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Public perception of geothermal energy at the local level in the UK

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ABSTRACT

Successful development of a new renewable energy technology does not only rely on the success of pilot projects but also to a significant extent on the development of an adequate public engagement strategy. To be able to develop such a strategy a good understanding is required of the public perception of the new technology. Geothermal energy is still an emerging technology in the UK; in the absence of public debate on this topic, media reporting provides a suitable proxy for its public perception. Therefore, this study has gauged the public perception of geothermal energy in the UK by evaluating local news articles from 1980 to 2018. A coding scheme was developed to derive the main themes and to identify both the perceived advantages and hurdles for geothermal development. We focussed on local newspapers to be able to compare public perception in different regions in the UK. Results show a mainly positive perception of geothermal energy in all geographical regions across the UK. Only few articles mention risks, induced seismicity and environmental pollution. In contrast, advantages and positive aspects of geothermal energy, such as its carbon neutral footprint, the enormous amount of available geothermal heat and the potential contribution of geothermal development to the revival of local economies, are much more frequently mentioned. Perceived hurdles that are mostly described in the articles are: (1) the absence of geothermal legislation and subsidies in the UK; (2) the lack of available funding; and finally (3) technological and geological challenges or uncertainties. Finally, we show that geothermal energy is most often related to electricity generation and granite resources, while the only successful deep geothermal site in the UK is a direct-use heating scheme exploiting a sedimentary aquifer.

1. INTRODUCTION

Despite being at the forefront of EGS development and the realisation of an operative direct-use system in Southampton in the 1980s, geothermal development in the UK stagnated in the following decades (Gluyas et al., 2018). After three unsuccessful exploration wells in northeast England between 2004 to 2011, a new wave of new geothermal exploration recently commenced in 2018. In this year, drilling started for a deep doublet at the United Downs site near Redruth, Cornwall (GEL, 2019), a Deep Geothermal Single Well in Penzance, Cornwall (Collins and Law, 2014), and a mine water district heating project in Glasgow. The first pilot projects were initiated in the 1980s. Only one of those, located the Southampton, was turned into an operational site providing heat to a small district heating network. An overview of British geothermal exploration wells is presented in Table 1. Between the 1980s and 2018, geothermal exploration mainly took place through feasibility studies focussing on various types of resources all over the country from granites in Scotland (e.g. Mccay and Younger, 2017) to Hot Sedimentary Aquifers in several regions in the UK (Busby, 2014; Comerford et al., 2018; Harber and Gilies, 2013). In addition, repurposing of suspended hydrocarbon infrastructure (e.g. Watson et al., 2019) was considered, as well as the use of single well heat exchangers (Collins and Law, 2014; Westaway, 2018a). The technical success of such projects and communication of outcome of feasibility studies are crucial for the revival of geothermal development in the UK. However, the debate on UK shale gas showed that not only technical potential plays a key role in the early phase of the development of new types of energy resources; public perception proved to also be an essential factor. Therefore, public engagement strategies have to be carefully designed, based on an adequate understanding of the public perception of each technology. How the public perceives a technology is influenced by a large number of factors, including technical features, the purpose of the technology, the location of infrastructures, risks and benefits, socio-demographic factors, cultural factors as well as media discourse (Carr-Cornish and Romanach, 2014; Chavot et al., 2018; Nisbet et al., 2002). So far, however, geo-energy related public perception studies in the UK have been very limited (e.g. Stewart and Lewis, 2017), and mainly focus on shale gas and CO_2 sequestration (e.g. Whitmarsh et al., 2015, 2019). In general, world-wide public perception studies of geothermal are limited. One reason for this is that geothermal energy is still in an early development phase, that there are few projects and hence the public has very little information and experience with the technology. Few examples of studies come from France (e.g. Chavot et al., 2018), Switzerland (Stauffacher et al., 2015; Wüstenhagen et al., 2007), Germany (Wallquist and Holenstein, 2012) and Australia (Carr-Cornish and Romanach, 2014). The reason for the interest in geothermal public perceptions in these regions is most likely related to their longer history with geothermal exploitation and also because of the negative media attention it received after induced seismicity events creating significant hurdles for geothermal development (e.g. Stauffacher et al., 2015; Trutnevyte and Ejderyan, 2018).

