Geothermal Urbanism

Making the elemental explicit in Reykjavík

DPhil Geography & The Environment

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Abstract

This research explores the distinct places shaped by human processes and proximity to geothermal heat. It underlines the concept of elementality as critical for understanding energy, the urban, and everyday life. Advancing from the rematerialistion of geography it draws upon approaches to other geo urban phenomena through relational and more-than-human terms. This has emphasised networked, assembled, and processual understandings; through which a distributed agency concerning the human and non-human alike has been utilised to foreground a geologic vitality. With a focus on Reykjavík in Southwest Iceland, attention is turned to the sites of infrastructures, architectures, and human bodies. It examines the distinct materialities of Reykjavík's geothermal urban environ; their relational properties, elemental capacities, and the palpable affective sense of place that arises as the geothermal is articulated through the urban form. It engages a more-than-representational methodology: utilising video, photography, and interviews with Reykjavík's inhabitants. Field materials provide a detailed illustration of the city's emergent geothermal urban lifeworld. As 'surfacing', geothermal urbanism is revealed as a *geo*sociotechnical process. As 'atmospheric', it is experienced as gathered, elementally infused, and palpable. As 'affective', the geothermal urban is understood as embroiled with an embodied geothermal elementality, tracking the processual and the atmospheric. These findings culminate in a necessary revision of the geothermal field from an exclusively chthonic entity; extended beyond the subterranean into the urban, and understood as atmospheric and affective. Additionally, a discrete geothermal form of geopower is identified. This advances a non-carbon geologic agency, intersecting the geological and the affective. Geothermal urbanism is established as requiring a geosociotechnical ontology, an elemental epistemology, and characterised by distinct practices of embodied dwelling.

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Abbreviations

ÍSOR
Íslenskar Orkurannsóknir [Icelandic Geo-survey]
A state owned, non-profit, self-financing organisation focused on geothermal exploration, development and utilisation.

OR
Orkuveita Reykjavíkur [Reykjavík Energy]
The publically owned Icelandic energy and utility company that provides geothermal water/steam for heating and electricity production.

ON
Orka Náttúrnnar [Power of Nature]
The sales arm of Orkuveita Reykjavíkur.

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My **fellow OUCE/SoGE DPhils**: we share in each others' successes.

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1 | Introduction

"Ingólfur fór um vorið ofan um heiði; hann tók sér bústað þar sem öndvegissúlur hans höfðu á land komið; hann bjó í Reykjarvík"

"Ingólfur travelled in spring across the moor; he made his home where his pillars had come ashore; he lived in the smoky bay"
Landnámabók, C13th[1]

.

This thesis is about elemental forces, and how they are articulated via urban spaces and the practices of everyday life. It considers explicitly the geothermal urban and geothermal urbanism as the places and practices, respectively and interchangeably, of geothermal urban relations. 'Thermal' simply means relating to heat (coming from the Greek for heat: *θέρμη, thermē'*), whilst geo prefixes as of-the-Earth (from the Latin: *geo*, and Greek: *γεω*), the 'geothermal' explicitly meaning 'heat from the Earth'. It explores, through the lens of Iceland, how the geothermal urban forms and might be understood; how it resonates within infrastructures, architectures, and bodies; and foregrounds an otherwise ubiquitous background elementality. It develops from wider interests in more-than-human geographies, and speaks back to the broader body of work that concerns urban theory and the complexities of nature, energy, materiality, and everyday human lives.

1.1 | The geothermal city

In the old-town area of Iceland's capital city, Reykjavík, there is a public space called Ingólfstorg (Fig. 1.1.). Ingólfstorg is, at first glance, a relatively typical modern town square. Its central area is a recently paved expanse where people meet, pass through, and occasionally public events are held. It is surrounded by roads on all sides and has, at its edges, a mixture of shops, food outlets, and hotels. Some of these buildings are of a routine modern design, whilst others maintain the older style of Icelandic wooden buildings. The more traditional architecture gives the square a sense of Nordic, if

[1] The *Landnámabók* is the written account of settlement of Iceland, of which surviving versions date to circa the mid-13th century, having thought to have been originally written in the 12th century. The book forms part of the wider Settlement Sagas which recount Icelandic history back to 874CE.

not decisively Icelandic, place. Familiar well-maintained amenities, like street lighting, telecommunications cables, and signage, embed the square within the realm of homogenous urban modernity. Yet, there is something undeniably unique about Ingólfstorg. Something, mostly under the surface but at times also in plain sight, which makes the square especially interesting.



Fig. 1.1. *Even during a summer's day, steam can still be seen emerging from Ingólfstorg's basalt columns, as everyday urban life unfolds.*

Ingólfstorg is named after Ingólfur Arnarson, understood through the Icelandic Sagas to be the first Norse settler of Iceland and founder of Reykjavík, or to translate into English, "The Smoky Bay". This smoke, or steam as it can also be translated, is a direct reference to the geothermal energy which is just underfoot and surfaces at Reykjavík and across Iceland. The Sagas tell of how Ingólfur threw wooden pillars into the sea when his boat first arrived at Iceland and swore to settle where they washed-up. They were eventually sighted in the smoky, steamy, bay where Reykjavík was founded. In reference to this, in the south-eastern corner of Ingólfstorg, there is a curious piece of modern art which anchors and animates the square. Two hexagonal basalt columns, formed of the cooled lava that dominates Iceland's landscape, sit upright with geothermally heated steam occasionally released from attached valves. This piece of public art repositions and juxtaposes the volcanic landscape of

Iceland from aside to within the urban. The geological is enmeshed with the city and in doing so underlines a unique sense of geothermal urban place. Skateboarders fly through the square whilst geothermal heat, extracted from underfoot via pumps and pipes, drifts past them as steam. Daily life in Reykjavík has an undeniable chthonic, "[d]welling in or beneath the surface of the earth" (Oxford English Dictionary 2017), quality. Life on the surface is directly connected to subterranean energies emerging through rock and steam, sometimes immediate and often subtle. Ingólfstorg - Reykjavík - presents a distinct relationship between the human and the geothermal, providing a compelling locus with which to unpack geological-anthropological relations.

What happens when we think of specific cities rather than the concept of them? Chicago, Venice, Melbourne, Timbuktu, Moscow, Manaus? Each of these cities has distinct "urban" characteristics - humans, buildings, infrastructures; but each is also unique on account of non-human factors. Chicago is the "Windy City", Venice is the "Bride of the Sea", Melbourne is regarded for its lively laneways as a cool escape from the Australian sun, Timbuktu for the Saharan sand that covers its streets, Moscow for picturesque ice and snow in winter, and Manaus for the jungle which permeates its fabric. Each of these urban spaces, and they are identifiable as distinctly urban, possess shared characteristics but are also completely differential distinct phenomena. These characters, the distinct sense of, or spirit of (Norberg-Schulz 1980), place might lead us to think of each city as a different case of the "urban uncanny" (see: Huskinson 2016; Collins 2008; Kaika 2005, pp.51–78; Gandy 1999, pp.33–35). If "[t]he city is uncanny when it reveals itself in a new and unexpected light[,] when, for example, its familiar streets and buildings suddenly appear strange" (Huskinson 2016, p.2); in what ways might Reykjavík be unfolded as the geothermal urban uncanny?

Farías (2010, p.14) comments that "[u]nderstanding the city as a multiple object involves thus a major challenge for urban research: identifying, describing and analysing these multiple enactments of the city and understanding how they are articulated, concealed, exposed, and made present or absent". Reykjavík consists of multiple flows, as with many cities, of people, products, capital, water, power. Gandy (2014), assesses these sorts of flows in his work The Fabric of Space, with a valuable focus on water, "inextricably linked with the idea of infrastructure as a technical and organizational domain

that underpins the functional dynamics of urban space" (Ibid., p.2). Similarly, Kaika (2005, p.6) notes that as water flows "it undergoes changes in its physical, socio-political and cultural character". Reykjavík of course might also be understood through the context presented by Gandy (2014) and Kaika (2005), given that it too is a city surrounded by water-based infrastructures. With Reykjavík however, there is an additional dimension: the geothermal. The water which flows around Reykjavík is different to the water which flows around London, New York, Mumbai or Athens. This geothermal water is literally, chemically and molecularly different, but its flow is determined by a different and unique capacity, alternative infrastructures, and idiosyncratic politics. Clark (2012) begins to hint at better integrating thinking about the human and geophysical in a more unified manner, by briefly commenting on the mobilities of humans moving across the Earth's surface juxtaposed against the mobility of the crust itself through seismic activity. Christchurch in New Zealand is drawn out as one example, along with Naples in Italy. A complexity between the human and the nonhuman is sparked here, but ends all too soon, forming questions as to how might elemental mobilities, flows, be further thought about, especially in the context of Reykjavík and the geothermal urban.

Hubbard seeks out to "review some of the best known and most influential theoretical frameworks which have been employed for making sense of cities" (2006, p.11). In doing so, he travels: an emerging focus on the city following the global move towards urbanisation (modernity), the work at the beginning of the 19th century of the 'Chicago School' (human ecology, ethnography), Weberian and Marxist theory (capital, labour, commodification), and post-structuralism (feminism, holistic urban political ecologies, and relations). For Hubbard, this in itself is "a somewhat breathless tour" (Ibid., p.56), and while it is important to acknowledge the depth and history of existing thought on the urban, there is of course a necessity to focus-in, "tailored to answer specific questions" (Ibid.). Hecht (2012) for example, traces the distinctive qualities and capacities of uranium in turning to question different ways of 'being nuclear', Vannini & Taggart (2013b) to practices of solar energy in 'off-grid' living, and Edensor (2010) highlights how celestial phenomena, the aurora borealis, are caught up with the practice of tourism in Iceland.

Geographers have frequently attended to specific aspects of urban life relating to physical processes and energies. Examples include bodies of work on the electric city (Platt 1991), water in the city (Swyngedouw 2004; Gandy 2014), and aerography (Adey 2014; Engelmann 2015), amongst others[2]. Relational accounts of varying other geo-urban phenomena (for example Gandy 2002; Gabrys 2012; Gissen 2014; Starosielski 2015) allow for livelier, animated, interconnected, holistic and valuable understandings of unique places. By "concentrating instead on movement, on process, on the constant hum of the world as the different elements of it are brought into relation with one another, often in new styles and unconsidered combinations… attempting to rediscover the *richness* of the world" (Bingham & Thrift 2000, p.281), new understandings of how life on Earth is shaped by elemental forces come into focus. Recent thinking from Gandy (2017), in turning to air and light, has questioned elemental urban atmospheres, sitting aside work from Adey (2015), Squire (2016) and McCormack (2016). This emerging body of work has begun to open up questions relating to the affective and atmospheric aspects of the geo-urban, and combined with insights from Clark & Yusoff (2014; 2017), draws in the geologic. Examining heat and warmth in particular is valuable as such work "can yield interesting knowledge about the relation between culture, spatialities, technologies, and bodies" (Vannini & Taggart 2013a, p.62), that span different types of energy, varied contexts, and can open pathways for understanding other phenomena. Researching the geothermal urban, geothermal urbanism, contributes to the valuable discussion of relations between the elemental, energy, non-human agency, human processes, and the experience and formation of everyday life.

This work sits under, develops from, and speaks to a much broader body of study within geography that expands into anthropology, ethnography, science and technology studies, and the wider social sciences. The more expansive issues that frame this research are those which have contributed to and stemmed from urban theory such as the complexities of space and nature (Smith 1984; Hinchliffe 2007), materiality (Lees 2002; Thrift 2004b; Bennett 2010) and everyday human lives (Harvey 1996; A Amin & Thrift 2002). Specifically these concern the more-than-human (Whatmore 2006), which has refocused interest on the non-human, to address an excessive anthropocentrism that had taken a-hold within research and debate: "returning to the rich conjunction of the *bio* and the *geo*" which

[2] See Castells & Hall (1994) on "technopoles" and the technopolis.

"enjoins the technologies of life and ecology" (Ibid., p.602, *emphasis in original)*. By continuing to turn to non-human agency by further extending material concerns to a broader spectrum of phenomena, such research develops these more-than-human optics and further (re)orientates our understandings of everyday encounters. For the geothermal, this extends a re-regard for the geo on geological terms. "[G]eographers can make important future contributions to more-than-human geographies by sustaining the questions around…society/nature relations" (Panelli 2010, p.85), of which research into distinct phenomena such as the geothermal urban contributes.

Human social life is deeply connected to the non-human and collects and intensifies within urban settings. Urban contexts in particular have been a focus of the more-than-human, as the interaction between urban social life and the non-human enact and articulate a politics and ethics that has diverse implications (highlighted by the afore-mentioned studies in electricity, water, and air). Exploring these sites and intensities (which are multiple, shifting, yet-to-be-uncovered), continues to inform and develop our understandings of distinct phenomena and broader expansive concepts. Turning to the geothermal complicates understandings of the connections between society, technology, and nature, by questioning concepts such as hybridity (Swyngedouw 1999; Whatmore 2002), the cyborg (Haraway 1985; Gandy 2005) and sociotechnical (Graham & Marvin 2001) with geologic inflections. Human energy use is of specific interest as on one hand it is critical to sustaining human life, yet on the other, it threatens the sustainability of the entire planet through climate change (Elliott 2007; Bulkeley 2012; IEA 2014). In attending to the geothermal as a form of non-human phenomena which is non-organic and elemental on explicitly earthly terms, an alternative perspective can be brought to conversations that concern energy, resources, and geo-urban/geo-human relations and relationships. On these terms, the geothermal directly matters to urban theory and more-than-human concerns via a new materialist discourse; as it differs (origin, character, capacity) from previously featured subjects, and thus stands to question and develop existing knowledge within these fields. This research proceeds with the objective of critically pursuing everyday human life, tied to a provision of energy that is distinct on account of a non-carbon geologic ontology, with the potential to contrast existing geo-urban narratives.

1.2 | Reykjavík: 'The Smoky Bay'

Heat

The entire island of Iceland is explicitly geophysically dynamic, notably in its volcanic, tectonic and seismic activity. Iceland straddles the northern end of the Mid-Atlantic oceanic ridge (Fig.1.2), a significant tectonic plate boundary where the continents of Europe and North America are pulling apart over thousands of years at a rate of 2cm per year (Mawejje 2007, p.257). This constructive margin sees the Earth's mantle plume upwards, forming new land as the two tectonic plates move apart resulting in lava flows, earthquakes and geothermal heat rising to the surface (Gudmundsson & Jacoby 2007, p.1). In essence, it might be plainly put that: "[t]he existence of Iceland is believed to be due to its location on the mantle plume" (Mawejje 2007, p.257). This is an essential observation worth holding onto as the geothermal urban begins to focus, as will be outlined, the existence of Reykjavík in its modern form is directly connected to the accessible abundance of the geothermal.

"Geologically, Iceland is a young volcanic island, built up during the later part of the Cainozoic", note Denk *et al.* (2011, p.17). The Reykjanes ridge forms part of the Mid-Atlantic oceanic ridge within the south-west of Iceland, giving rise to the West Volcanic Zone. This area is the one most close to Reykjavík and responsible for the region's geothermal heat rising to the surface: "The inland part of the mid-ocean ridge is characterized by rift zones or volcanic zones with active faulting and volcanism extending from the southwest to the north" (Ibid.). Further, the dominant bedrock geology of this part of Iceland dates from 0.78 Ma to 11.5 Ka[3] years ago, "The volcanic rocks of this period are mostly interglacial basaltic lavas and subglacial pillow lavas and hyaloclastites" (Ibid. p.21). What this means, is that Iceland has a turbulent, 'lunar' or 'prehistoric' landscape wherein young lava has only been slightly eroded, maintaining a jagged, clumped and uneven appearance. The heat from magma escaping the ground resonates through the landscape via geothermal energy that still surfaces as steam from mud-pots, hot springs, and fumaroles; and is echoed in the visual, tactile qualities of cooled lava that dominates the ground. Crucially, this is not limited to areas which might be broadly

[3] Within Geology, the terms Ma (mega-annum) and ka (kilo-annum) are used to abbreviate a million and a thousand years respectively. So, 1 Ma is one million years and 1 ka is one thousand years.

defined as the 'countryside'. As urban spaces, specifically the Reykjavík Capital Area, have developed upon and within this active landscape.

