. It is evident that district heating systems are quite widespread in the region with the exception of Norway, where electricity covers 70-80% of heating demand, with the remainder primarily met by bioenergy (7%), oil (7%) and district heating (4%) (NVE, 2013).

These district heating systems rely on various fuels depending on local conditions and supply. An example is shown for Sweden in Figure 5.

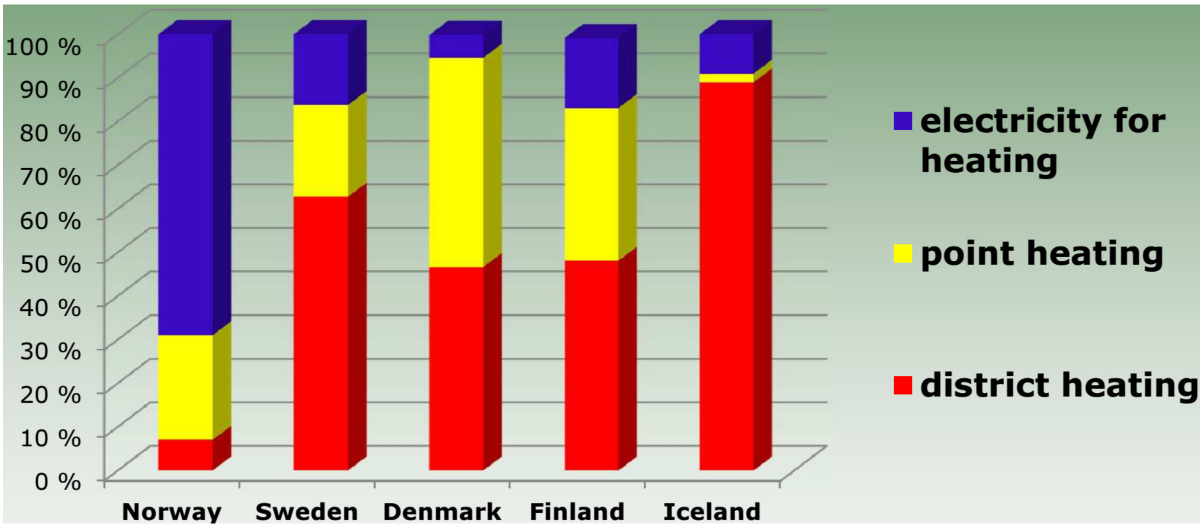

FIGURE 4: Heating in the Nordic countries by energy carrier and energy sources (Hohle, 2011)

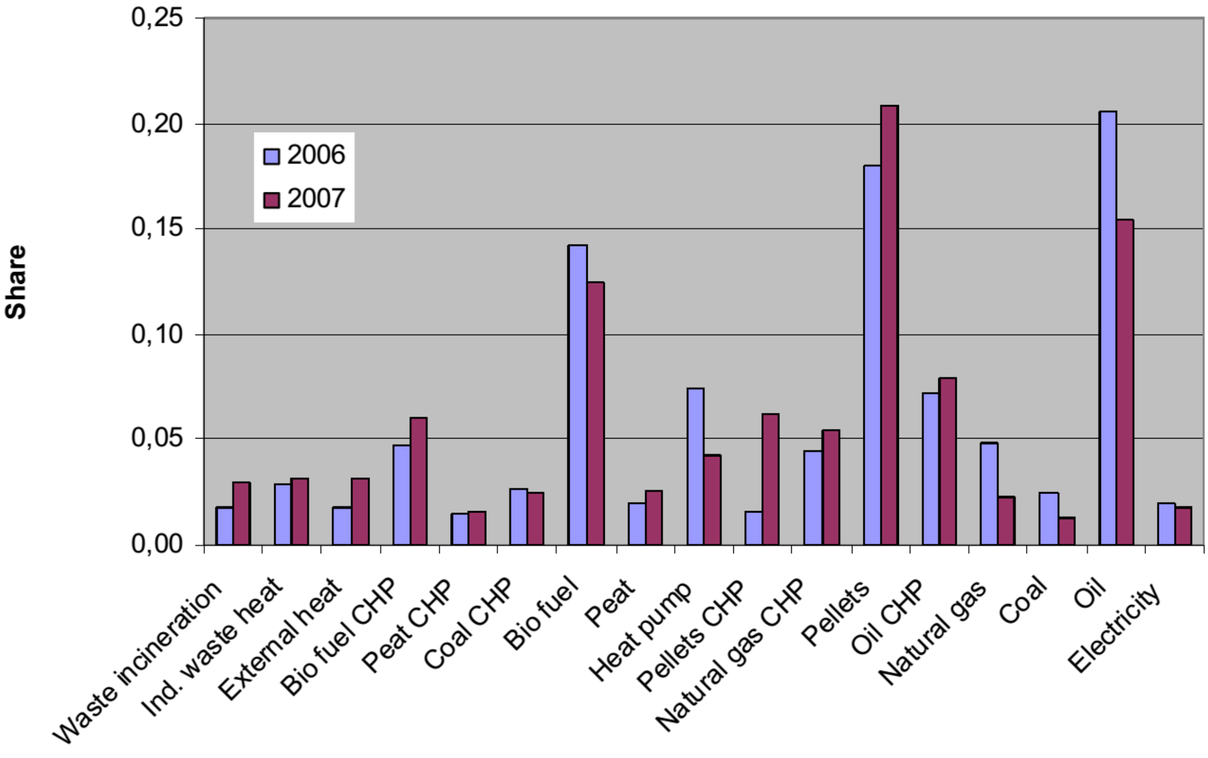

FIGURE 5: Energy source contributions to district heating systems in Sweden in 2006 and 2007 (NEP Research Group, 2009)