Public perceptions of geothermal energy have been studied through surveys, focus group research or case studies (Carr-Cornish and Romanach, 2014; Chavot et al., 2018; Pellizzone et al., 2015). However, it is difficult to assess public perceptions in an early phase of the development of a technology: the public might not "perceive" the existence of the technology yet and therefore will not have developed any attitude towards it. Furthermore, results obtained in early surveys or experiments might not reflect public perception once the technology is deployed (Siegrist, 2010). Some studies have used media analyses to assess the public perception of (deep) geothermal energy in the absence of large-scale deployment (Romanach et al., 2015; Stauffacher et al., 2015). While media reporting does not reflect public perception, research has shown that it is indirectly linked to public perception in that the way it presents a technology is likely to trigger reactions (Nisbet et al., 2002).

Moreover, negative media attention on technological failures during pilot projects could create equally large hurdles for geothermal development by reducing the public support and funding for new projects. Therefore, close attention to media articles is also essential for the UK. As a first step to gauge the UK public perception of geothermal energy we used a media analysis focussing on local newspapers. With this focus we aim to evaluate if geothermal interest is region specific. Furthermore, we investigate how frequently geothermal energy is discussed in the local news, and which themes are present in this discourse. In addition, we explore whether geothermal energy is more often related to electricity production, heat production or heating and cooling, and which types of resources are most frequently mentioned. We therefore aim to provide one of the first steps towards understanding the British public perception of geothermal energy, as a basis for development of adequate public engagement strategies for the emerging UK geothermal industry.

Table 1: Overview of British geothermal exploration drillings, updated after Gluyas et al. (2018).

Year	Pilot project
1980	Marchwood, Hampshire
1981	Rosemanowes RH11, Penryn, Cornwall
1981	Rosemanowes RH12, Penryn, Cornwall
1981	Larne, Northern Ireland:
1981	Southampton, Hampshire
1984	Cleethorpes, Lincolnshire
1985	Rosemanowes RH15, Penryn, Cornwall
2004	Eastgate 1, County Durham
2010	Eastgate 2, County Durham
2011	Science Central (Newcastle Helix), Newcastle upon Tyne
2018	Jubilee Pool, Penzance, Cornwall, DGSW
2018	HALO, Kilmarnock, Scotland, DGSW (proposed)
2018	United Downs 1, Redruth, Cornwall, EGS production well
2019	United Downs 2, Redruth, Cornwall, EGS injection well
2019	UKGEOS, Glasgow

2. METHOD

The media analysis in this study has covered shallow to deep geothermal resources used for electricity generation, heating, cooling and storing energy. The focus was on local newspapers in the UK. Articles were searched from the Nexis database using a combination of the keywords "geothermal energy" and "geothermal heat", and the condition of three or more occurrences per article. The initial batch of articles was screened to filter out duplicates, as several local newspapers may be owned by a single company and the same articles are published in each. The length of the articles ranges from a single paragraph to many paragraphs. The time period for the analysis was 1980 to 2013; this period was chosen because in the early 1980's several exploration wells were drilled across the UK (Gluyas et al., 2018; Table 1). However, no articles on geothermal energy from before 2001 were found in the database. For time from 2001 onward, we found 137 articles from 11 regions in the UK and Ireland and 35 different local newspapers (figure 1). The majority of these articles were published in the Southwest England region, where two exploration wells were drilled in the 1980's and two new pilot projects were developed in 2018. Local newspapers in Scotland published the second most articles on geothermal energy. This could also be explained by the numerous exploration and feasibility studies in this region, as well as two proposed pilot projects in Kilmarnock (now cancelled) and the UKGEOS site in Glasgow that is being developed at the time of this writing. Surprisingly few articles in our collection originate from Northeast England, where three exploration wells were drilled between 2004 and 2011. Also, very few articles originate from Southeast England where the Southampton project has been the only active geothermal district heating scheme for decades. Our article collection was derived from only one database. Because of the limited reach of local news journals, their large variety, we are not sure about the comprehensiveness of the database. Our collection might only cover a fraction of the articles that were actually published.