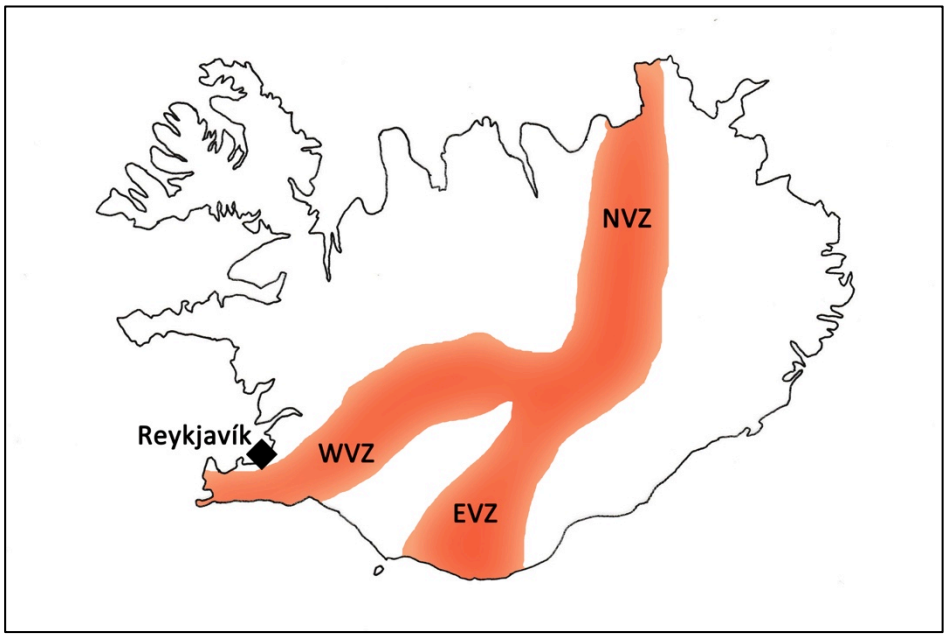

Fig. 1.2. *The approximate location of the Mid-Atlantic Ridge (orange) through Iceland, the North (NVZ), East (EVZ) and West (WVZ) volcanic zones and Reykjavík. Based on Einarsson (1991, p.262) and Ward et al. (1969, p.671)*

Reykjavík itself sits on top of geothermal fields, the two most notable being Laugarnes and Elliðaárdalur at the north and east of the city - "[t]he Reykjavík thermal fields are situated on the southern margin of the Kjalarnes central volcano´ (Tomásson et al. 1975, p.3). Reykjavík is truly a city surrounded by geothermal heat, "The Reykjavík thermal areas lie within or just outside the city boundaries, but the Reykir thermal area [is] some 15km NE of the city centre, and slightly closer to the active volcanic zone" (Ibid., p.6). Some of the geothermal heat comes to the surface via conduction through rock, however most of it surfaces via steam and water that rises with pressure: "The high surface thermal gradients inside the thermal areas are due to localised transport of water from the thermal systems at depth to the surface" (Ibid., p.7). Indeed, temperatures of up to 100°c are recorded within the city limits around Laugarnes and Elliðaárdalur (Björnsson et al. 2000, p.5). As well as Laugarnes and Elliðaárdalur, Reykjavík is situated close to two other key geothermal fields, both of which are utilised to provide hot water for the city. The first is Mosfellssveit, northeast of Reykjavík, which is split into the areas Reykir and Reykjahlíð. The other is Hengill, approximately

30km east of Reykjavík, and home to two geothermal plants, Nesjavellir and Hellisheiði. The Hengill geothermal field sits atop the Hengill volcanic system, where "[t]emperatures within the Hengill geothermal resource varies from about 200°C to about 320°C" (Franzson et al. 2010, p.1).

In contrast to the emergence of heat so idiosyncratic to Iceland, is a climatic element much more in keeping with the nations name. Iceland has a climate broadly identified as cool continental/subarctic and tundra (Einarsson 1984). Iceland's weather is, essentially, cold. During winter, snow and ice dominate the landscape as cold winter winds blow. Summers are mild and fresh, with temperatures rarely much into double digits (celsius). Add into this the country's latitude, and whilst there is more daylight in summer, it makes for dark long winters which add to the low temperatures. As such, everyday life has centred around keeping warm, and in Iceland this has included making extensive use of the geothermal heat underfoot. Iceland's surface climate is important to note as it is in such contrast with the vast amounts of thermal warmth underground. A chthonic link, embroiled in practices of keeping warm, begins to emerge.

Humans

In the introduction to 'Planning in Iceland: From the Settlement to Present Times', arguably the most comprehensive account of the unfolding urbanisation of Iceland, Trausti Valsson (2003) commences by overtly outlining the geophysical and human aspects of a thousand years of dwelling: "we will trace how the cohabiting of man and land evolved in Iceland" (Ibid. p.12). As Valsson's "intentionally broad" (Ibid. p.1.) text unfolds, he maps both the distinct geological features of Iceland (including - but not limited to - its geophysical, geomorphic, geothermal qualities) and the unique path of human settlers (attending to the role of developing culture and law, to modern ideas about urban planning and modern developments). Curiously, Valsson is quite direct in connecting human settlement with the non- or pre-human landscape, in a sub-section titled "Interplay of Planning and Natural Features". However, the section, and indeed the book, take a direction away from an explicit analysis of the distinct geothermal urban link. Valsson draws a connection between the geothermal and the urban as simultaneous and juxtaposed but holds back from questioning their relations.

It is well documented, mainly thanks to the written accounts of the afore-mentioned Icelandic Sagas, that the island of Iceland was inhabited approximately 1100 years ago, by Norse settlers (and their British slaves) in the 9th century. There is additional evidence of Irish monks that might have lived in Iceland before then ('Papar' documented in the key Sagas text, the Íslendingabók), however it is the Norse with whom significant prolonged settlement occurred. Human population levels have fluctuated, but the overall trend has been towards significantly increasing numbers, and with another notable aspect: increasing rates of urbanisation, and decreasing rural living especially since the 20th century (Sigurdur 1961). The current population of Iceland stands at approximately 330,000 (Calian & Harðarson 2016), and the Reykjavík Capital Area, in particular, "consists of seven municipalities with approximately 200,000 inhabitants, comprising two-thirds of the Icelandic population" (Visitrekjavik.is 2013). Valsson (2003) summarises in detail how the population of Iceland grew through the 20th century[4], and that Reykjavík has seen significant urbanisation over the past 100 years in order to house the increasing population[5].

Schmal (2011) outlines Iceland – and Reykjavik's – move towards urbanisation through its evolving architecture. Most notably, the materials used have changed significantly, from turf houses to stone, to wood, and eventually, concrete. Architectural styles have altered over time too – from the Viking settlers' long-houses, to enlightenment/late-baroque influenced churches to a "century of concrete" (Ibid., pp.19–21). The later, spanning the 20th century and into the early 21st, is notable in coinciding with architectural styles in the vein of national romanticism and modernism. Notably, there is a connection between architecture in Iceland and its unique geothermal environment. National romantic style architecture, which in Iceland drew upon the landscape to reflect the character of the people, led to buildings with features that mimic the volcanic landscape – most notably basalt columns, influencing buildings such as Kristskirkja, Hallgrímskirkja (Fig. 1.3.) and the National Theatre (Fig. 1.4).

[4] This coincides with Denmark offering Iceland increasing levels of home rule starting in 1874, culminating in full independence in 1944.

[5] Reykjavík has been the seat of Iceland´s parliament (Alþingi) since 1843 – which itself used to meet at Þingvellir, a spot within a rift valley that marks the crest of the Mid-Atlantic Ridge in southwestern Iceland. Reykjavík has been the capital of Iceland since 1918.



Fig. 1.3. *The concrete columns of Hallgrímskirkja mimic natural basalt columns.*



Fig. 1.4. *Basalt columns have been placed outside the National Theatre.*

Further, with the arrival of modernism and new housing from the 1960's onwards, open-plan living was facilitated by geothermal water being plumbed into homes to heat them. As such, the population growth of Reykjavík, and its increased urbanisation has both facilitated and been facilitated by a network of infrastructures (pipes, pumping stations – Fig. 1.5, storage tanks) which draw up, process, distribute, and use geothermal heat. Today, almost every building in Reykjavík is plumbed to receive geothermal energy where "space heating is by far the most important direct utilization, covering 90% of all energy used for house heating in the country" (Ragnarsson 2015, p.1). Geothermal water and steam are used to heat homes, melt driveways and pavements, for washing and cleaning, and provides for multiple communal swimming pools which are central to daily life in Reykjavík.



Fig. 1.5. *A typical geothermal pumping station in central Reykjavík.*

The process of urbanisation, which has unfolded in Reykjavík, is recorded in more detail within its urban planning history. Again, it is Valsson (2003) who has collated and analysed this history. The first general plan for Reykjavík was made in 1927 and was followed by further plans in 1937, 1948, 1957, 1965, 1977, 1982, 1988, 1992, and 2002. Urban planning in Reykjavík has been heavily

influenced by the "Danish" 1965 plan. This plan, itself inspired by Fordism, which influenced much urban development at the time, was produced by Danish planners as Iceland had a shortage of its own. It created a city reliant on the car, with many new (sometimes large) roads, and remedying the downsides of planning overly focused on the car (segregated communities, public transport issues, dominant infrastructures) has been the focus of planning in Reykjavík since – and specifically the most recent iterations. Work began on the most recent plan, The Reykjavík Municipal Plan 2010-2030, in 2009. A draft was made available in 2009, and the plan was approved in 2013, published in 2014 (City of Reykjavík Department of Planning and Environment 2014, p.6). The key observation to be made across each of these plans is the growth of Reykjavík to accommodate more people, most notably the extension of suburbs in the northeast, east, and south of the city. These expanding suburbs have required an expansion to amenities and infrastructure, so has been met with a growth in the geothermal heating system that services the city: more pipes, pumps, storage tanks, and geothermal swimming pools. Over time the various flows that animate Reykjavík, of people and heat, have been altered and expanded.

Iceland (and more specifically Reykjavík), presents as a pragmatic and illuminating geothermal urban case study, but will differ to other cases such as those located in New Zealand, Italy, Japan, The USA, The Philippines, Indonesia, Kenya, China, Australia or the UAE; each of which have their own contexts and applications (some focused on electric generation and thus conversely cooling rather than heating). Reykjavík carries similarities with other urban spaces that utilise geothermal heat, whilst emerging from a unique geophysical and distinct social, economic, and political context. On geophysical terms, it is the relatively shallow depth of its geothermal fields and geologically active landscape that draws parallels with other settings that are also permeated by geothermal heat (Chandrasekharam & Bundschuh 2008; Glassley 2010). As a city, it contains the complexities of people, infrastructures, and mobilities, that afford it value and purpose in speaking of and to urban contexts. On this basis it is suitable and possible to draw upon accounts from Reykjavík to speak to a wider geothermal urban experience. Notably, in terms of an interest in the elementality of geothermal heat, Reykjavík presents an exemplar on account of its direct use and application of geothermally heated water within the city.

Reykjavík's social, economic, and political context, arguably differs widely in comparison to other settings. The city can still speak to an enhanced understanding of the geothermal urban experience, but does so on terms that have permitted an equitable, sustainable, and accessible use of geothermal heat. On these logics, a study of Reykjavík proceeds with the caveat that it is a case study further contextualised by a relatively stable economy (even in the aftermath of the 2008 global financial crisis which almost bankrupted Iceland), and robust welfare state typical of Nordic social democratic politics (Indridason 2005; Arter & Bill 2016). Further, any exploration of the geothermal has a context of potential geophysical instability, such a seismic activity and the threat of volcanic eruption. Iceland is no different in this regard, although the geologic risk to Reykjavík is less severe; a result of reduced physical proximity to such hazards, and the relatively well-developed socio-economic infrastructure that supports and surrounds geothermal provision. These observations do not invalidate Reykjavík as case study of geothermal urban phenomena, as all research must commence within contextual limits, but serves to outline the parameters from which this research and its claims emerge.

1.3 | Making the elemental explicit

Across Reykjavík's landscape, within the ground that underpins it and up into the realm of daily human life, flows geothermal heat. It can be traced through cooled lava, is present and frenetic within infrastructures channelling it from deep within the earth, and is absorbed and resonates within and through bodies, buildings, and objects. This research is concerned with making the elemental more explicit, and explores geothermal urbanism with an aim to better understand the places formed of human processes proximate to geothermal heat. In doing so, the chapters of this thesis unfold in the following way:

1 | Introduction

This introduction has outlined Reykjavík as distinct and interesting on account of its geothermally infused composition. Set amongst existing work on geo-urban phenomena, exploring and understanding the geothermal city has been presented as a valuable avenue for contributing to wider understandings of the relations between urbanism, human processes, energy, the elemental, and the

experience and formation of everyday life. It has set out that the focus of this thesis is to understand how the geothermal is articulated through the urban, and the places and practices formed of and forming these relations.

2 | Heat, Elementality, Urbanism

Through a literature review, this chapter forms the theoretical foundation of this research, situated within current thought on heat, elementality, and the urban. It summarises how existing research into geothermal heat and the urban has failed to engage the complex relations between the phenomena, and underlines a need for an account that draws upon post structural, new materialist, more-than-human thinking that foregrounds the geologic within the urban (Whatmore 2002; Grosz 2008; Bennett 2010), concluding by proposing three key research questions.

3 | Attuning to the Geothermal

This chapter outlines and evaluates efforts to undertake more-than-representational (Thrift 2004; 2007) fieldwork, and the production of vibrant, animated, and valuable empirical materials. It details performative embodied videographic methods, as well as the conduct of semi-structured site-based interviews, employed to attune (Stewart 2007; Stewart 2011) to the geothermal throughout Reykjavík.

4 | Infrastructures

Turning to the sites of geothermal exploration, extraction, and distribution, this chapter traces geothermal heat through the urban via the Reykjavík district heating system. It understands geothermal urban phenomena as reliant upon non-human and human forces and structures, that result in a critical surfacing, drawing the geothermal urban as a *geo*sociotechnical (Graham & Marvin 2001) process.

5 | Architectures

This chapter explores geothermal heat through the places and spaces of geothermal urban dwelling, understood as envelopes of heat, termed 'geothermospheres'. In doing so, the geothermal is

encountered as a territorializing-deterritorializing (DeLanda 2006) aspect of a wider assemblage, that gathers elementally infused and palpable atmospheres.

6 | Bodies

This chapter concerns the intimate felt experiences of the geothermal as it comes into direct human use, resulting in an embodiment of the geologic understood as geo-cyborgian (Haraway 1985; Haraway 1991). It considers the affective capacities of geothermal elementality, perceived as senses of cosiness and warmth, and how distinct practices of dwelling continually form and form from the geothermal urban.

7 | Conclusion

Bringing this research to a close, this final chapter calls for a revision of the geothermal field as atmospheric and affective, and outlines a distinctive form of geothermal geopower advancing non-carbon geologic agency. Geothermal urbanism is understood as requiring a geosociotechnical ontology, elemental epistemology, and characterised by distinct practices of embodied dwelling; with implications for broadening understandings of other geo-urban phenomena.

- vignette i -



On the surface.

Houses in and on lava.
Geothermally heated water keeping them warm.
Human lives entwined with the geophysical.

2| Heat, Elementality, Urbanism

"The earth is evident in nearly every courtyard"
- John Reynolds, 2002, p.27

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This chapter forms a literature review which collates, connects and evaluates existing work on aspects of the geothermal city. In doing so, it explores useful and valuable ideas on heat, elementality, and urbanism, forming a point of theoretical departure for the critical analysis and development of geothermal urbanism as a concept. Literature has attempted to understand heat, map the utilisation of geothermal energy, and has rather extensively turned to the urban and urbanism. However, it has not yet explicitly turned to or engaged the geothermal city or geothermal urbanism. First, this chapter addresses a need to review varied thinking about heat, gathering otherwise hermetic works together to form a contextual understanding relevant to geothermal urbanism. Secondly, a need to review materiality in the context of geothermal urbanism is addressed; this involves critically evaluating ideas on matter and drawing in the idea of elementality as a potentially useful perspective. Thirdly, a need to review understandings of urbanism via the sites of infrastructures, architectures and the human body is undertaken. This chapter comprises a speculative mapping of a route with which to approach geothermal urbanism based on existing knowledge and literature. Through the drawing together of relevant material, it culminates by informing the development of research questions that drive the remainder of this thesis.

2.1| Heat

Heat is a curious phenomena. It can be highly variable and erratic, as well as predictable and constant. Heat plays a central role in creating and sustaining life and is observed throughout the universe, and yet it is not fully known. Heat exists within and is understood through multiple contexts, and has been engaged with geographically, via science and philosophy, through the lens of: the geophysical (Gunnlaugsson, Gislason, et al. 2000; Gunnlaugsson, Frimannson, et al. 2000; Ragnarsson 2015), meteorological (Mogil 2007; McGregor 2007) and climatic (Taha 1997;

Santamouris 2001; Motavalli 2004; Pittock 2005; Garnish & Brown 2012); as human produced/maintained energy networks (Henninga et al. 2006; Lund et al. 2010; Persson & Werner 2011; Chapman et al. 2013) and effects (specifcally the urban heat island effect: Bornstein 1968; Oke & Maxwell 1975; Saitoh et al. 1996; Gartland 2008); culturally (Heschong 1979; Sigurðsson 1999; Harrison & Popke 2011; Fennell 2011; Hamilton 2012; Pyne 2012); and sensorially[6] (Rodaway 1994; Ong 2012; Vannini & Taggart 2013a), to list a few. Each of these pockets of knowledge help to build an understanding of heat - where it arises and how it manifests. They do so with a breadth that reaches far across and well beyond the urban, or a focus that begins to draw out the otherwise discreet details of specific urban heat. The following section pulls together otherwise hermetic knowledge about heat as energy, as a fundamental component of geothermal activity, and as playing a part in homeostasis via the built environment and biology. It advocates that to attended to geothermal urbanism, heat must be understood: (i) in and of itself, (ii) in the context of proximate subterranean sources, and (iii) as a part of urban based homeostasis.