Although a considerable fraction of the energy supplied to district heating systems in Sweden derives from fossil fuels, this method of heat distribution offer the possibility of using local wastes, waste heat, biofuels, and environmental heat (including geothermal) along with electricity through the use of heat pumps. It can be assumed that the heat for district heating systems in Denmark, Finland and Norway, as well as other European countries, derives from varied sources also and this, along with policies and tax regulations in each country, affects the district heating price to the consumer. In this context, it is enlightening to compare average district heating prices in different European countries in 2009, based on a survey conducted by Euroheat & Power and shown in Table 3.

TABLE 3: Average district heating prices in Europe, the United States and Korea (Euroheat & Power, 2014)

Region	Country	Price (EUR/GJ)	Price (EUR¢/kWh)	Price (USD¢/kWh)
Nordics	Iceland	2.58	0.93	1.24
	Finland	12.8	4.6	6.2
	Sweden	16.55	5.96	7.97
	Norway	20.8	7.5	10.0
	Denmark	25.03	9.01	12.05
Europe (other)	Russia	4.48	1.61	2.16
	Croatia	8.95	3.22	4.31
	Poland	10.4	3.7	5.0
	Estonia	12.25	4.41	5.90
	Slovenia	12.44	4.48	5.99
	Latvia	13.89	5.00	6.69
	Romania	14.04	5.05	6.76
	Austria	15.96	5.75	7.68
	France	16.61	5.98	7.99
	Czech Republic	17.1	6.2	8.2
	Lithuania	17.6	6.3	8.5
	Slovakia	18.08	6.51	8.70
	Germany	19.55	7.04	9.41
America	United States	8.64	3.11	4.16
Asia	Korea	12.14	4.37	5.84

Although comparable data are available for 2011, 2009 is chosen in line with the previous scenarios. The price of 1.24 USD¢/kWh for Iceland errs only 9.5% from the 1.37 USD¢/kWh obtained from the data published in NEA's 2010 report, which suggests that the values in Table 3 can be accepted with reasonable confidence. It is worth noting that the 1.37 USD¢/kWh value is calculated directly from sales figures from Icelandic geothermal district heating companies and the estimated heat usage for buildings, using the average exchange rate for 2009 from the Central Bank of Iceland to convert the price to US dollars, whereas in Table 2 the price is given in 2014 dollars, arrived at by first correcting for inflation in Iceland to February 2014 and then converting to US dollars using the average exchange rate for that month as reported by the Central Bank.

Out of all countries surveyed by Euroheat & Power, Iceland has the lowest district heating price of 1.24 USD¢/kWh compared with an arithmetic mean value of 6.74 USD¢/kWh, a standard deviation of 2.60 USD¢/kWh, and a maximum value of 12.05 USD¢/kWh. The great variation in prices within the Nordic countries, which all have cold climates and therefore a considerable need for heating, is of particular interest. Out of the 20 surveyed countries, the highest price is encountered in Denmark and the second highest in Norway, whereas Sweden has the 8th highest price and Finland lies slightly below the average. It is probable that the reasons are not only economic, but also political. In general, taxes tend to be high in the Nordic countries and countries with limited domestic energy options, such as Denmark, may want to keep energy prices high in order to promote efficiency and limit consumption. Furthermore, environmental considerations may contribute to high prices. The fortune of Icelandic consumers is therefore the abundance of low-value, environmentally benign geothermal heat that translates to the lowest average district heating price on record in Europe and the wider world.

In the United Kingdom, one of Iceland's neighboring countries, the main source of energy for heating is gas (Association for the Conservation of Energy, 2013). In 2009, the average gas price in the UK was 11.84 EUR/GJ, including all taxes and levies (Eurostat, 2014). Assuming 80% efficiency (Association for the Conservation of Energy, 2013), brings the price up to 14.80 EUR per GJ of usable heat. This translates to 5.33 EUR¢/kWh, or 7.12 USD¢/kWh, which is slightly above the average price for district heating in Europe, and substantially higher than the price in Iceland.

From these comparisons, it is evident that Icelandic geothermal district heating prices are very competitive. However, it is important to be aware of differences in climatic conditions between countries that lead to differences in the length of the heating season. Shorter heating seasons may lead to higher unit prices, as district heating companies must cover incurred costs based on sales over a limited time period each year. Other factors that influence heat demand, and thus consumers' wallets, include:

- *Ambient temperature*: The heat flow through a building wall is directly related to the temperature difference over the wall, indicating that year-to-year fluctuations in ambient temperature affect heat demand as was clearly observed in Norway in 2010 (NVE, 2013).
- *Indoor temperature*, which is influenced by personal comfort choices, habits, prices and other factors, and can therefore vary over the population of a country. It is possible that averages are slightly different between countries.
- *Insulation and airtightness of buildings*, which may vary between countries.
- *Ventilation* preferences of home owners.

5. CONCLUSION

Despite hypothetical arguments, imprecision in data, and a rough methodology, the comparisons presented show that the utilization of geothermal resources for space heating in Iceland is of substantial economic benefit to Icelandic consumers.

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