2.1 Coding

The articles were analysed using thematic coding. A coding scheme was developed to classify sentences and paragraphs into major themes and sub-themes. The importance of these themes was derived from the relative frequency of references to the individual themes and sub-themes. The scheme was developed iteratively, initially following the approach of Morrone et al. (2012) and Xu, (2018). After a first screening round, four main themes were identified: Economy, Environment, Project Finance, and Technology. References to energy security, job generation, or future energy demand are classified as Economy sub-themes. If references relate to costs or profitability of specific projects, they were related to the Finance theme. References to pollution, climate change and renewable energy are classified as Environmental sub-themes. Statements about the capacity of a geothermal project, explanations of the technical concept of exploiting a geothermal resource, description of risks, advantages or challenges for geothermal were all considered as Technology related references. An overview of this scheme is listed in Table 2, including examples of categorised sentences. In addition to the themes, we identified and counted references to UK pilot projects or feasibility studies as well as references to examples from abroad. Finally, we evaluated the frequency of references to different types of resources, e.g. granites, disused mines, Deep Geothermal Single Well heat exchangers (DGSW), Ground Source Heat Pumps (GSHP), and Hot Sedimentary Aquifers (HSA), and the frequency of references to different applications of geothermal energy, such as electricity generation, heating and cooling.

Region	Local News Journals
Scotland	Aberdeen Press and Journal
	Aberdeen Evening Express
	The Herald (Glasgow)
	Haymarket
	Scotsman
	Donside Piper & Herald
	Paisley Daily Express
	Scottish Daily Mail
Southwest	Western Morning News (Plymouth)
	Western Daily Press
	Evening Herald (Plymouth)
	West Briton
	Cornish Guardian
	Falmouth Packet
	The Cornishman
	Bournemouth Echo
West Midlands	The Stoke Sentinel
	Worcester News
	Coventry Evening Telegraph (England)
Northwest	Leyland Guardian
	Crewe Guardian
Northeast	The Journal (Newcastle, UK)
	The Northern Echo
Yorkshire	The Huddersfield Daily Examiner
East Midlands	Grimsby Telegraph
	Nottingham Evening Post
	Lincolnshire Echo
East	North Norfolk News
	East Kent Mercury
Southeast	Oxford Mail
Northern Ireland/Irish Republic	Belfast Telegraph
	Irish Examiner
	Ballymena Times
	Belfast News
Greater London	London Lite

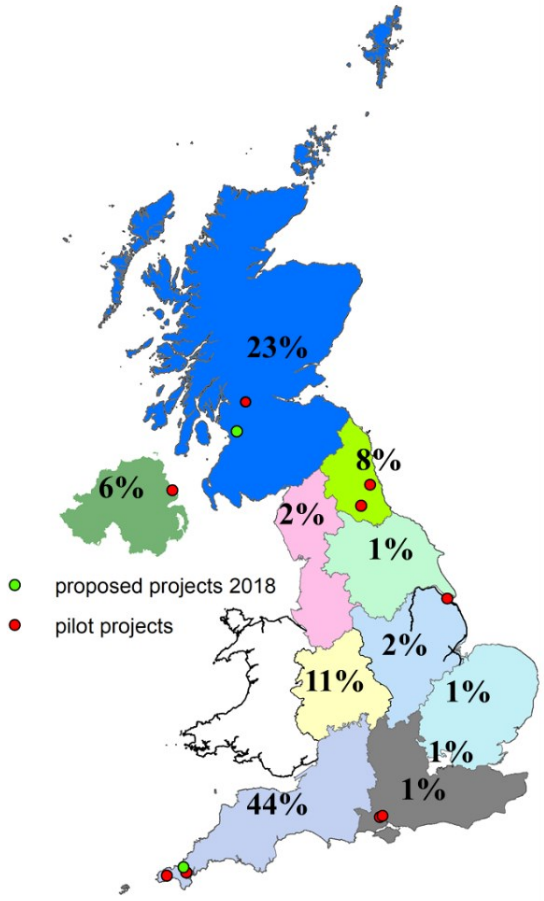

Figure 1: Overview of the journals and associated regions and where most of publications in our collection originated.

Table 2: Overview of themes, sub-themes and examples of references to these themes.