Thermal Energy

Heat, at its most fundamental, is the transfer of energy - "energy in transit" (Blundell & Blundell 2006, p.13). Heat, thermal energy, transfers in three main ways: radiation, convection and conduction. With radiation energy transmits through space via waves; convection is the movement of energy through bodies of substances like air and water; and conduction is when heats transfers directly from molecule to molecule - "[Heat] may be conducted through the soil to the surface and then radiated or convected into the atmosphere" (Smithson et al. 2008, p.27). Whether heat originates from the sun, nuclear power stations, the friction of a bike's break-pad, the burning of carbon or the centre of the earth, it is thermal energy. Whilst the 'thermal' relates to both the concepts of heat and temperature, they are quite different things. Temperature is a measure of thermal energy, "[d]uring the process of heating, energy flows from one part of a system to another, or from one system to another, by virtue of only a temperature difference" (Zemansky & Dittman 1997, p.80). Heat is the flow (transfer) of thermal energy across various gradients - flows which might be endothermic or exothermic - either transferring energy to or from, warming or cooling, a system.

[6] See also: Bille (2014), on comfort and warmth in relation to domestic/urban lighting.

What is meant by a system is that "any portion of matter, any part of the material world, can be a system…the most important attribute…that it has definable (though not necessarily rigid) boundaries which separate it from its surroundings and other systems" (Ramsay 1971, p.11). Science, or more specially the branch of science concerned with thermodynamics (the relations between heat and other forms of energy) is specifically concerned with heat transfer, temperature, and systems. This is because it understands heat as being present within defined systems (see Kreith & Bohn 2001, pp.1–58) which are constantly headed towards equilibrium - that is that via endothermic or exothermic heat transfer the energy within a given system will flow to the point of temperature balance. This view is directly connected to the laws of thermodynamics and the concept of entropy (the amount of 'order' or 'disorder' in a system). Entropy increases (disorder) as temperature rises and more thermal energy (heat) is present within a system, and decreases (order) as the temperature drops and thermal energy leaves the system[7]. There are different types of systems (isolated, open, homogenous), with the open system, "one which can exchange both matter and energy with its surroundings" (Ramsay 1971, p.12) the kind with which understanding geothermal urbanism is concerned. That is because geothermal heat, as it leaves the ground and enters the urban realm dissipating into buildings, bodies and the atmosphere, allows for both matter and energy to come and go. Heat must be understood as a force - energy - which flows, and is capable of movement and transformation.

The Geothermal

Heat can originate from a variety of sources, each unique in terms of characteristics such as temperature (maximums, minimums, averages), flow (consistency and duration of energy transfer) and prevalence. Science has come to identify and define one specific form of heat as geothermal. The origins of geothermal heat go very deep, spatially and temporally, down to the Earth's core and linking back to energies (kinetic, gravitational) involved in the planet's formation, and (now dominantly) radioactive isotopes that decay over millennia (Garnish & Brown 2012). Physical geography, geology, and geomorphology, has mapped geothermal heat to specific locations, understood as geothermal areas and geothermal fields. Precise scientific understandings of geothermal fields, specifically concerning temperature, proximity to volcanism, and working fluid, are

[7] See Pippard (1964) and Zemansky & Dittman (1997) for more detailed commentary.

still debated and researched (see: Keiding et al. 2010; Falcone 2015; Pinti et al. 2017; Alçiçe et al. 2017). For Christopher & Armstead (1978, pp.39–60), geothermal areas are locations on and within the Earth's crust with temperature gradients above 40°c per km of depth, whilst geothermal fields bear the same characteristics also containing "working fluid…water and/or steam…a medium for the conveyance of deepseated heat to the surface" (Ibid. pp.40). Saemundsson (2009, p.1) summarises that the geothermal field is "a geographical definition, usually indicating an area of geothermal activity at the earth's surface…[, or i]n cases without surface activity…to indicate the area at the surface corresponding to the geothermal reservoir below". This recognition of a geothermal field as a 'geographical definition', along with the afore-mentioned on-going investigations into the geothermal within other disciplines, underlines the fluidity of any conceptualisation and that it is possible that how geothermal fields are understood may well be reviewed and revised. This potential for revision can also be applied to the heat systems addressed in the previous sub-section, "the idea of a system is nothing more than a conceptual device whereby we restrict attention to one particular part of the material world" (Ramsay 1971, p.12). Geothermal fields are given form by the presence of heat that has originated from within the Earth, and the ability for that heat to surface within a specific kind of system. Whilst this is fundamental, there is something arbitrary, loose, or at least flexible, regarding how geothermal fields are defined and understood.

What makes geothermal fields so interesting is that "geothermal fields are rarities" (Christopher & Armstead 1978, p.39). To have the right mixture of geothermal heat and a geology and hydrology which permits it to surface is limited to a number of specific locations. For these reasons, geothermal fields are located near volatile and active geological areas (such as the Laugarnes, Elliðaárdalur, Mosfellssveit and Hengill geothermal fields mentioned in the introduction). To have geothermal fields coincide with urban spaces provides an additional layer of rarity and curiosity. The Reykjavík Capital Area sits on, within, geothermal fields. This leads to new questions regarding the definitions and limits of the geothermal field as its warmth extends into the urban. Further, it has been previously noted that all heat is thermal energy, and it should be added that all thermal energy is the same. Heat is heat, much as light is light, gravity is gravity and magnetism is magnetism. Heat can vary in source but is always thermal energy. Whilst this means there is nothing different or distinct

about the kind of *energy* produced by geothermal compared to solar, nuclear, or carbon sources; it can be observed that there are differences in terms of volume, intensity, continuity and character – *the kind of heat*. Geothermal thermal energy is the same as that from an electric fire, the sun, or a burning candle; but there is a unique geography associated with each different source. There are spatial and temporal differences, which effect political and economic differences, and experiential and sensorial differences. As such, human engagements with *heat* vary greatly, and it is this that means it is valuable to think about how a geothermal city may vary from a solar, nuclear, hydro, wind or carbon city. The geothermal field should be regarded as a diacritical location within which a discrete form of thermal energy, geothermal heat, is able to emerge.

Homeostasis

Over the course of human history, connections have been made between the heat escaping from volcanoes, fumaroles and mud-pits - as well as the heat given off by warm streams, springs and water - and the deep earth, for example: "[v]estiges of Japanese culture have been unearthed near the Yuda hot spring…dating from the pre-pottery period before 11,000 B.C…. [p]ublic baths became common at hot spring localities in the Roman empire around two thousand years ago extending from England to Tunisia and Syria" (Friðleifsson 2001, p.301). It is not surprising that such a connection would be made in Iceland, a place that is so overtly and immediately geothermally active. There is evidence of Vikings having lived in warm caves (Iceland Review 2013) and of more recent inhabitants using geothermal heat for cooking bread and growing potatoes and cabbages in the heated ground, as well as washing (clothes and themselves) with warmed water (Friðleifsson 1999); indeed one of the most famous Icelandic saga's, Laxdaela Saga, tells of a woman, Gudrun Osvifursdóttir, living by a geothermal pool at Laugar in Sælingsdalur[8]. As it has been associated with better human health, thermal comfort has increasingly become more prominent in architecture and building design, most notably as new technologies and air conditioning systems have become far more commonplace (Erell et al. 2011, p.125). In summarising the architectural science of thermal comfort, Szokolay (2014, pp.15–21) points out that the average human body outputs 100 watts of heat, "which must be dissipated to the environment, or else the body temperature will increase". An overly warm body, as

[8] "[B]jó á Laugum í Sælingsdal", translated as, "lived at hot springs in Sælingsdale" (Smiley & Kellogg 2001).

much as an overly cold one, will register as uncomfortable. For humans, maintaining a constant internal body temperature of 37°c is essential to life. Many variables can effect this, not least the environment (air temperature, air movement, humidity), and thus as buildings can enhance and maintain these factors, building design is essential to thermal comfort (Ibid., Billington 1952). Olgyay & Olgyay (1963) went as far as producing a chart that presented a variable 'comfort zone' for human habitation, taking into account air movement, temperature and humidity; an attempt at mapping an aspired ideal climate for outdoors and indoors, but models have been problematic as people adapt to their environment (Erell et al. 2011, pp.129–130) and shifting contexts. The human necessity for warmth, combined with technological innovation and curiosity has directed human beings into finding ways to make better - more formalised and more ambitious - use of geothermal heat. History tells us that their were early attempts at recording the temperature of the ground, dating back to France in the 1740's, forming the start of a process that eventually lead to the first modern geothermal district heating system in Idaho in 1892 (Dickson & Fanelli 2004). In Iceland, drilling for hot water began in Reykjavík in 1928, and by 1930 the first house was connected by the first pipes (Gunnlaugsson 2003, p.67). Prior to this period of technological innovation, no matter how rudimentary it was at first, the process by which geothermal heat escaped from the ground was phenomena unaided by human intervention. Whilst this is still clearly the case for the majority of geothermal heat, there are now spaces and places wherein which the surfacing of this energy is inflected by humans. In doing so, through infrastructures, architectures, and bodies, geothermal heat has become a part of homeostasis.

Homeostasis "is the maintenance (within varying limits) of the internal environment of the body" (Rizzo 2016, p.13), it is essential to survival, and a key aspect of it is a regulated body temperature, and as Angus (1968, p.1) notes "it is not always realized that the object of lighting a fire, or the turning on of a radiator in a cold room, is not to add heat to the bodies of the inhabitants, but to control the rate and the modes of their cooling". Human thermal sensations are tied to physiology and psychology (McIntyre 1980, pp.114–160) as heat directly physically effects nerve endings in the body, which generate signals then interpreted by the brain as perceived from hot to cold. Ong (2012, p.5) observes that "[t]he human sense of heat is arguably the most important sense we have as it

ensures homeostasis[…i]f this thermal balance is not kept we will literally die". Heat is critically vital to human survival and needs to be thought of beyond mere temperature, in a way that extends into objects and processes (Ibid. pp18). To regulate body temperature, the body creates its own heat, but also makes use of ambient heat sources. Given it generates heat, and is a very common way of doing so, fire has been the focus of much thought on energy and homeostasis. Pyne (2012, pp.53–73) offers a well-considered and original account of 'anthropogenic fire practices' having previously outlined humans as 'fire creatures' (Ibid., pp.41–52). In doing so, Pyne outlines how humans have developed a range of 'pyrotechnologies', leading to forms of 'cultivated fire' and 'built fire'. This is interesting as it can be applied to the geothermal as well as fire. A range of geo-thermo-technologies have been produced that allow for the cultivation of geothermal heat and the controlling of geothermal warmth within buildings and bodies. Crucially though, the heat source, practices, and engagements, are different between fire and the geothermal.

Clark & Yusof note that "most of the energy used by human beings, outside of their own bodily energetic reactions, comes from the combustion of fossilized organic matter that was originally powered – directly or indirectly – by photosynthesis" (2014, p.204). Homeostasis is mostly assisted by the combustion of carbon, be it in the burning of wood in a small fire, gas powering a boiler for central heating, or coal in a power station transferring energy for electric heaters. In the case of nuclear, solar, wind, and hydro, these energies are converted to electric power for heating. With geothermal heat there is an interesting departure from a carbon and electric 'normality' into alternative networks of energy provision and utilisation. Engaging the geothermal to maintain homeostasis produces a different, complex, entanglement of heat, infrastructures, architectures and bodies; "[r]esource dependency relates to communities and individuals whose social order, livelihood and stability are a direct function of their resource production" (Adger 2000, p.352). Gissen observes that "maintenance environments…negotiate specific environmental pressures…while ushering in the geographical and economical relationships, objects, and even subjects of the City's emerging…urban spatial order" (2014, p.181). Geothermal heat, as it emerges from the subterranean geothermal field into the urban, must be thought about in relation to the role it then plays in homeostasis and the way in which sustained human life alters the surfacing of geothermal energy.

This section has confirmed heat is a critical aspect of geothermal urbanism and that it must be understood in a number of ways and contexts. Firstly, geothermal heat is energy, a force that flows, seeks equilibrium and is not entirely fully known. Whilst this thermal energy is identical to all other thermal energy, its source at the centre of the Earth means it is discrete with unique intensities, forces, characteristics, and transformative capacities. Secondly, geothermal heat has a diacritical geography, surfacing at rare and specific locations for various durations, identified as geothermal fields. These geothermal fields are open to interpretation and thus have fuzzy boundaries ("spatial fuzzy sets" - Fisher et al. 2004, p.106) and are permeable (physically and conceptually). Thirdly, where it comes into contact with human life, geothermal heat is directly and acutely tied into homeostasis. This entangles geothermal heat's exclusive character with human networks, infrastructures, architectures, and bodily sensations, in a way that is different to other energy sources. These ideas (of heat as energy, emerging from the subterranean, and a part of homeostasis) combine to form a platform from which to approach geothermal urbanism in the context of its inherent energy, society, biology and geology.

2.2| Elementality

Clark & Yusof (2014, p.206) undertake what they term a "combustion-centred analysis" as they "bring human collective life into closer contact with the geochemical and geologic conditions of earthly existence" (Ibid.), drawing extensively on Bataille (1991; 1993) and the earlier work of Pyne (notably: 1994; 1997a; 1997b; 2001). This valuable line of thought outlines the 'pyro practices' of humans and opens up the "deep energetic constitution of human…existence" (Clark & Yusoff 2014, p.224), viewed as a "geo-social formation" (Ibid.) connecting the social and the geological through fire-based, carbon-based, energy flows. Two key considerations can be drawn from this thinking. Firstly, that the identified geo-social formation put forward has both a materiality (wood, bodies, thermal energy) and an elementality (fire, air). Secondly, "combustion-centred analysis" focused on the ignition of carbon, in wishing to attend to the geological, should be expanded to consider the kinetic and radioactive geothermal ("The primordial Earth did not have fire", Pyne 2012, p.15). This section turns to ideas on materiality and elementality, arguing for an extension of Clark & Yusof's (2014; 2017)

work towards a geothermal-centred analysis. In doing so, it is possible to hypothesise a distinct geothermal urban materiality and unique elementality, correspondent to the chthonic energies embroiled within.

Beyond brute matter, a non-dualist new materialism

Following the cultural turn in geography, which saw geographers move attention from the tangibly quantifiable to cultural concerns, there came a criticism that focus had swung too far towards the semiotic (Barnett 2009, pp.134–135). Notably, Jackson (2000) and Philo (2000) called for a 'rematerialisation' of geography, an approach to the stuff of the world "without simply 'reading off' symbolic meanings" (Jackson 2000, p.13) but which also "rigorously avoids…'object fetishism'" (Ibid.). As Lee (2002, p.102) put it, "[d]efining what we actually mean by material and immaterial ought to be the first step in rematerializing geography", this, "toward an expressive physicality" (Kearnes 2003, p.149). For Anderson & Wylie (2009) this was not about the need for geography to be 'rematerialized', but that material and materiality 'remain untheorised' (Ibid. p.332). They proposed a refocus of 'attention to the multiplicity of relations that materialities are entangled with' (Ibid. p320) , forming "the basis of an agenda aiming to write through materialities anew" (Ibid. p. 332). In the introduction to 'New Materialism: Ontology, Agency, and Politics', Coole & Frost (2010, pp.1–39) "share the feeling current among many researchers that the dominant constructivist orientation to social analysis is inadequate for thinking about matter, materiality, and politics" (Ibid. pp.6). In their volume, they outline how progress in physics and biology have necessitated an advance of the materialist philosophies of Marx, Nietzsche and Freud towards a new ontology of matter, agency and posthumanism. This reorientation, to draw in Latham *et al.* (2009, p.62), reflects an emerging consensus that "materiality does not just designate brute matter…[and] any account of the materiality of urban geography must involve more than an inventory of its obvious physicality".