Theme	Sub-theme	Examples
Economy		
	UK energy independence	"Second, for our energy security - this energy is under our feet here in Britain, so we don't have to rely on other countries for it". Western Morning News, 15 May 2009.
	Future low-carbon energy mix	"Mr Law added: "Geothermal energy is a renewable, green and economical power source we must develop to meet the energy needs of the future." The West Briton, 29 October 2009.
	local economy stimulation	"There is significant potential for geothermal energy to encourage investment into the region and re-empower the local community." The West Briton, 4 February 2010.
Environment		
	Landscape or air pollution	"In the long term it certainly seems a good way of providing heat, obviously at no cost to the environment." Aberdeen Press and Journal, 7 July 2015.
	Sustainability/CO_2 reduction/ climate change	"The study explores how natural heat from the Earth could be used to meet demand more sustainably across the county especially for growers." Worcester News, 7 February 2017.
Finance		
	Financial advantages	"In Germany the geothermal industry is worth in excess of 4 billion and more than 150 geothermal projects are in development." Irish Examiner, 24 September 2010.
	Funding allocation	"Keele University has landed a £500,000 grant to help further plans to generate its own power." The Stoke Sentinel, 28 December 2010.
	Financial disadvantages/ need for legislation	- "The legislative and planning permission framework needs to be adapted effectively. So there are huge obstacles to overcome." The Herald (Glasgow), 17 March 2015. - A recent report for the UK Government by Atkins said heat wells - typically several miles down - are too deep to be exploited commercially. Aberdeen Evening Express, 16 November 2013.
	Development costs	"Mr Hanly said the estimated construction cost of the facility is 30m:". Irish Examiner, 24 September 2010.
Technology		
	Concept	"In very basic terms we are talking about pumping hot water, turning that into steam and using it to heat anything." Grimsby Telegraph, 16 December 2010
	Capacity	"If the test site proves a success, a power plant could be operational by 2020, and could produce enough electricity to fully supply up to 1,500 homes." Cornish Guardian, 21 December 2017.
	Technological/geological challenges	"But it is a difficult and expensive process, and today's mechanical drilling technology has limitations, despite considerable advances in recent years in the context of oil & gas resource exploitation." Aberdeen Press and Journal, 1 August 2016
	Advantages of geothermal vs other renewables	"The great thing about geothermal is it's not intermittent. It's constant energy that goes on going." Evening Herald (Plymouth), 26 October 2009.
	Fracking	"One of the benefits of the proposed system is that it does not require hydraulic fracturing or "fracking" to deliver which means that it is unlikely to cause earthquakes." Aberdeen Press and Journal, 28 March 2016.
	Risks	"Hazardous gases and minerals may also come up from underground." The Herald (Glasgow), 4 July 2011.
	Comparison of geothermal and hydrocarbons	"But it is a difficult and expensive process, and today's mechanical drilling technology has limitations, despite considerable advances in recent years in the context of oil & gas resource exploitation." Aberdeen Press and Journal, 1 August 2016.

3. RESULTS

3.1 frequency and origin of the local news articles

The majority of the 137 articles in our collection were published between 2007 and 2018 (Figure 2). A possible explanation is that interest in renewable energy increased only in the past decade. In addition, digitalisation of local news articles might have been limited between 1980 to 2000, reducing the number of articles that we retrieved from the database from this period. Some ten to twenty articles were published per year covering geothermal energy between 2010 and 2018, with a peak in media attention in 2011. This indicates that there is no apparent relation between the frequency of geothermal publications and the timing of realisation of pilot projects. Most likely this is because many articles cover feasibility studies instead of only pilot projects.