The materiality of the urban is bricks, windows, people – but also movement, breath, sensations of warmth, "rather than 'grounding' the immaterial, paying increased attention to the material actually demands that we begin to take seriously the real force of the immaterial" (Latham & McCormack 2004, p.704). This "new materialism" which emerges through the thinking of (1996) and Braidotti

(2002), as inspired by Deleuze and Spinoza (see: Deleuze 1988), has at its core a move away from nature/culture dualisms towards a 'transversality' (Van der Tuin & Dolphijn 2010): "The strength of new materialism is precisely to be found in its ability to show that agential…nature of all matter" (Ibid. pp159). As authors developed a new materialism, the concepts have begun to be re-understood in the vein of multiplicity, excess and emergence. As Nieuwenhuis summarises, "[a] materialist geography should seek to…re-appropriate the ground as a relational and fluid place…[r]ather than abandoning the ground altogether, a materialist approach should challenge ideas of it as a stable surface" (2016, p.313). This perspective on materiality is one which engages the 'multiplicity of relations' Anderson & Wiley sought to explore and foregrounds emergence and materiality as tied to the processes of being (Heidegger 1996) and becoming (Deleuze 2004)[9], (Nieuwenhuis 2016). Latham & McCormack (2004) embrace the idea of emergence in such a way that engages some of the concerns of Anderson & Wylie (the need not to rematerialize, but to ontologically rethink materiality). Drawing on automobility and psychoactive substances as examples, Latham & McCormack outline urban materialities as "emergent in that the sense of the urban is an ongoing outcome of the interaction between a myriad of small-scale self-organizing processes that are not determined by a central controlling or decision-making unit" (Ibid. p.707). The materiality of the urban extends beyond things as merely physically tangible; formed of and forming relations, processes and assemblages. In such a way that is supportive of this relational approach to materiality (signalling Deleuze, Bennett, and Haraway), Coole & Frost position towards "new critical materialisms[,] materiality in a relational, emergent sense" (Ibid. pp.29). This sense is echoed by Barry (2013, p.13) whom notes "[m]aterial artefacts never exist in isolation, but are themselves evolving entities that form part of a constellation of dynamic relations with other evolving entities (Pickering 1995; Barry 2005)…material entities are 'partially formed by the aspects of other events from their environments' (Whitehead 1985, p.133)". At first glance we might consider the fundamental materiality of the geothermal urban as exclusively the brute matter of geothermal water, steam and rock; and as the matter of human things: concrete, glass, metal, bodies. From there, we might also be concerned with the less/'un'-tangible; heat, emotions, sensations. In looking

[9] See also Biehl & Locke (2010) on 'Deleuze and the Anthropology of Becoming'.

at the ways in which materiality might be opened up even further, it becomes clear that to comprehend the geothermal urban, these materialities must be understood in the context of their combining, co-transformation, and plurality. Materiality via this 'new' lens has been understood as more than distinguishable objects, more than tangible matter, and as emerging from the relations from which the world is made. The geothermally warmed body may be thought of on these terms as a complicated gathering of matter, in movement, alive - the geothermal is given breath and breath distinctly geothermal. To draw once again on Anderson & Wylie (2009, p.318), matter "takes place with the capacities and properties of any element (i.e. earth, wind, fire, air) and/or any state (i.e. solid, liquid, gaseous)… materiality therefore far exceeds any invocation of ground or physicality". This brings about an essential focus in thinking the possible materiality of the geothermal urban: that there is a force of elementality that unifies and runs-through the locus of such phenomena.

Vibrant matter, emergent elemental geopower

Tuan (1974, p.18) observed that "[t]he contents of nature are enormously varied….in different parts of the world people have recognised a few basic substances or elements that underlie the multiplicity of phenomena, for example earth, water, wood, air, metal and fire". McCormack (2016) paints three readings of the elemental. Firstly, "in terms of the four classical elements of earth, wind, air and fire… understood as states of matter from which every other material is derived… as a kind of generative chaos (Ibid., p.4)". Secondly, "as the physico-chemical, as the electromagnetic organization of matter-energy into patterned entities with relatively predictable properties and capacities" (Ibid.). By this reading of the elemental one may "foreground how the properties and capacities of particular objects, bodies and forms of life are shaped and sustained by bonds, affinities and reactions" (Ibid.). Thirdly, as a "mingling of the first two: this is the elemental as an environmental milieu within which different forms of life are immersed, enveloped and take shape" (Ibid.). This provides three ways with which to potentially approach, elementally, geothermal urban phenomena, bounded by the idea that "we can consider an elemental geography as fundamentally about thinking with, feeling with, living with an element…as an indefinite and incomprehensive background" (Adey 2015, p.71; citing Sallis 2000). Firstly, as possessing a curious form of the element fire – geothermal warmth – that mediates through the other three elements (air, water, earth). Secondly, through the specific

kinetic/radiative qualities of geothermal warmth as they extend into objects, buildings and bodies. Thirdly, as these ideas combined presenting an elementally underpinned geothermal urban *genius loci*.

Resonating strongly with mapping out the geothermal urban from an elemental perspective is the scholarship concerned with new materialism outlined above, but especially with attention turned to Haraway (2003), Yusof (Yusof et al. 2012; Yusof 2016; 2017), Grosz (2008; Grosz et al. 2017), Bennett (2004; 2010), and Clark (Massey & Clark 2008; Clark 2011; 2012a; 2012b; 2015; Clark & Yusof 2014; 2017): "Matter, for the new materialists, is active in ways always already excessive to simply human ken" (Jackson & Fannin 2011, p.438). This is to take seriously the vitalism, the "thing power" of the non-human, "the possibility that attentiveness to (nonhuman) things and their powers can have a laudable effect on humans" (Bennett 2004, p.348). Bennett, drawing on Deleuze & Guattari (1987), and the flat ontology of (Latour 1993), puts forward through "thing-power" a vital materiality which holds that it is not just the human, or indeed the biological that holds agency. In Bennett's work, "matter that we consider 'dead' such as fossils and stones is not actually dead but very much alive and is constituted by a lively and energetic play of forces" (Khan 2012, p.42)[10]. In essence, this is materiality complicated in compelling and interesting ways, suggesting that there is a vital force at play in the world, "[t]hing-power materialism is a speculative onto-story, a rather presumptuous attempt to depict the nonhumanity that flows around but also through humans" (Bennett 2004, p.349). Read along with Grosz's (2008) work on 'geopower'[11], which in developing Foucault (1980) characterises "the geological, inhuman and preindividuated forces that subtend and provoke organic life" (Grosz et al. 2017, p.134), elemental capacities and properties (to return to Anderson & Wylie 2009) are exposed. In this exposure, thing-power and geo-power are also revealed to be emergent, wherein the "locus of agency is always a human non-human collective" (Khan 2012, pp.52–53). What Haraway (2003) terms 'natureculture' is "a provocation for collapsing and transgressing the dominant metaphysics that dichotomizes nature and culture" (Latimer & Miele 2013, p.11). In the vein of

[10] Turn to Kahn's (2012) interview with Jane Bennett for more on the philosophies antecedent to new and vital materiality.
[11] See Grosz et al. (2017, pp.138–140) for additional detail on geopower's ontological origins.

Bennett and Grosz, this is to underline the falsehood of a nature-culture binary and a call for the need to engage the new materialist position of a more-than-human (Whatmore 2006)[12], geologic, ontology.

It is curious, but perhaps no surprise that Stengers (2010, pp.172–261) turns to the thermodynamic in her development of a "Cosmopolitics". Stengers asks, "[w]hy does the fact that a 'force' or phenomenon is 'dissipative' today simply indicate that its definition is 'approximate'…" (Stengers 2010, p.190). Here, Stengers is questioning the supremacy of scientific knowledges as outlined in the 'science wars', building towards her argument for a valuable multiplicity of knowledge: "I said that my project was to bring into existence the question of an ecology of practices, not as a solution but as a learning process" (2011, p.407). What a cosmopolitics offers, is the opportunity to take forward the geothermal urban as one of relationality and the relationality of concepts, to engage the "unfamiliar view of…network infrastructure" suggested by Starosielski (2015, p.2). "If 'political ecology' is to be worthy of its name, it has to be more than another term for 'environmental politics', and instead should seek to conduct critical analysis of the political factors that underlie competing definitions and explanations of environmental reality", notes Forsyth (2003, p.278). An exploration of the geothermal urban should be concerned with the relational and push beyond political ecology, via a cosmopolitics of energy (Gabrys 2014). Critically, this approach must engage and concern itself more with the geological non-human, as Yusoff (2015:399) echoes: "identity is always in excess of itself…this excess is not only social, but has origins that are non/inhuman; conceptually, biologically and geophysically".

In *Place as Material Culture,* Gheorghiu & Nash (2013) consider the place, materiality, time and ritual of human lives in past landscapes. In doing so, they unearth how everyday human lifeworlds are bound within a realm of materiality that, retrospectively, is overtly connected to the geological reality of the time. Through this archaeological perspective, it is possible to frame present human lifeworlds in the same way, explicitly extending any interpretation of the materiality of today's geo urban phenomena as contingent upon the present geological epoch (the Anthropocene) and proximate geology, geophysics and geomorphology. This is mirrored by Clark (2011, p.23): "Deleuze and

[12] Extending work that Lorimer refers to as a "relational-materialist manifesto" (2008, p.554).

Guattari's geophilosophy, Serre's rhythmically pulsing planet, and Bataille's energetic geophysics have each in their own way gestured towards an expansive sense of the earth and cosmos as the volatile ground of human and other creaturely life". Clark is concerned with "Deleuze and Guattari's philosophical engagement with the way disparate materials come into association" (Clark 2012a, p.30). Applied to the geothermal urban, a need to consider carefully the elemental background is underlined by this ontological position - especially given the geothermal is so acutely elemental. Clark (2012, p.31) continues: "Actors - whether human or nonhuman, animate or inanimate, real or imagined - are to be defined not by any a priori category to which they may be ascribed, but by the difference they make to other actors and to the wider world (Latour 1999, p.122)". Elementality is not prescribed, but rather something that is only produced in the present: "[P]erhaps the thing with which we inevitably begin is less matter as such than a discursive, phenomenally constituted elemental moment in an assemblage dynamic… [-] that discursivity is predicated itself on elemental assumptions about the materialisms under analysis" (Jackson & Fannin 2011, p.437). In merging earth science and social science with feminist geo-philosophy, Clark & Yusof show that "social and political agency is both constrained and made possible by the forces of the earth itself" (2017, p.3). Foreshadowed by Massey (2005, p.138) when commenting that "organic life can affect the tectonic, and so forth" in thinking through "migrant rocks" (Ibid., p.130), Clark & Yusof traverse new materialism to arrive at what they term the 'geo-social', or "human geologic agency" (Clark & Yusoff 2017a, p.5); a product of vibrant matter, an elemental geopower. To think elementally is highly important: it reorientates materialities and spacetimes countering the notion that "while natural elements have long been considered factors in social and political realities, they remain inert, as backdrops, constraints, or resources" (Lehman 2013, p.485, *cited in* Squire 2016, p.547). In essence there is a need to take on McCormack's (2015, p.86) call that "the argument could be more elemental" engaging the challenge to "step outside the domain of life, vitality, the organic and into the realms of the mineral, the lithic, the planetary, the cosmic[;]…political-ontological framing" (Clark 2013, p.48).

This section has mapped a speculative (non-exhaustive) inventory of the 'stuff' of the geothermal urban, an attempt to commence engagement with phenomena by outlining its materiality. New

materialism is identified as an especially valuable way with which to approach geothermal urbanism, specifically underlined by the need to attend to heat which presents as tangible, ethereal, and emergent. Bennett's thing-power (as giving licence to think directly the capacities and agency of the non-human), and Grosz's geopower (as the stuff of the world animated through inherent earthly forces), directs towards a geological elemental emergence. In thinking through the 'socio-natural relations' and 'socionatural–technical complex' of the matter of carbon, but missing the (subsequent) new materialism and elementality which would emphasize an essential geologic agency, Bumpus (2011) presents a paper which now seems deadened. Whilst not going as far as to engage new materialist approaches within geography, Bumpus does present a post-structuralist view that connects to broader relational thinking (via Swyngedouw 1999; Castree 2002). This underpins valuable understandings of urbanism (specifically as actor-networks) which new materialism (specifically the geo-social) has drawn from, and with which elementality might be applied. This suggests a need to attend to the geothermal urban through a lens which considers the presence of the elemental as an innate geologic force. Building on Yusof & Clarke, a potential 'geothermal geopower' provides a route with which to think elementally about non-carbon geological agency; wrapped up in heat, pipes, water, air, buildings, skin, washing, and homeostasis. Following that "elementality seeps into both the fundamental life sustaining act of drinking water and the sovereign act of establishing national infrastructure" (Squire 2016, pp.553–554), the sites of infrastructures, architectures, and bodies as they intersect with the geothermal, present a critical locus for any enquiry into geothermal urbanism that aims to employ an elemental epistemology. These points are not necessarily fixed, but are rather the moments of such phenomena coming into being. Geothermal heat, much like water for Gandy (2014, p.224), "remains vital and elusive; in its oscillation between different cultural and material realms, it underpins both the limits and the possibilities of modernity".

2.3| Infrastructures

Infrastructures have been of interest to geographers due to their tendency to occupy extensive spacetimes and their complex positioning which intersects materialities. Broadly understood as the

systems, places, and physical manifestation of flows (anything from water to legal advice), infrastructures can be identified as networks of underground pipes, transport systems or community services (see: Larkin 2013, pp.328–330; Amin 2014). Less literal and more metaphorical, within Marxism, infrastructure refers "to the forces and relations of material production that…provide the foundation (or 'base') for a legal, political and cultural 'superstructure'" (Johnston 2009, p.383). Infrastructural phenomena exists in a way that defies rather than enhances any nature-human binary; forming at, and critical to, the intersection of phenomena such as moss (Gabrys 2012), rice (Morita 2017), fat (Marvin & Medd 2006) and human waste (McFarlane & Silver 2017). This section considers how geographers have understood infrastructures (specifically drawing from actor network theory: Latour 1996; Latour 1999a; Law 1999; Latour 2005, and the concept of assemblage: Deleuze & Guattari 1987; DeLanda 2006; Farías & Bender 2010), and in turning to their intersection with geothermal heat, will outline the potential for developing a geo-social and elementally infused perspective.

A flat ontology for infrastructures

Emerging from Science and Technology studies (STS), Latour, Callon and Law developed Actor-Network Theory (ANT) in the 1980's. Most notably ANT removes scale, presenting a flat ontology in which all aspects of a 'network' are equal in terms of *a priori* importance and power: "ANT asks us that we do not think about hierarchies or categories, but rather think about constant circulations and flows" (Bosco 2006, p.139). This has specific importance in shaping how infrastructures might be viewed, specifically as networks of mobile materialities such as Latour's (1986) "immutable mobiles", "phenomenon whose form and function remains stable across different contexts and place" (Castree et al. 2013). For Latour (2005), the interest is in tracing connections, that is to draw out the 'social' as the relationship between actants both human and non-human. Rather than a theory, ANT is more an "actant-rhizome ontology" (Latour 1999a, p.19) in which "[i]t is the *network* which has power, agency and affect – not the individual elements in it" (Jones 2009, p.300). Through ANT there is a notable shift to viewing agency as distributed; "actors are network effects that take the attributes of the entities which they include; entities and things are produced or 'performed' by and through relations" (2006, p.136, citing Law 1999), thus "[a]gency is, in fact, *decentred*…a decentred notion of agency by

defining *agency as network*" (Ibid., p.137, *emphasis in original*). What can be understood from this, is that the various materialities which infrastructures intersect comprise a complex and fluctuating network, which is itself productive of agency. This network should not be perceived as having scales, but circulations and flows through which different components come to the fore. ANT 'works' most effectively when the formation of relations is considered, how and why they come into being or in relation. ANT is about thinking "*relationally*, in terms of associations rather than separations… ANT argues that things (including humans) are only definable *in relation to* other things" (Castree 2002, p.118, *emphasis in original*). For places like Reykjavík, this underlines a need to think about how pipes, water, steam, heat, buildings, bodies and other objects come together to form a network which is generative of geothermal urbanism.

For Müller (2015, p.30) "ANT is as an empirical sister-in-arms of the more philosophical assemblage thinking". Assemblage, note Müller & Schurr, "as a concept is not straightforward to define, particularly because it is dense and intertextual, and something of a culmination of previous works" (2016, p.219), but much like ANT assemblage thinking views the world as relational, emergent, made of associations, and topological (Ibid., p.217)[13]. Critically, in enhancement of actor-network theory, assemblage thinking underlines and highlights the temporary nature of relations, "elements are drawn together at a particular conjuncture only to disperse or realign, and the shape shifts" (Anderson & McFarlane 2011, p.125). Turning to Graham & Marvin, we can further connect ANT and assemblage thinking as that which "abandons any *a priori* distinctions between the 'social' and the 'technological'…contemporary life…seen to be made up of complex and heterogeneous *assemblies* of both social and technological actors" (Graham & Marvin 2001, p.185). It is possible to understand and apply this to infrastructures in thinking them as an assemblage of materialities constantly forming and unforming, specifically in light of new materialist thinking: "the default locus of agency is presumed to be an assemblage of human and non-human, of physiological, physical, and technological elements…a configuration of an ontologically diverse range of actants, of vital materialities of various sorts that produce effects" (Bennett, in Kahn 2012, p.44). Assemblage is a relational concept, but differs to and extends beyond networks in that an assemblage is *overtly*

[13] For more detail on assemblage and its emergence from *agencement* see also: Anderson *et al.* (2012)

multiple and considers the excesses of phenomena. ANT inspired approaches to infrastructure allow us to view "where events transpire: a space irrespective of scale where things (human or non-human, conscious or non-conscious, single or group) *take place*" (Allen 2011, p.278, *emphasis in original*). Assemblage theory takes ANT and multiplies its networks and relations. For DeLanda, "entities in relations are not fully determined by these relations, but always exhibit a surplus, something that is outside relations, and enables them to plug into other assemblages" (2006, p.220). Harrison & Popke (2011, p.959) evaluate "energy poverty as a geographical assemblage" in order to "be attentive to the ways in which lives, networked infrastructures, and the porous materiality of the built environment come to be". Their use of assemblage thinking supplements traditional accounts of energy poverty to include a greater focus on the relations between the various materialities of networked infrastructures, but their focus on a "socio-natural metabolism" (Harrison & Popke 2011, p.955) lacks consideration of the vital geopower present within such networks with no regard for heat's elementality. Given the importance of elementality within the geothermal urban, and its diffuse, excessive, malleable character; it is important to consider that "[t]he notion of urban assemblages in the plural form provides an adequate conceptual tool to grasp the city as a multiple object, to convey a sense of its multiple enactments" (Farías 2010, p.14). Assemblage thinking provides additional flexibility with which to attempt to understand the elementality of phenomena. The geothermal urban may be presented as a "multiplicity of networks" (Bender 2010, p.306), as an urban assemblage open to the vitality of elemental forces: multiple, mobile – immutable? Assemblage "makes possible a double emphasis: on the material, actual and assembled, but also on the emergent, the processual and the multiple" (Farías 2010, p.15). Both ANT and assemblage thinking facilitate a move away from an Euclidian to a topological view of spatiality and materiality, following "Serres and Deleuze…to assert a multiplicity of spaces" (Martin & Secor 2014, p.424). Embracing the flat ontology, topology, afforded by ANT and assemblage thinking, there is scope for the elemental to be given greater prominence aside the social and the technical within infrastructural networks.

Sociotechnical infrastructures – the elemental underplayed

In Splintering Urbanism, Graham and Marvin examine the idea of a "standardised ubiquity" being a goal for any infrastructural network, and that networks are "being 'unbundled' and 'splintered' as a

result of widespread movement towards privatisation and liberalization" (Graham & Marvin 2001, p.382). In doing so the authors observe that "we are starting to see a dramatic renewal in the physical, social, political and discursive salience of urban networked infrastructures and the diverse technological mobilities that they support and mediate" (Ibid., p.382). In this volume, the authors also develop a valuable way of thinking the urban: "the life and flux of cities and urban life can be considered to be what we might call a series of closely related 'sociotechnical processes'" (Ibid., p.10). Connecting with actor-networks, hybridity (Whatmore 2002) and cyborg urbanism (Haraway 1985), they note that "[i]nfrastructure networks…are vast collectives of social and technical actors blended together as sociotechnical hybrids that support the construction of multiple materialities and space-times" (Ibid., 2001, p.185). Sociotechnical processes are very much an attempt to expand the cyborgian perspective, to draw upon a mixed materiality of technologies and human bodies played out more explicitly through vast infrastructural networks, and as relational and underlining their processual nature.

Alternatively, but also highlighting the social and technical, Barry (2006) refers to "infrastructural zones" as "associated with the creation of common connection standards" (Ibid.: pp.239). This thinking might be applied to the Reykjavík district heating system, in which standardised connections enable the flow of goethermal heat throughout the city. This geothermal 'infrastructural zone' carries with it a distinct political ecology that will vary from that, of say, oil pipelines in the Caucasus (Barry 2013). Infrastructural zones must be understood as possessing a common connection not merely in terms of the physical connections of pipes, wires and chains but in terms of their social organisation and operation: "pipelines form part of dynamic assemblages in which the expertise of engineers, metallurgists and other material scientists have come to play a critical part…[t]hey have become informationally enriched" (Ibid., p.138). For Barry (Ibid., p.183), "[t]he political significance of materials is not a given; rather, it is a relational, a practical and a contingent achievement". Here, we can connect with Graham & Marvin (2001) whom acknowledge these interconnections between what they identify as sociotechnical processes, material infrastructures, capital accumulation and geopolitical power.

In Amin's consideration of land formation and informal settlements in Belo Horizonte, "the urban infrastructure turns out to be not only as active as any community or institution, but also the medium through which much of the latter is orchestrated" (Amin 2014, p.156). Boelens et al. "define and explore hydrosocial territories" (2016, p.1), set out as "socially, naturally and politically constituted spaces that are (re)created through the interactions amongst human practices, water flows, hydraulic technologies, biophysical elements, socio-economic structures and cultural-political institutions" (Ibid.). Further, Gandy (2014, p.1) asks, "Can the flow of water unsettle our existing conceptions of space, technology, and landscape?...Water lies at the intersection of landscape and infrastructure, crossing between visible and invisible domains of urban space". In exploring "evolving relations between modernity, nature and the urban", Gandy (2014, p.2) notes "[w]ater does not constitute one object of analysis but rather an intersecting set of processes, practices, and meanings that cuts across existing…boundaries". Rather than being underplayed, along with the social and the technical, the natural (or the geo, geopower) is revealed as necessitating equal consideration. Sociotechnical processes require a geological qualification that creates and sustains them. The role of the natural is underlined by (Kaika 2005, pp.62–66) in addressing the 'selective porosity of the modern home', in which social and natural processes are both outlined as critical to the phenomena of modern urbanism and technologically infused modernity. Whilst this research draws attention to the geo, the natural, towards the elemental; it stops short of thinking through the elementality of such infrastructure networks in a way that could call upon a new materialist inspired perspective.

Geosociotechnical infrastructures – the elemental foregrounded

Infrastructures conjure images of, and relate directly to, technologies and social organisation. In the context of energy, especially geothermal energy, the physicality of mass infrastructure networks are as much the brute tangible power and force of the energy itself as the pipes, pumps, storage tanks and human organisation. The pipes of Reykjavík´s district heating systems contain great pressures and high temperatures wrapped up in man-made objects as bounded forces. This invokes a sense of thermo-technology, or as Clark & Yusof drawing from Wertime (1964; 1973) and Pyne (1997b) progress, 'pyrotechnology', wherein "humans gradually divined the transformative effects of fire on other materials (Clark & Yusoff 2014, p.216). This pyrotechnology can be traced right up to the

modern era, currently culminating in vast and increasingly complicated infrastructural networks of heat and other materialities, applied not just to fire but adaptable to the nuclear, solar, and the geothermal. In spite of the grander scale implied by infrastructures, it is in the more discreet aspects of such 'pyrotechnologies' with which such networks are acutely experienced and understood: "perhaps it is the more subtle, simmering engagement with the geologic elements that is the key to the city's role in the gradual transmutation of the Earth" (Ibid., p. 217). Swyngedouw prefigures pyrotechnology with the broader "technonatural" characterised by the "intermingling of things material and things symbolic produc[ing] a particular socio-environmental milieu that welds nature, society and the city together, often through many layers of networked technostructures (like pipes, cables, relay stations, logistical apparatuses and the like) (Swyngedouw 1999)" (Swyngedouw 2006, p.105). The technonatural is a further attempt to reject any binary nature-society/technology division specifically with a focus on the infrastructural. This reflects the idea of "cities…wholly natural: raised out of wood, sand, iron, stone and the like…*of* nature" (Watts 2005, p.143, *emphasis added*). In turning to Reykjavík it can be hypothesised that the geothermal is as much a part of the processes that form infrastructures, and thus enables geothermal urbanism, as the social and the technical - indeed, the process should be understood as *geosociotechnical*. This suggests that the critical geologic component of urban phenomena should be foregrounded, "[e]ventually, urban centres…grow into geological forces in their own right: 'enormous and dense tectonic plates of humanity', in the words of Michel Serres (1995: 16)" (Clark & Yusoff 2014, p.217).

Starosielski (2015) attends to what can be termed the geosociotechnical phenomena of the ocean and large-scale telecommunications wires that traverse the world – "Rather than envisioning undersea cable systems as a set of vectors that overcome space, *The Undersea Network* places our networks undersea: it locates them in this complex set of circulatory practices, charting their interconnections with a dynamic and fluid environment" (Starosielski 2015, p.2). Starosielski uncovers the complex political ecology of countless kilometres of wired infrastructures, vast oceans and beaches, and the socio-cultural processes that they enable (and are enabled by). With trans-oceanic cables, the natural resource utilised is focused away from the light and electric energy travelling through the cables, and onto the environment that supports the infrastructure's placement;

how the Atlantic and Pacific oceans, for example, accommodate these extensive networks. Thinking through the contemporary importance of such infrastructures, literally supported by the ocean, underlines "that an urbanised nation-state rests upon a fundamentally 'natural' resource whose infrastructures may well be invisible to urban dwellers" (Latham et al. 2009, p.72). This arrangement may be applied to the large heating system that warms Reykjavík. In the Icelandic case the infrastructures themselves carry the natural resource of geothermal heat, but are also supported and facilitated by the natural landscape, providing a surface for the required pipes to run over and through. Further, the geothermal, the earth itself, may be thought of too as infrastructural (drawing on 'the geoengine', Yusoff 2013). Viewing infrastructures as geosociotechnical develops "[a]ctor network theory and cyborgian perspectives… [which] rightly suggest caution as to whether any meaningful distinction between 'technology' and 'society' or 'infrastructure' and 'cities' can…be made – so seamlessly are the interpenetrated" (Graham & Marvin 2001, p.212). Equally with the undersea network, the geothermal network is likely to have a complex - unique - political ecology: chthonic geothermal energies and lava-born landscapes and the sociotechnical processes that they enable through kilometres of plumbed infrastructures. Importantly, any political ecological perspective should be opened up and complicated by an engagement with the elementality of such phenomena.

This section has reviewed how geography has come to understand and approach infrastructures, connecting with current literature that employs a relational approach drawn from both actor network theory and assemblage thinking. Enhanced by new materialist approaches which took the flat ontology of the rhizome and distributed view of agency it affords, attention can be drawn to the non-human. By further employing the looser approach of assemblage thinking, the geological can be foregrounded, advocating the significant value of understanding infrastructures as comprising an innate elementality (specifically in relation to energy networks). In mapping out how more detailed understandings of geothermal urbanism should be approached, two key directorial inflections have emerged, both of which require an expansion of existing political ecological perspectives. Firstly, there is a need to approach infrastructures as elementally infused. This invokes questions regarding how the sociotechnical is recast in the context of (geothermal) elementality; how does this reframe a view of infrastructure as "a gathering force" (Amin 2014, p.1)? Secondly, if "the most immediately

spatial implication of adopting an assemblage or ANT perspective is their view of space as topological (cf. Martin and Secor 2014)…[, i]n other words, what counts is not metric distance but how closely connected entities in a network are" (Müller 2015, p.35); how does geothermal heat fit this definition? Geothermal heat is earth-bound, whilst it can be understood topologically it is by nature physically immediate, complicating any attempts to fully turn away from an Euclidian ontology. Secondly, there is a need to consider the Earth itself as infrastructural. This provokes questions as to the extent and capacity with which the Earth might be considered infrastructural, and broader questions as to how the infrastructural vocabulary at use within geographical debates might be reframed and enhanced. Approaching the geothermal urban as rhizomatic and relational allows for attention to be turned (albeit not exclusively or with undue bias) to the elemental; demonstrably mobilised through human and non human vectors towards the diffuse and the discrete. Whilst relational understandings of infrastructures have been employed to facilitate spatially expansive and tangibly immediate materialities, there is an additional aspect to such phenomena: the experiential. Infrastructures ultimately channel material flows to a point. In the case of the geothermal urban, geothermal heat is channelled into buildings. Within these architectures, geothermal heat is experienced, and thus it is vital to turn from the infrastructural towards the architectural and the atmospheric.

2.4| Architectures

Architectures have frequently been the subject of discussions and analysis which focus on their formal properties, social uses and meanings (Latham et al. 2009, pp.78–87). These broad approaches to varied architectural forms is reflected, for example, by Reynolds when thinking about the courtyard, which "can represent many things: an oasis in the desert of city streets; a fragment of nature (thus a reminder of natural landscapes beyond the city); a centre of interest for the building; a concentration of light, sound, and water; a life-sustaining refuge of safety and privacy" (2002, p.25). Likewise, Sinou (2007, pp.19–23) highlights the value of, and connections between, architectural and thermal diversity. The former concerns geometry, orientation, urban context, materials, and landscape; the latter temperature and air movement; both towards a semiotics and open to new

materialist interpretations. If infrastructures can be understood as the spread-out networked sites of the assembled materialities of geo urban phenomena, architectures encapsulate the more focused and acute sites of such relations. Architectures can emphasise the geo through their design and use and have the capacity to highlight the unique character of any given natures by either engaging with and incorporating the environment, or contesting and contrasting against it. Reynolds proposes an interesting question: "Did fire generate the courtyard form?" (2002, p.31), suggesting that courtyards developed as places of cultivated heat, through aforementioned pyrotechnologies (Pyne 2012; Clark & Yusoff 2014). Alternatively, Gissen (2014) outlines the complexity of contemporary interior environments, suggesting that nature (the geo) be understood within and through architectures via a complicated contextual politics and agency. Following this approach, Reykjavík's architectures should present a unique and distinct geothermally infused interior environment, constrained within spatial envelopes bounded by man-made boundaries like walls, ceilings, and doorways. This is not necessarily straightforward, though, as Kaika (2005, p.4) notes what may be "perceive[d] as a compartmentalised world, consisting of neatly and tightly sealed, autonomous 'space envelopes' (the homes, the city, nature) [is], in fact, a messy socio-spatial continuum". Viewing architectures as bounded and hermetic is to ignore the porosity and emergent and temporary nature of their material assemblages. Stewart (2014, p.553) in exploring the road, observes how it is "not finished matter or representation but an assembling, registering machinery of impacts and potentialities". For Stewart the road consist of and produces affective atmospheres. Kraftl & Adey (2008) in their consideration of architectures, showed 'how individual buildings and their architect[ures] preconfigure, limit, and engender particular affects', towards distinct affective atmospheres. This section understands architectures as the locus of gathered materialities (following Gissen (2009) and Ingold (2000b) and emergent affective capacities (after Deleuze 1988b; Massumi 2002; Thrift 2007); suggestive of distinct elementally enriched geothermal atmospheres.

Elemental gathering

Gissen outlines how collated "material on smoke, exhaust fumes, dust, the heat of crowds, and mud addressed a type of nature that was wholly undertheorized, underdiscussed, and undervisualized in architecture" (2009, p.21). This lead Gissen to theorise "peripheral and often denigrated forms of

nature", referred to as "subnature" (Ibid.). This subnature is interesting in two ways. Firstly, in reading sections in Gissen's work on atmospheres and matter from a new materialist geopower perspective, it can be noted that the geosociotechnical is indirectly implied. Secondly, this implication outlines how materialities (including the geo, elementality) are gathered by and within architectures. The architectural much like the infrastructural is enthused with geopower in such a way that suggests passing moments in which the geosociotechnical is acutely felt and experienced. Not necessarily exclusive to architectures, but more characteristic of them, architectures act to amplify and focus this gathering of materials. Gissen continues "[s]ubnatures enable us to better understand our environment as a product of social and historical processes, as something tied to social history, as much as natural history" (Ibid., p.213). In the context of the geothermal urban, this may be understood through geothermal energy collecting a moment longer in buildings to form much more acute gatherings of and engagements with the geosociotechnical. Where Gissen's work becomes problematic is in suggesting that "subnatures often operate within social and architectural frameworks, more so than technical or geological ones" (Ibid.). Whilst it is pertinent to suggest that subnatures operate within social and architectural frameworks, this fails to engage the new materialist geopower perspective, which also outlines the geologic and calls for a disbandment of hierarchy.