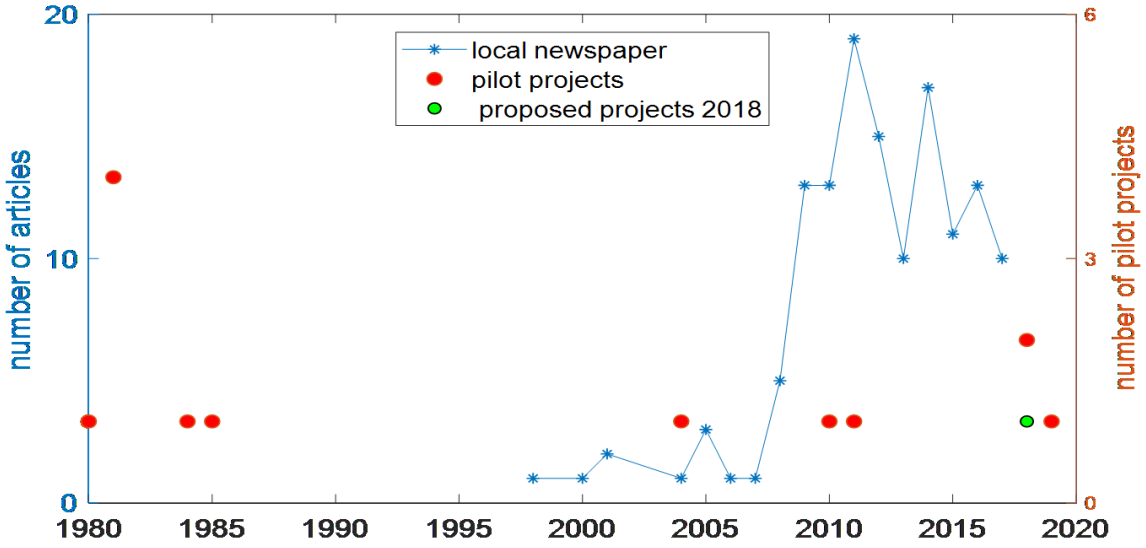

Figure 2: Frequency of publications on geothermal energy over time related to the realisation of the pilot projects in Table 1

3.2 Geographical regions to which geothermal energy is associated

Almost 40% of the articles mention geothermal activity outside of the UK, often as part of an explanation of what geothermal is (Figure 3-A). The USA, Germany and Iceland are amongst the most frequently mentioned countries. This highlights that geothermal energy is often associated to other countries and considered as a new feature for the UK by local journalists in the UK. Some seventy percent of the articles have references to projects within the UK (Figure 3-A). Most of these references relate to a pilot project or feasibility studies in the Southwest, such as the Rosemanowes or United Downs projects (Figure 3-B, Table 1). Pilot projects in the Northeast, Scotland, Northwest and West Midlands are referenced in some 10% of the articles.

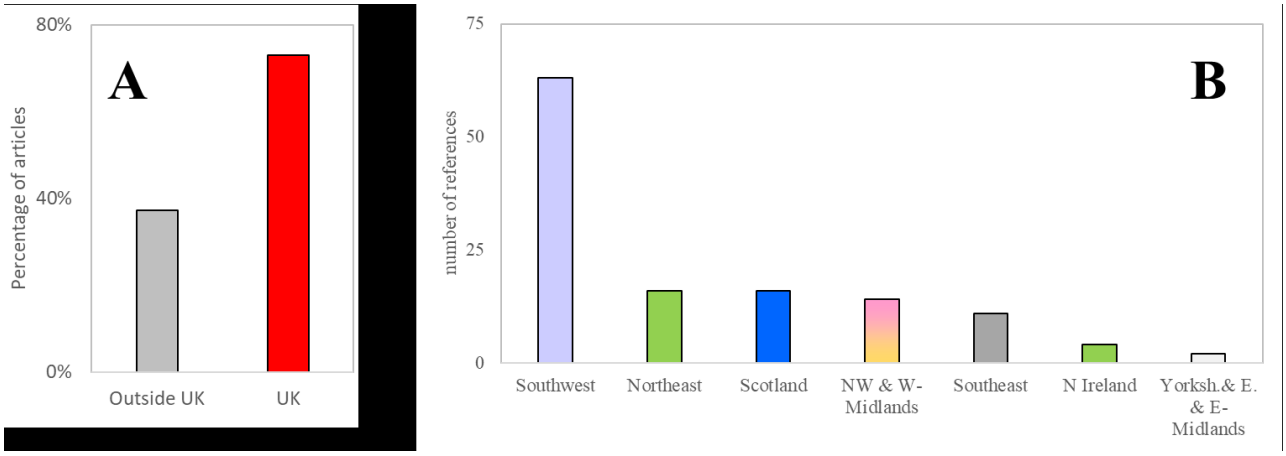

Figure 3 (A) percentage of the articles that have a reference to a UK feasibility study or pilot project, and or a reference to geothermal activity abroad. (B) overview of the references to the different regions in the UK, the Northwest (NW) and West Midlands are merged into one group is this figure as well as Yorkshire, the Southeast, East and East Midlands.

3.3 Themes

Technology is the most frequent occurring theme, 72% of the articles containing references to one or more of the Technology sub-themes (Table 4). In 50% of the articles the technological concept of producing geothermal heat is explained and in 42% of the articles the potential output of a geothermal system or the recoverable energy from a resource is mentioned. This indicates that authors think the audience is unfamiliar with the subject and therefore explanations are required of how geothermal exploitation works and what it could deliver. Technological advantages, such as the non-intermittent nature, and challenges, such as geological uncertainty, are both mentioned in 18% of the articles. Nevertheless, the overall tone of the articles is positive. This is derived from the limited recognition of references to risks and fracking, while advantages, such as revival of the local economy and reduction of UK dependence on fossil fuel imports, are more frequently mentioned. This suggests that the increased media attention after 2011 (Figure 2) is not or at most in-directly related to a series of earthquakes occurred in the Blackpool area following hydraulic fracturing operations (Green et al., 2012; Westaway 2016) and the resulting stirred-up public debate on shale gas safety in UK. Although these seismic events might have increased media attention for geo-energy subjects in general, the authors of the articles only rarely related shale gas induced seismicity to geothermal energy.