In The Perception of The Environment, Ingold interprets gathering as "operations that take place in nature, consisting of interactions between human organisms with 'needs', and environmental resources with the potential to satisfy them" (Ingold 2000b, p.46). In this vein, the key purpose of architectures within the context of geo urban phenomena is to gather together distinct materialities to the benefit of humans. This, when applied to the geothermal urban, opens up a line of enquiry regarding the role of architectures: the materialities they gather (specifically geothermal heat), the processes by which they are gathered, the spaces and places (*genius loci*) they create, and in-turn how these materialities might influence these architectures. Kaika (2005, p.5) argues that "although the programming vision [of modernity] was to render cities independent from nature's processes, the materialisation of this vision was predicated upon establishing intricate networks of flows of natural elements…which… wove them together more closely into a socio-spatial continuum". To return to

Gissen's idea of subnatures, this is "not about what is natural to architecture; it is about the natures we *produce* through our most radical architectural concepts" (Gissen 2009, p.214, *emphasis added*). Architectures through this thinking, as the sites of gatherings of complex geosociotechnical materialities, are productive of specific geo urban natures. The processual aspect of gathering, production, allows geo urban phenomena to come into being. To advance this notion of production, we might call apon Farías' observation that "[a]ssemblages do not form wholes or totalities, in which every part is defined by the whole, but rather emergent events or becomings" (2010, p.15). This being (Heidegger 1996), or becoming (Deleuze 2004), is articulated and amplified through architectures (but is also found in and at other sites: infrastructures and bodies). Ingold provides some additional comment, suggesting that: "To be…is not to be in place but to be along paths…[t]he path, and not the place, is the primary condition of being, or rather of becoming" (2011, p.12). What Ingold highlights here, is that rather than reading architectures as fixed and rigid, they are themselves continually coming into being (specifically referencing Deleuze & Guattari's (1987) *A Thousand Plateaus:* 'lines of flight' and 'lines of becoming'). As such, any geo urban phenomena is also coming into being in and through architectures, re-underlining the geosociotechnical through a sense of gathering: "There could be no places were it not for the comings and goings of human beings and other organisms to and from them…[p]laces, then, do not so much exist as occur" (Ingold 2000a, p.1808). Ingold's (2007) 'weather-worlds' are also useful here, the idea that 'to inhabit the open is not to be stranded on a closed surface but to be immersed in the fluxes of the medium, in the incessant movements of wind and weather' (Ibid., p.34). This can be connected with Kaika's (2005) 'porosity' of architectures and notions of geopower and elementality to suggest not just weather worlds but a world of elementality, of life occurring immersed in earth, wind, water, and fire. Two critical points emerge from thinking architectures as gathering geosociotechnical materialities. First, in light of assemblage thinking and geo-agency, it must be thought that geosociotechnical materialities gather architectures as much as architectures gather geosociotechnical materialities. Secondly, these gatherings must poses and multiply a distinct emergent elementality that resonates in and through such architectures.

The geothermal urban is, in various ways, bounded. It might be bounded to individual atoms, it might be bounded by a building, it might be bounded within a body. In drawing-out gatherings, for all its relational qualities, the geothermal urban is presented as absolutely bounded. Indeed, the very nature of geothermal energy – as earthly – is bounded to an oblate spheroid: planet Earth. The geothermal urban must exist in and through spheres: be they the physical planet they originate from, or the ethereal atmospheres they form. Recently, the idea of spheres has begun to surface through the translation into English of Sloterdijk's *Spheres Trilogy* (2011; 2014; 2016), "a vast collection of cosmological and architectural traces that works towards an understanding and exhaustive description of the sites of production of human beings" (Couture 2016, p.55). These sites are understood through various spheres - a sphereology – bubbles, globes and foam. Couture provides an insightful companion to Sloterdijk's work, one that will be used extensively here, noting that: "For Sloterdijk, the metaphor of the sphere is the means of updating[…]spatiality, which calls for a threefold enquiry – microspherological, macrospherological, and plurispherological – into the three gradients of spherological reason (bubbles, globes, and foams) that are used to explain[…]spaces" (Ibid., pp.62–63). That sphereology might be useful in rethinking the geothermal urban is rooted in the idea that "the interest of spherology stems perhaps from the fact that it obliges philosophy to return to being geocentric, if not geodesic" (Ibid., p.57).

With 'globes', Sloterdijk attends to the domestication of the global, that is "human beings…solely interested in the surface of the earth and its naked crust" (Couture 2016, p.70). It has already been noted that the geothermal by its nature is bounded by the globe of the Earth, but it is also wrapped-up in the process of human habitation, landscape transformation – surfacing and infrastructures. With foams, Sloterdijk turns to habitation which can be connected with senses of pampering, homeostasis, dwelling, and hygge (cosiness). There is a regard for "multiple space composed of linked compartments" (Ibid., p.66), the home, architectures, thermospheres as "atmospheric islands" (Ibid.). With bubbles, Sloterdijk turns to the body and the cellular, "[i]ncubating and birth constitute the first spherological exercise and transference" (Ibid., p.72). This paints a sphereology of the geothermal urban bounded to bodies, dissipating towards alternative spheres: from bubbles, to foams, to globes and *vice-versa*. "If coexistence engenders existence, human beings are 'creatures

who inhabited and administered a sphere' (SII 47)" (Ibid., p.55), within these spheres the geothermal urban forms and operates, present within a grand relational and co-creational geosphere. A sphereology of the geothermal urban orientates us towards an affective elementality of life.

Elemental affects

Drawing from the philosophical thinking of Spinoza; Deleuze, Bergson, and Massumi (Deleuze 1988a; Deleuze 1988b; Massumi 1995; Massumi 2002) expanded understandings of the concept of affect, which through the work of Thrift (2000; 2004b; 2004a; 2007) found its way into geography via the 'affective turn' (see also: Lorimer 2008; Anderson & Harrison 2010). Seigworth & Gregg's (2009) introduction to *The Affect Theory Reader*, a foundational volume that draws together varied thinking on affect, provides a description of affect which is striking as it resembles the geothermal:

> "Affect arises in the midst of inbetween-ness: in the capacities to act and be acted upon. Affect is an impingement or extrusion of a momentary or sometimes more sustained state of relation as well as the passage (and the duration of passage) of forces or intensities. That is, affect is found in those intensities that pass body to body (human, nonhuman, part-body, and otherwise), in those resonances that circulate about, between, and sometimes stick to bodies and worlds, and in the very passages or variations between these intensities and resonances themselves".
>
> (Seigworth & Gregg 2009, p.1)

Geothermal heat can be observed as something that "rises in the midst of inbetween-ness", "is an impingement or extrusion of a momentary or sometimes more sustained state of relation as well as the passage (and the duration of passage) of forces or intensities" and is "found in those intensities that pass body to body…and resonances" itself. This similarity is not just metaphorical, geothermal heat can be understood as affective. For Stewart "affect is a surging, a rubbing, a connection of some kind that has an impact…[it is] about bodies literally affecting one another and generating intensities: human bodies, discursive bodies, bodies of thought, bodies of water" (2007, p.128). If affect can be

generated through bodies of water, it can be generated through air, earth and fire. Affect can be understood as something very similar to geopower and elementality.

Whilst "ANT has a richer conceptual vocabulary for analysing the stabilisation of relations", Müller & Schurr suggest "assemblage thinking could and indeed should bring to ANT a greater appreciation of the capacities of bodies to affect and be affected" (2016, p.226). This is especially important given the capacities and character of the geothermal. For DeLanda (2006, p.22), there are "two roles that components play in an assemblage[:] material and expressive". Whilst the material capacities of the geothermal urban have been outlined and theorised in previous sections, the expressive capacities have not. As Bingham & Thrift (2000, p.299) argue, what is missed is "'the sizzle of the event' – in other words, the affective dimensions of interaction between actants" (Jones 2009, p.302). Notably, these expressive capacities are tied to the elementality of the geothermal: heat, warmth, an emotive intensity drawn from a higher temperature. The elemental has an affective capacity, resonance, that exceeds its material form and expands its agency. Further, the geothermal affects and is affected by other (human, urban) materiality. "[N]ot only are humans as material as the material they mould, but humans themselves are moulded, through their sensuousness, by the 'dead' matter with which they are surrounded" (Pels 1998, p.101, *cited by*, Whatmore 2002, p.141) - this 'dead' matter being the geothermal, which has been revealed to be anything but dead (Grosz 2008; Bennett 2010). What is key to recall here, is that existing relational understandings of urbanism have underplayed the power and multiplicity of the geo and in doing so have muted its affective capacities, resulting in a failure to fully know such phenomena. Through this, fault can be found with the idea that "[f]or Husserl, in the words of Jaques Derrida: 'the earth… is the *exemplary* element (being more naturally objective, more permanent, more solid, more rigid, and so forth, than all the other *elements*; and in a broader sense it comprises them)'" (Clark 2012, p.23, *emphasis in original*). There is no doubting the thermal (heat, fire) as an element finds its way through earth, air, and water; questioning any exemplary status afforded to earth. Indeed, as Gandy (2014, p.224) says of water, can and must also be said of heat: "[It] remains vital and elusive; in its oscillation between different cultural and material realms, it underpins both the limits and the possibilities of modernity".

Elemental Atmospheres

As multiple affects gather, multiply, and build, they are understood to form atmospheres: atmospheres "invisible but sensed within our bodies, as feelings, and understood and expressed, as emotions: while the three (affect, feelings and emotion) are interrelated and all work together, they are never quite the same (McCormack 2010, p.643; see also Anderson 2006)" (Pile 2010, p.8). As Stewart explains further, '[t]he ordinary hums with the background noise of ruts and disorientations, intensities and resting points…[a]n atmospheric fill buzzes with the resonance or nascent forms quickening or sloughing off, materialities pressing into the expressivity of something coming into existence' (Stewart 2011, p.446). Pile and Stewart understand atmospheres as gatherings of affect which are sensed. Gandy explores "some of the tensions and anomalies that permeate contemporary understandings of urban atmospheres" (2017, p.353), noting that "[u]rban atmospheres cut across strikingly diverse ontological realms…marked by shifting geometries of perception" (Ibid., p.368). By specifically attending to atmospheres via air, Gandy concludes that "[t]he intensity of affective atmospheres, and their socio-spatial capacities, moves our focus from the bounded human subject towards more porous forms of urban sentience (Ibid., p.369). The 'socio-spatial' echoes the socio-technical, and whilst for Gandy air (as elemental) possesses affects, there is a sense that *geo*-socio-spatial capacities should be centred. Geothermal affect should be understood as mimicking its materiality. Just as heat seeps through infrastructures, into architectures and bodies, it has an affective capacity that plays through and with these sites. "An atmosphere is not an inert context but a force field in which people find themselves" Stewart continues, "It is not an effect of other forces but a lived affect – a capacity to affect and to be affected that pushes a present into a composition, an expressivity, the sense of potentiality and event" (Stewart 2011, p.452). The affective 'force field' in this way, is the distinct and unique atmosphere of geothermal urban place; hygge[14], it's *genius loci*: "atmospheres are real phenomena…[t]hey 'envelop' and thus press on a society 'from all sides' with a certain force…[on] the other, they are not necessarily sensible phenomena" (Anderson 2009, p.78).

Zumthor (2006) considers the atmospheres that architecture forms to be those of feeling and sensation, mood, emotive. Presented through the case of an 'elementary experiment', Zumthor

[14] cosiness, comfort (see: Bille 2014)

(Ibid., pp.15–19) talks about the experience of the warmth and shade of a flower market within a square, “I remove the square and my feelings disappear”. The affective capacities of heat are considerable, mobile, and multiple and thus so are their atmospheres. Thrift's (2004, p.83) concern that geography can be frustrating, that “[m]uch of it seems to follow the logic of the corpse, interested in the broken, the static, the already passed” can be seen to be remedied by a non-representational view of the geothermal: “forging a new kind of ethics, one which is concerned, above all, with changing our stance to the world by working on the faculty of judgement as it is actually exercised – in the immediate present” (Ibid., p.93). Theorising the *affective* geothermal urban, geothermal urban *atmospheres*, requires an alteration and update of its political ecology to consider the pre-cognitive (Pile 2010, p.8) agency of the thermal – its elementality and elemental atmospheres. Thrifts call for “a kind of politics that is about producing situations in which new ‘orders’ can speak and, even if in the most limited of ways, produce points of emergence” (Thrift 2004b, pp.96–97). Thrift suggests three kinds of politics , the politics of readiness, witnessing and intercession, “each of them of affective, experimental, plural” (Ibid., p.97). This translates as a call for a better political ecology, or as Thrift phrases it, a “need to be more political” (Ibid., p.98). This journey into the affective atmospheres of the geothermal urban is pinned to a political ecology of the emergent: “[a]tmospheres are perpetually forming and deforming, appearing and disappearing, as bodies enter into relation with one another…[t]hey are never finished, static or at rest” (Anderson 2009, p.79).

This section explored how existing literature has understood architectures as the sites of gatherings (Gissen 2009; Ingold 2000b) of vital (new) materialities and have the ability to amplify inherent affective capacitates (Deleuze 1988b; Massumi 2002; Thrift 2007) forming distinct affective atmospheres (Anderson 2009; Stewart 2011); a *genius loci*. Exploring the affective and atmospheric capacities of the geothermal urban has been foregrounded as an essential aspect of engaging both the geopower and elementality speculated as a critical part of such phenomena. Gandy asks: "Does an emphasis on atmospheres offer fundamentally new insights or merely a semantic shift?" (2017, p.369). The literature above would strongly suggest new insights, especially in attending to affective atmospheres through an elemental geopower. The geothermal urban should be approached as a

"maelstrom of affect" (Thrift 2004b, p.57), bearing there needs to be further attention to "the embodied experience of technological networks, different conceptions of agency, [and] the microcomponenets of urban space" (Gandy 2014, p.5).

2.5| Bodies

To arrive at the body is to arrive at the most immediate of human sites, and one that is unquestionably tied to geo urban phenomena. For Rodaway (1994, p.31) the (human) body provides "orientation", "measure", "locomotion" and a "coherent system", contributing "both to spatial and temporal perception" and "mediates between us and the environment, giving us access to a world beyond itself" (Ibid.). Further, Rodaway suggests that the various senses might work in "cooperation", "hierarchies", "sequences", with "thresholds", and with "reciprocity" (Ibid., pp.36–37). This reminds us that the body is a versatile and complex tool, which impacts on the environment it occupies as much as the environment impacts upon it. In approaching geo urban phenomena we cannot avoid the human body's role: as a part of phenomena's materiality, as a part of networks and relations, and as having its own affective capacities. This section approaches the human body in the spirit of "throwntogetherness" (Massey 2005, pp.149–162) to consider its involvement in the production of the geo urban. In doing so, it is suggested that existing literature concerning embodiment and hybridity (Whatmore 2002) may be enhanced by the concepts of geopower and elementality to position the human corpus as an essential site of geothermal urban phenomena.

Elemental embodiment, elemental hybrid

One of the special qualities of the elements is that they connect with each other. Heat is no exception; radiating, convecting, and conducting into and through earth, water, and air. In doing so, it interacts with bodies in multiple ways: "each human uses around 360 litres [of air] per hour…[w]e push and pull it in and out of our bodies, infusing blood with the oxygen from the air" (Adey 2014, p.7). In the simple act of breathing, a body within a geothermally heated home becomes immersed in geothermal heat as warmed atoms enter the lungs and bloodstream. This "suggests a kind of intimate geography; one which begins with the senses and reaches out to questions of sense and

reality" (Rodaway 1994, p.x), wherein "the ongoing emergence of urban space is a process in which bodies of all kinds participate, metaphorically, materially and affectively" (Latham et al. 2009, p.113). Through bodies, within the urban, the geothermal may be pre-consciously engaged (warming), felt (warmth), and given meaning (warmed). This means there is a need to take seriously the sensual abilities of the body and with that the value of accepting and investigating a sensuous geography that: "may…lay some claim to reasserting a return of geographical study to the fullness of a living world or everyday life as a multisensual and multidimensional situatedness in space and in relationship to places" (Rodaway 1994, p.4).

Tuan (1977, p.36) comments that "[t]he human being, by [their] presence, imposes a schema on space…[and m]ost of the time [they are] not aware of it". In addition to this Squire obsevres how attending to the geo urban can "demonstrat[e] the significant intersections between the elemental and the human body" (2016, p.545). Whilst both these authors note how the body might impact upon place, nature and the elements; the body may also be impacted by all that surrounds, immerses, and goes through it. For Squire, there is a significant value in moving to "elucidate the intricate relationships between bodily volumes and elemental volumes", wherein "site specific qualities of the elements and how their (in)visibility can in itself unearth geopolitical fractures, realities and possibilities…mak[es] the case for an elemental ontology" (2016, p.546). McCormack suggest that "it might be that bodies are not simply immersed in an elemental field that exceeds them, but that bodies are themselves also elemental...[a]nd it might be that we need to devise a range of new ways of thinking about the relations between these bodies" (2015, p.87). This leads to two lines of enquiry. Firstly, what might these new ways of thinking be? Secondly, does this require a rethinking of human bodies as themselves geological?