Geothermal is not only disassociated to fracking in the media, this is also the case for legislation. In the UK, following government acceptance of a proposal by Green et al. (2012), induced seismicity caused by 'fracking' for hydrocarbons is very tightly regulated, while, induced seismicity caused by hydraulic fracturing for other purposes, such as EGS development, is exempt from this regulation. it is covered in the UK only by default regulations affecting all forms of vibration nuisance caused by industrial activity; as Westaway and Younger (2013) have discussed, the regulations for this, expressed in terms of thresholds of peak ground velocity, probably equate to magnitudes of ≥3 for typical depths of injection. This apparent anomaly has been raised in the media, a notable article being that by Lyons (2019). In this, a representative of the shale gas industry is quoted as saying he was 'disappointed by the blatant double standards being applied to the shale gas industry with no scientific basis or credible research' and an environmental critic noting that 'you would assume, given the similarity of the processes, that there would be similar regulatory oversight for both'. This article also addressed the United Downs project, which involves development of a deep geothermal reservoir exploiting flow through a natural fracture in granite in Cornwall (GEL, 2019). It quoted a spokesman for this project denying that the development process for this project has any similarity with 'fracking' for shale gas, stating that 'the geothermal concept we are trialling in Cornwall relies on pre-existing natural fractures, not on creating new artificial fractures like the fracking process. The pressures, flow rates and volumes of any well treatments we carry out will be much lower than stimulations carried out in shale exploration. We will be circulating water, not complex chemical mixtures.' However, this latter statement is not fully accurate, since it is well known that if the natural permeability of the fracture being exploited at United Downs is insufficient to allow operation of the project with circulation at the required rate, the system will be engineered using 'chemical stimulation' to increase the permeability. For example, this planned activity has been reported in the programme of tasks for one European Commission funded Horizon 2020 research project (MEET, 2019). A recent inventory study by Buijze et al. (2019) has identified that induced seismicity associated with EGS activity is strongly associated with projects involving injection into granite. An extreme example is the Pohang earthquake (M_W 5.5) which occurred in association with an EGS project involving injection into granite, for which the effect of 'hydrochemical corrosion', or dissolution of the granite causing unclamping of the seismogenic fault, is the probable mechanism (Westaway and Burnside, 2019; Westaway et al., 2020). This project, intended as an example of hydraulic fracturing, can thus be regarded as an unintentional instance of chemical stimulation (Westaway et al., 2020). This newly-discovered explanation has been reported in a public forum (Westaway, 2018b), this being a productive way of facilitating public engagement with new scientific discoveries. It is hoped that the proposed chemical stimulation at United Downs will not result in another case study of significant induced seismicity. In the meantime, a member of the public has commented on the online version of the Lyons (2019) article in relation to the United Downs project 'just stop all fracking & anything like it at once. Dumb thing to be embarking on …'.

The perception of the financial competitiveness remains ambiguous because in 28% of the articles a statement is made that suggests financial competitiveness or financial gain of geothermal projects, while in 20% contrasting references are made to financial disadvantages such as higher associated costs, the need for subsidies or lack of investor interest (Table 4). The other financial sub-themes where more neutral: notifications of development costs or the allocation of a grant or funding for a feasibility study or pilot project.

References to environmental themes were present in 66% percent of the articles, highlighting that geothermal energy is generally discussed in relation to renewable energy, as a measure to combat climate change. The absence of references to this theme in 34% of the articles indicates that in a significant number of articles no references are made to environmental merits (or otherwise) of particular projects. A case in point is the HALO project in Kilmarnock, which has been publicised through many favourable articles in the Scottish media. However, analysis by Westaway (2018a) showed that this DGSW project could not achieve anything like the heat output that its proponents had claimed. The heat output feasible over any worthwhile lifespan was indeed found to be so low that this project represented an extremely poor investment of public funds. Around the same time as this analysis was published, a review of this project led to the DGSW element being dropped. This is thus an example where the public played no role in the abandonment of what was evidently an unsound project; the decision depended on expert assessments. The idea that some geothermal projects are unsustainable has nonetheless featured in other discussion intended as public engagement (e.g., Fontaine, 2015). However, this point has long been recognized within the geothermal industry (e.g., Rybach, 2003). Accompanying this is the recognition that geothermal developers have a professional obligation to design projects sustainably, and not to claim exaggerated outputs that will deplete any resource and damage its long-term potential (e.g., Ketilsson et al., 2010), as members of the public are not in a position to challenge the developers' calculations (as the HALO case study indeed demonstrated).

In 46% a statement is present that relates a new geothermal project to generation of jobs and cheap energy, stimulating the economy at a local level, which is clearly a major theme in the geothermal energy discourse in the UK. Often not only stimulation but also revival of economically deprived areas is mentioned. Slightly fewer articles relate geothermal energy to economic benefits at the

national level, for example relating it to reduction in fossil-fuel import dependency or indicating geothermal as one of the means to meet growing future (low-carbon) energy demands. Overall, the broad range of recurrence of all four themes indicates that no single specific theme or sub-theme is dominant in the media discourse. Authors tend to describe a broad range of aspects, aiming to inform the audience about this new technology.

Table 3: frequency of references to themes and sub-themes.

Theme	Sub-theme	Present in % of articles
Technology		72%
	Concept	50%
	Capacity	42%
	Technological/geological challenges	18%
	Advantages of geothermal vs other renewables	18%
	Fracking	7%
	Risks	6%
	Comparison of geothermal and hydrocarbons	5%
Environment		66%
	Sustainability/CO_2 reduction/climate change	64%
	Landscape or air pollution	23%
Finance		62%
	Financially advantage	28%
	Funding allocation	22%
	Financially disadvantage	20%
	Development costs	19%
Economy		61%
	Local economy stimulation	46%
	Future low-carbon energy mix	22%
	UK energy independence	17%

Geothermal energy is related to electricity generation in 49% of the articles (Table 4). Slightly fewer references are made to geothermal heat production, either in combination with electricity generation or as stand-alone direct use. Only 4% of the articles relate geothermal energy to cooling. Specific extraction methods, such as Ground Source Heat Pumps, Deep Geothermal Single Well heat exchangers or doublets are rarely specifically mentioned. The most frequently mentioned type of resource is granites, even though successful exploitation of this type of resource has not been demonstrated yet in the UK. Very few articles mention disused mines as geothermal resources. All these observations casts doubt as to whether the public understands the different forms of technology and geology, the readiness levels of different exploitation types and their applicability to particular types geological resources.

Table 4: frequency of references to different exploitation methods, resource types and applications.

Application	Present in % of articles
Electricity production	49%
Heat production	41%
Cooling	4%
Extraction scheme/method	
GSHP	10%
DGSW	7%
Doublet	1%
Resource type	
Disused Mines	7%
Granite	31%
Sedimentary aquifer	3%

4. CONLCUSION

Our analysis shows geothermal energy is a new subject to the UK public. This is derived from the frequent referencing to geothermal projects abroad, the frequent explanation of the technological concept of extracting geothermal heat and the broad range of subjects that are discussed. No specific aspect or status of the industry is discussed at the local level. The tone of the articles is predominantly positive, with frequent references to the potential capacity of geothermal projects, CO_2 reduction, and potential stimulation of the local economy, and few references to risks and fracking. The authors mainly relate geothermal energy to electricity generation. This is surprising because so far only one heat production project and several shallow heating and cooling applications have been active, while no pilot project for geothermal electricity generation has so far proved to be successful.

These results have several implications for practice and project development with regard to public engagement strategies. First of all, there is a clear association of geothermal energy to other renewable energies as well as to CO2 reduction. Such topics are currently positively connotated and should be used as a basis to communicate about geothermal energy projects. Furthermore, the purpose of geothermal energy projects to be carried out in the UK should be explained carefully. While the media often reports about geothermal energy abroad and talks about electricity generation, many local projects will likely be focused on heat. Therefore, unrealistic (positive) expectations should also be managed. Finally, although is not a salient topic at the moment, it should not be neglected in public engagement strategies, as information about potential risk is present in the media and might be picked up by the public.

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