In attending to the former, Squire suggests that we may attempt to head towards "an elemental ontology that functions through and with the proclivities and molecular specifities of the elements" (Squire 2016, p.545). This, "in order to better understand…the relationship between elemental and bodily volumes, and the site specific geopolitical realities, fractures and possibilities that are laid bare as the elements are unearthed" (Ibid.) In attending to the latter, we must think about how we

understand bodies some more. A point of departure here, is Whatmore's *Hybrid Geographies* (2002), which "diagrams between the technical and corporeal emphases" (Ibid., p.5) and undertakes "efforts to accommodate 'non-humans' in the fabric of the social" (Ibid.). Drawing upon relational approaches proffered by ANT and Science and Technology Studies (STS) Whatmore expands and unpacks hybridity to "force us to attend to ways in which the nonhuman makes its presence felt in social life and to find a way of registering [this]…in our accounts of the world (Ibid., p. 145). Whatmore's development of hybridity is deliberately and necessarily multivariate, but might be summarised as "more than just the conjoining of differing elements to make new compounds; hybridity is a characteristic of the elements themselves" (Jones 2009, p.301). For Jones, "The capacities of hybrid bodies or assemblages are greater than the sum of their parts" (Ibid., p.301), suggesting a view of the wider geo(thermal) urban as an elemental hybrid. Kaika sees "the city…exemplified as the metabolic and social transformation of nature through human labor, a 'hybrid' of the natural and the cultural, the environmental and the social" (2005, p.27). Applying this to Gandy (2002), Kaika continues to note that "the creation of urban infrastructure has been essential to…economic viability…and at the same time has fostered possibilities for new kinds of mediations between nature and society" (Ibid., pp.74–75). The geothermal urban under these parameters is hybrid:

> "The primary feature of hybridity is clearly the idea of integration and diffusion, of a thing that is derived from heterogeneous sources, and composed of incongruous elements…It is hybridity itself that has provided the broadest interpretive framework for the idea of a creative mixing process that has led to the formation of something distinctly new and different, but that contains within it the (often contradictory) traces of its progenitors".
>
> (Mitchell 2005, p.188)

Mitchell interestingly draws out Batkin's (1981) thinking on hybridity as either 'organic' or 'intentional'. This thinking is originally applied to linguistics, but can also deployed as a way to demonstrate the two ways in which the geothermal is hybridised. The connect here, is with thinking the geothermal urban as incidental or constructed. It is incidental (organic) when geothermal heat happens to rise up from the ground, through geothermal fields that happen to be under Reykjavík. It

is constructed (intentional) when it is domesticated and is involved in a geo-sociotechnical process, or hybridised: "…[H]ybridity is often celebrated as a process rather than a thing; its inherent resistance to fixed binaries causes it to remain in a perpetual state of flux, related to and yet not originating form or causing other moments, spaces or entities" (Mitchell 2005, p.189).

Elemental cyborgs

Haraway's Cyborg Manifesto paves the way for thinking "a hybrid of machine and organism" (Haraway 1985, p.291). For Haraway, "we are cyborgs[, t]he cyborg is our ontology; it gives us our politics…an argument for *pleasure* in the confusion of boundaries and for *responsibility* in their construction" (1991, p.192, emphasis in original). In developing a cyborg thesis, Haraway suggests three "boundary breakdowns": firstly "the boundary between human and animal is thoroughly breached", second "there was always the spectre of the ghost in the machine", and thirdly "the boundary between the physical and the non-physical is very imprecise" (Haraway 1991, pp.193–194). Gandy observes how, "If we understand the cyborg to be a cybernetic creation, a hybrid of machine and organism, then urban infrastructures can be conceptualised as a series of interconnecting life-support systems" (2005, p.28). If urban infrastructures can be life support systems, then how about the elemental itself? Human life depends upon homeostasis, requires water, breathes air and must have a footing on and in the Earth – elementally reliant. "Haraway comments that the genetic space of the cyborg pertains to the lived geography of women in circuits of culture and capital" (Shields 2006, p.211), might these circuits be opened up to include the geothermal? Gandy goes further, to note that: "The reading of the city as a 'cyborg' highlights the tension between a focus on the technological augmentation of the individual human body and the wider sets of technological networks that sustain modernity" (Gandy 2014, p.11). Why not also add to that tension the geo, mindful that Bennett's "notion of 'distributive agency' creatively affirms the necessity of human embodiment, understood as one site of agency within and across a multiplicity of other material bodies and formations" (Khan 2012, p.42).

Drawing from Shields (2006), the cyborg "emerges relationally at concrete sites of action" (Farías 2010, p.5). It is possible to apply this to two understandings of the geo urban. Firstly, that the geo

cyborg exists in a fixed spacetime, a locality, that can be understood through distinct envelopes of differing natural influences. Secondly, that the geo cyborg comes into being, is formed, in such as way that it is processual. Whilst we can view the geothermally warmed body as cyborgian and formed of a processual relationality, there is one critical observation to be made: what of the elemental, the geothermal? The cyborg is a concept which speaks to the processual hybridity of the technological and the human, but what about the geological, geodynamic, elemental: "the human is always in excess of itself…[i]f thinking, inventing, acting, are characteristics of even material forces, then the human is composed of intensities that are themselves not human, or not only human" (Grosz et al. 2017, p.143). Farías points out that "'cyborg urbanization' displaces the focus of attention from the city as a sociotechnical system and enormous apparatus to hybrid forms of being human" (Farías 2010, pp.5). In doing so any sense of the *geo*, not lest the elemental, about the cyborg has been neglected. Whether you turn to a vast district heating system, a cosy enclosed architecture, or an individually warmed body; the geothermal is critical. Further, even if the geothermal is put aside, the technologies involved in creating the cyborg are inherently geological. Any modern day smart-device will have in it components that were mined from the Earth, let alone the metals and minerals that make up vast infrastructure networks like Reykjavík's heating system. Haraway comments (1992, p.297) that "[i]f the world exists for us as 'nature', this designates a kind of relationship, an achievement among actors, not all of them human, not all of them organic, not all of them technological". Not all of them organic, not all of them technological: some of them, the geothermal urban suggests, geological.

Questioning geothermal urbanism

The provision of geothermal energy points to a distinct and different relationship between landscapes, technologies, and practices of warmth and warming; alternative to other energy uses and urban environments. To draw on Hinchliffe, these "are practical, empirical… spaces of variability…for and of…bodies, rocks, office blocks…spaces of and for difference" (Hinchliffe 2007, p.61). These differences, which may be subtle and overlooked, stand to speak back to much broader disciplinary concerns with nature and society. The concepts addressed above form a theoretical bridge between discreet phenomena and wider concerns, but "are not of themselves enough to allow us to

understand the way things work, don't work and the manner of reality that we want to call nature" (Ibid. 2007, p.69). An interest in the geothermal urban thus proceeds focused on the distinctiveness of the phenomena in question, and further contextualised by and able to contribute to, wider (multi)disciplinary debate.

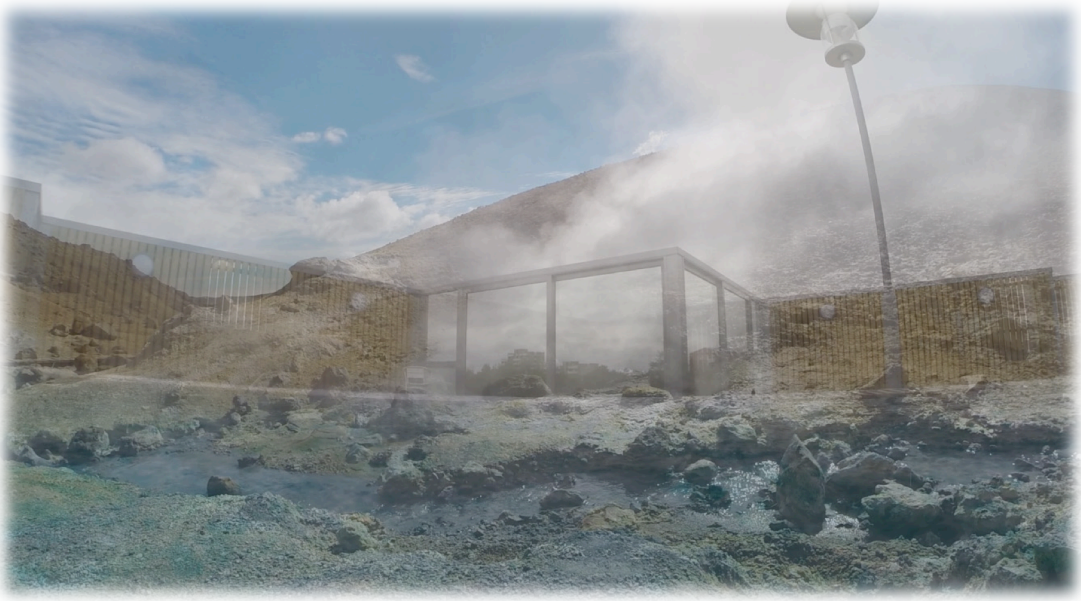
This chapter has allowed some speculative assumptions to be formed, suggesting how the geothermal urban might be understood based upon the academy's analysis of other geo urban phenomena. In doing so, it has outlined how a move towards an ontology of the geothermal urban must draw upon a holistic and relational geography, with a need to be "post-phenomenological…to foreground the non-humans of which the human is composed" (McCormack 2015b, p.88). To progress further, these ideas need to be developed in light of fresh empirical observations and analysis; "theories seek to connect a variety of empirical evidence to construct an explanation…to make the city legible to us in some way or another…an attempt to think space in a new manner" (Hubbard 2006, p.10). Through this chapter, three principal issues have emerged from gaps within the current literature. Adapted, these form focused research questions that address the aim to better understand the distinct places shaped by human processes and proximity to geothermal heat. Further, they all work towards developing a conceptual vocabulary with which to define observed forms of geothermal urbanism:

1. How might the relation between the geothermal and the urban be understood? *This concerns the issue that the geothermal urban comprises opaque boundaries (geothermal fields are "spatial fuzzy sets" (*Fisher et al. 2004, p.106) *open to interpretation) and is under-theorised. The geothermal field and the geothermal are somewhat synonymous, and require a reconsideration in light of post-structuralist and new materialist geographies, relational thinking, geological agency, and elementality.*

2. How is the elementality of the geothermal articulated through infrastructures, architectures, and bodies? *This question responds to a concern for the gap in understanding non-carbon geologic (geothermal) agency. It seeks to draw out the unique elemental properties of geothermal urban materialities; thinking through forces, structures, capacities, and qualities.*

3. What kinds of practices and places are characteristic of geothermal urbanism? *This is in response to the practices and places of the geothermal urban, geothermal urbanism, being undefined. It seeks to understand some of the discreet embodied practices that form and emerge from the geothermal urban, and map out more distinctly the spaces and places of geothermal urbanism.*

- vignette ii -



Emerging.



Hot springs and swimming pools.
Fumaroles and pumping stations.
Geothermal energies surface at Krýsuvík & Rekyjavík.

3| Attuning to the Geothermal

"A real difficulty is in just apprehending the sensation of a ubiquitous, sometimes ritualised, often taken-for-granted exposure to geothermal energies in Reykjavík.

Everyday I take a shower. On some days the heat seems over-powering and the sulphuric smell potent. There is a moment of 'geo-shock' as the chthonic energies rush into the home. A form of domesticating nature, and of nature flooding the domestic setting with a chaotic energy. On other days, the shower seems less warm, and the smell far more subtle. These energies drift in and out of focus: sometimes overt, sometimes subtle. Poetically like the steam that might escape from Reykjadalur valley, or the shower-head in my home, or a faucet in a cafe.

If I just wash my hands under a hot water tap - say doing a chore like the washing up - I take far less notice. Possibly because I'm not naked or attending to my own body and am somehow less exposed. And then, I might go for a swim, and it all becomes far more obviously ritualised. There is a social complexity connected to geothermally-heated public swimming baths in Iceland. Rules that insist you take a naked shower before swimming. And in a way the contact with these energies, the heat, becomes more personal and the pre-personal aspect intensifies.

And then it is all so subtle again. Pipes directing flows of energies underfoot. Entirely unnoticed."
- Field notes, 12th June 2014

"Is the encounter at the heart of fieldwork ultimately unspeakable?"
- (Laurier & Philo 2006, p.353)

"[G]eopowers are what create the public realm"
- (Yusoff 2017, p.122)

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Understanding geothermal urbanism sets up the task of successfully apprehending geothermal urban phenomena. This chapter provides an account of the methodology deployed to engage and understand the geothermal, geologic, and elemental in an urban context; turning to infrastructures, architectures, and bodies as key sites. It justifies the application of an underpinning elemental, geologic, more-than-human rationale (Whatmore 2006), and provides a reflective and critical chronological summary of a geothermally focused field practice. Drawing upon actor-network-theory's distributed understanding of materiality in flux, the geothermal urban has been speculated as a form of assemblage (DeLanda 2006; Farías & Bender 2010), and a methodological direction tied to the need to trace, apprehend, and attune to the geothermal within urban loci presents. With a concern for the emergent nature of the geothermal, the urban, and thus the geothermal urban; the

chapter explores methodological techniques that allow a following of the various pathways of geothermal extraction, distribution, and utilisation are foregrounded. In this way, the emphasis is on how "[t]he path, not the place, is the primary condition of being, or rather of becoming" (Ingold 2000a, p.1808).

The first section outlines a research design concerned with *apprehending the experience* of the geothermal within an urban locus. It turns to the practicalities, positionality, and ethics of locating and tracing the geothermal, and the need to become geothermally warmed in order to engage and understand its capacities, qualities, and urban articulations. This is presented as an 'attunement' (Stewart 2011), understood specifically through a process of contextual (literal) warming ('*hlýnun*'), and drawing upon a 'more-than-representational' (Thrift 2004b; Thrift 2007) approach to fieldwork. The following two sections justify and detail the fieldwork process, outlining the practical engagements employed to produce vibrant, insightful, and valuable field materials: digital video recordings and photography produced through site exploration, and field interviews. The former is a performative, immersed and embodied engagement with the geothermal (see also: Shepherd 2019), very much embroiled with a literal warming and designed to apprehend the subtle, affective, and atmospheric; exploring a geothermal urban world. The latter is the undertaking of geothermally focused conversations, which relay the experiences (past) and experience (present) of life with (and without) geothermal energy; exploring geothermal urban lives. Combined, these 'ethnographic exposures' (Dewsbury 2010, p.327) form empirical, lively and informative, 'generated materials' (as per Whatmore 2003) with which to discuss and understand geothermal urban phenomena. Engaging and employing these methodological approaches presented challenges, and the difficulties and limitations met in the completion of the practical study, and which shaped the research, are critically reflected upon in the context of the fieldwork narrative. Following on from this, the final section turns to the period after elemental fieldwork, and discusses the complexities of working with, and making use of, more-than-representational and elementally imbued materials. In closing the chapter, a number of evaluative observations are made regarding the effectiveness of such methods for engaging the elemental and the geologic, and their potential for contributing to other research agendas.

3.1| Hlýnun (Warming)

As geothermal heat passes through Reykjavík, its thermal energy transfers, heating the city. The methodological scope and direction for this research is shaped by questions concerning the relationship between the geothermal and the urban; the articulation of geothermal elementality through components of the city - infrastructures, architectures, and bodies - and geothermal urban practices and places. Geothermal urban phenomena, by virtue of its inherent heat, is both warming and experienced as warmth. Resonating from pipes, within buildings, and through bodies, to engage and understand the geothermal requires being warmed by it. As such, a suitable method for exploring the geothermal is one of warming – to it and by it; which localised within its Icelandic context can be termed *hlýnun.* That is, metaphorically in attuning (Stewart 2011) to Reykjavík´s geothermal urban environ - but also literally, wherein as a researcher *I was warmed* (and had to allow myself to be warmed) by the geothermal in order to understand it within an urban context (following Latour 2004, p.205: "learn[ing] to be affected"). This section sets-up the task of developing a research design concerned with geothermal phenomenology, outlines theoretical underpinnings that provide a pathway for apprehending the elemental, and presents the rationale for generating pertinent empirical field materials through a process of becoming geothermal.

Geothermal orientations

A method for apprehending the geothermal urban must have regard for geologic agency, geo-power, and geothermal elementality (as outlined within Chapter 2). It needs to have a specific concern for making the elemental explicit on geothermal terms, so as to permit an analysis and understanding that clearly draws upon geothermal urban phenomena. In turning to Yusoff's (2013) “Minoritarian Manifesto for Reoccupying the Strata”, locating the geothermal would necessarily involve being lodged into unexpected forces and flows, modes of geologic expression, and surprising subterranean turns (literally and conceptually). In and around Reykjavík, various sites present opportunities for engagement with geothermal heat: points of geothermal origin (in the context of their urban connectedness), pipes, wires and cables, hot-water storage tanks (emphasis here on spaces such as Perlan, which double up as cultural spaces), historical locales (geothermal energy has been formally used since 1930), streets, roads and neighbourhoods (that, for example, benefit from underground

heating during winter), public spaces (such as the man-made Ylströnd thermal beach, or the Seltjarnarnes hot-pot), spaces of public art (Ingólfstorg, National Theatre), and everyday spaces (offices, cafés, homes) which are warmed by geothermal heat. These sites are echoed in research into other geo-urban phenomena which has centred around the built environment and the lives lived within and through them (see: Chapter 1). This raises the importance of a research design that is able to focus-in and draw out the explicit aspects of the geothermal within the urban; not merely as heat recorded by thermometers or mapped within system diagrams, but as a lived and embodied experience – as geosociotechnical (Chapter 2). These sites offer opportunities to explicitly engage and examine the geothermal as revealed and moderated via urban processes, technological systems *and* lived experiences (and in-turn raises the spectre of geothermal excess through breakdown, over-exposure, or failure to contain or manoeuvre the geophysical). They form lead 'trenches' from which, what Laurier & Philo (2006, p.359) term "'ethno-archaeological' routes" can be explored; key starting points from which the geothermal urban can be sought, experienced and located, "predicated on close attendance to 'what's happening here'" (Ibid.).

Opening up emergent assemblages, such a methodological approach permits the apprehending of "forms and the ways in which these forms *register* forces of all kinds" (Stewart 2014, p.449). This tracks closely with Adey's interest in elemental affinities which allow a "leaping beyond material substances…to a wider and yet intimate terrain of bodies, practices, cultures and technologies" (Adey 2015, p.60). Geologic agency and geothermal elementality are to be uncovered through close attention to a geothermal phenomenology that is tied to everyday human lives. This requires engagement with the distinct and discreet aspects of Reykjavík's geothermal urban environ, focused on drawing-out explicit geothermal qualities and capacities tied to infrastructures, buildings and bodies. A method concerned with apprehending the geothermal (its geologic agency and elementality), must engage the "urgent need to supplement the familiar repertoire of humanist methods that rely on generating talk and text with experimental practices that amplify other sensory, bodily and affective registers and extend the company and modality of what constitutes a research subject" (Whatmore 2006, p.607). Following this call, geothermal urban field sites are "to be understood less as a site 'out there' at which research takes place, but a space of distributed agency,

action, and encounter within which research materials are not so much discovered as co-generated" (McCormack 2008, p.5). Stewart's approach drawing "analytic attention to the charged atmospheres of everyday life" (2011, p.445) - understood as a process of 'attunement' - works as a key methodological direction here.

Apprehending the elemental

Recently, geographers have pushed further on the limits of methods and empirical materials to question 'representation'. This is exemplified in "non-representational theory", associated closely with the work of Nigel Thrift (2000; 2004a; 2004b; 2007), but ranging beyond to include various approaches. As Anderson & Harrison put it, "non-representational theories are a set of predominantly, although not exclusively, poststructuralist theories that share a number of questions or problems; how do sense and significance emerge from on-going practical action?" (2010, p.23). "Non-representational theory is…a machine for multiplying questions" (Thrift 2004b, p.82) and "a useful toolkit, a means of amplification" (Ibid., p.83). Non-representational geographies are valuable here, as they "attend to both life and thought as practiced…'in process' and 'open ended' (Cadman 2009, p.456). As non-representational theory draws upon phenomenology, new vitalism, and post-structuralism (see: Cadman 2009, p.457; Thrift 1999, p.303), it provides routes with which to develop and apply elemental methods. A non-representational approach to the world is designed to counter the 'inevitable scientism' (Dewsbury 2010: 322) that is seen as problematic in interrupting attempts to ascertain authentic understandings. It importantly permits an engagement with the geosociotechnical and non-carbon geologic agency on terms which allow for animation, vitality, and the pre-cognitive, so critical to heat and warmth.

A non-representational, or, as is perhaps descriptively preferred a more-than-representational[15] (Lorimer 2005, p.84) methodology, is 'a diagnostic tool…that takes some of the specificities of the present moment and weaves them into what might be called a speculative topography" (Thrift 2007, p.2). It seeks to "describe and present rather than diagnose and represent' (Cadman 2009, p.461) and

[15] Authors variably use 'non-representational theory', 'nonrepresentational theory', 'NRT', and 'more-than-representational'. My preference is for the latter as it underlines attempts to get away from representation but does not render representation obsolete; however, I interchangeably use each phrasing as per the authors which are being engaged.

in terms of being methodologically experimental, fosters "a hybrid genre for a hybrid world" (Vannini 2015b, p.3). This approach is important as, given the prominence of geologic agency as a critical point of question, "[n]on-representational theory and vitalism share a conviction that *worlds are sensed not just seen"* (Greenhough 2010, p.43, *emphasis in original*). Geothermal urbanism is wrapped up in events, relations, doings, resonances, and backgrounds (see: Vannini 2015b, pp.7–9), and a more-than-representational method can be explicitly employed to elucidate and enhance these qualities: to make the elemental explicit. This is to apply a method that attends to the "background 'hum' of on-going activity" (Anderson & Harrison 2010, p.7; see also: Lorimer 2008, p.556), the 'hum' in this case being geothermal heat. As "recent geographical work in a non-representational register has made novel and significant contributions to our understanding of socio-material events and encounter" (Popke 2009, p.84), the way is paved for a geothermal urban application. Indeed, "[t]he little, random cases or atmospheric attunements that [present in Stewart's work]…suggest something of the plasticity and density of lived compositions now proliferating in ordinary scenes of living" (Stewart 2011, p.446). As Stewart explains further, "[t]he ordinary hums with the background noise of ruts and disorientations, intensities and resting points…[a]n atmospheric fill buzzes with the resonance or nascent forms quickening or sloughing off, materialities pressing into the expressivity of something coming into existence" (Ibid.).

This is not to suggest that a more-than-representational approach is a "totalising discourse" (Graham 2005: 14) or panacea. Nonrepresentational geographies have been critiqued for neglecting the importance of representation, and for ignoring or underplaying power (Cadman 2009, p.462; see also: Cresswell 2012). However, this approach does open up the political and ethical. For Thrift (2004b, p.97) three kinds of politics are caught up with the non-representational: the politics of readiness, the politics of witnessing, and the politics of intercession. Drawing on this (as well as connecting to Thrift 2004a), Cadman (2009, p.461) outlines how non-representational theory has ethical and political consequences in its centring of affect, underlining of potentiality, and in placing the political and ethical within the more-than-human (by virtue of the precognitive). As an implication for deploying a more-than-representational method to explore the geothermal urban, the significant political and ethical value is in the foregrounding of geothermal affect within urban loci. This takes up

McCormack's (2003, p.501) suggestion that "the process of research must in and of itself take seriously the eventful…bound up in movements and relations that are no less important for being pre-personal and pre-cognitive", attending to the "ethical potential" of "enlivening any field…with transversal qualities of affect". This underlines the value of attuning to the geothermal as "we come to know and enact a world from inhabiting it, from becoming attuned" (Anderson & Harrison 2010b, p.9). A more-than-representational methodological approach offers a way with which to proceed with investigating the experiential aspects of the more-than-human on terms which seek not to constrain non-human phenomena. With regards to the geothermal urban this promotes the critical value of a research design that is concerned with attending to the elemental, geothermal geopower, and orientates a researcher to consider how methods might engage the capacities and qualities of such phenomena that are lost through representational techniques. This means approaching the geothermal urban in such a way that it is apprehended authentically and creatively, rather than reduced to maps, figures and data sets. It seeks materials created within and that echo the lived experience of the geothermal urban, rather than measurements like temperature, grid references and system diagrams, which alone limit an authentic understanding of the phenomenology of the elemental. The more-than-representational presents an epistemological framework with which to develop and employ practical undertakings that are generative of insightful elementally infused empirical field materials.

Becoming geothermal

> "That evening, myself and Hannah had invited a host of mutual friends to catch up over pizza. We had intended to play some games too, but the conversation took over. Throughout the evening I popped over to the two radiators that were heating the main living space – with the number of bodies (and possibly warm food) it was getting a little hot. The 'west' radiator went down from 4 to 2. The 'south' radiator went down from 5 to 2. The radiator in my bedroom was off. The next day I successfully didn't leave the flat. A flurry of emails and phone calls were sent and received to secure interviews with various contacts. At some point, one that I can't recall a day later, the radiators went back from 2 to about 4 each. As evening came and I also put lights on in the flat (all with warm yellow-ish bulbs and all lamps or small spot-like lights in the ceiling), and I felt rather snug. It occurred to me that

> the cosy feeling had a lot to do with having the heating on. A nicely lit room that was cold would not have felt cosy at all."
>
> Field notes, 2nd-5th February 2015

Locating the geothermal is itself a form of attunement, but once discovered, phenomena need to be contextually engaged, which requires an "emphasis on experience" that "encourages an affirmative ethos of experiment" (McCormack 2010b, p.203). For the researcher this also means "an ethical commitment to learning to become affected (in a Spinozist sense) by the relational movement of bodies" (McCormack 2008, p.9; see also: Dewsbury 2003 on 'witnessing space'). Becoming geothermal[16] was achieved by undertaking forms of geothermal dwelling: spending time in the spaces and places of geothermal heat, warming up and cooling down. This was through embodied acts like taking a shower in geothermally warmed water, sitting in a geothermally heated café, walking along a geothermally heated pavement, taking a swim in a geothermal pool, or standing by a geothermal pumping station. It required a specific regard for locating geothermal heat, attuning to its capacities and qualities, and tracing its complex integration with daily human life. This was a method that "involves an intensification of problems and requires staying with those problems for a while" (Anderson & Ash 2015, p.48). The initial practical action involved exploring Reykjavík to discover and engage initial sites where the geothermal urban was explicit, followed by seeking out where the heat went and how. Being in Reykjavík is to become geothermal, so inescapable is geothermal warmth, but its pre-personal and pre-cognitive affect is all-too-easy to miss. This is underlined further by McCormack, noting "the process of research must in and of itself take seriously the eventful matter of fact of its own emergence, and the matter of fact that this emergence is thoroughly bound up in movements and relations that are no less important for being pre-personal and pre-cognitive" (2003, p.501). However, this is no "argument for losing [oneself] in the activity and deterritorializing… completely from…academic remit" (Dewsbury 2010, p.326); there was a need to continually reflect and re-attune to the geothermal.

[16] See Wylie (2002) for an alternative take on "becoming icy".

Geothermal attunement, becoming geothermal, is not a useful research practice if it is not in some way productive of field materials. This is not so straightforward, though, when the geothermal "does not speak…[and w]e have to learn how things, processes, events – inhuman forces in their broadest sense – address us without language ever being adequate for the task" (Grosz et al. 2017, p.145). This requires an engagement with what Hawkins' terms geography's "creative (re)turn" (2015, p.248) and a move towards the performative (Bolt 2004; Haseman 2006; McCormack 2009). Whereas "[d]ifferent modes of representation can unearth ironic or unexpected elements that might otherwise remain hidden" (Gandy 2014, p.23), different modes of more-than-representation can unearth the elemental that is embedded in the pre-cognitive. This is especially valuable as "reframing research as a creative, performative practice allows the researcher to address some novel questions about the cultures of everyday urban experience that more conventional, representationally orientated, methods fail to address adequately" (Latham 2003, p.1994). Because of this, geothermal urban affects cannot "be laid out on a single, static plane of analysis…[t]hey are, instead…emergent in disparate scenes and incommensurate forms and registers; a tangle of potential connections" (Stewart 2007, pp.3–4).

By performative, what transpires is an engagement with the geothermal through embodied actions that allow for a literal warming: "performativity means tuning-in to the event-ness of the world, taking a witness stance to the unfolding of situated action, and being open to the unsettling copresence of bodies affecting each other in time-space" (Vannini 2015a, p.321). Further, a performative approach to research fits with a non-representational framework in that, "[s]ince non-representational theory does not proffer any single methodology, it propagates instead a raft of creative approaches and techniques, rethinking the usefulness and purpose of empirical investigations" (Paterson 2009, p.779). This creative approach is essential to remedy concerns that "there are conceptual limits to just how the field is being rendered as a site of affect and how it might be researched" (Adey et al. 2013, p.301). Performative methods do not require some elaborate re-imagination with which to attune to and apprehend the geothermal urban: "rather than ditching the methodological skills that human geography has so painfully accumulated…we can imbue traditional research methodologies with a sense of the creative, the practical, and being with practice-ness" (Latham 2003, p.2000). Whatmore points at "research as a process of knowledge production…[that]

is always, and unavoidably, an *intervention in the world* in which all those (humans and non-humans) enjoined in it can, and do, affect each other" (2003: 90, *emphasis in original*). Ultimately a methodological focus on attunement, to be warmed by the geothermal, becoming geothermal, living geothermally, is to in some way have a 'conversation' with a geothermal urban landscape (see: Benediktsson & Lund 2010)[17] that pushes further in more-than-human, geologic, and elemental terms distinct from other phenomena.

As will be discussed next, exploring and understanding geothermal urbanism through practical fieldwork involved hybridised applications of familiar methods: videographic recordings, photography and interviews; albeit with a concern for geologic agency, elementality, and a more-than-representational ethos. The fieldwork unfolded through two periods of geothermal attunement (See Fig. 3.1). The first was a six-month period spent exploring Reykjavík's geothermal urban world; tracing geothermal heat from the ground into the district heating system, buildings, bodies and dissipating away. Whilst the materials produced during this period of geothermal attunement were highly valuable in terms of orientating myself as a researcher, they fell short of exploring and explaining a wider geothermal urban experience as from other people's perspectives. This led to a second two month period exploring geothermal urban lives, speaking with and documenting others´ experiences and engagements. These interviews allowed multiple tales of geothermal urbanism to be told, which preceded by my own experiences, provided the leading empirical material from which the geothermal urban, in the context of Reykjavík, could begin to be understood.

[17] This reference to "Conversations with Landscape" is all the more poignant for its Icelandic connection: in terms of the authors, various focuses on Iceland within the volume, and that Katrín Anna Lund in particular assisted with the hosting of my fieldwork at The University of Iceland.

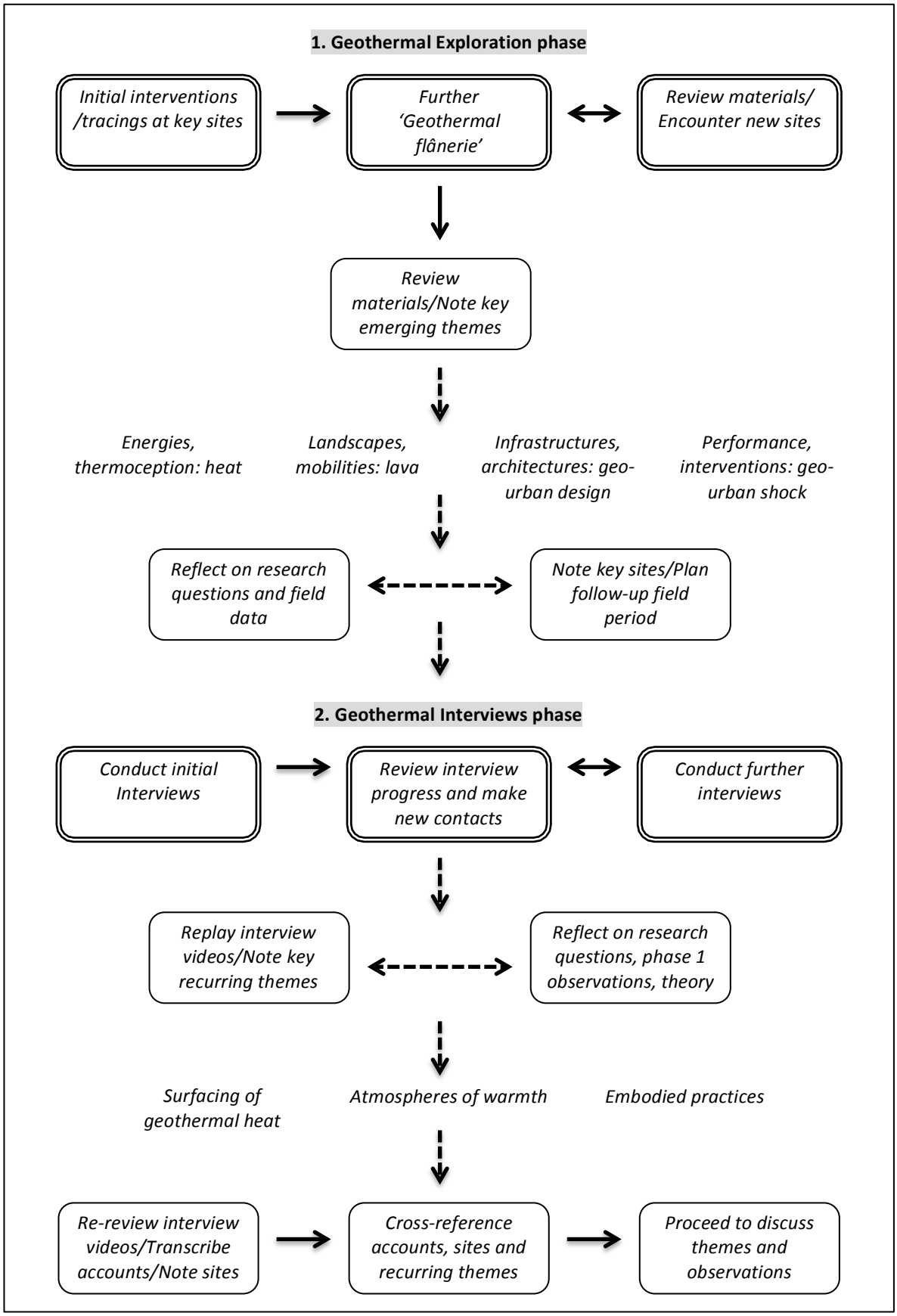

Fig. 3.1. Fieldwork and analysis process outline.

3.2| Exploring a geothermal urban world

Herein commences a reflective account of how the first period of geothermal urban exploration and analysis unfolded, retelling and reflecting upon the inceptive practices and practicalities of attuning to the geothermal within Reykjavík. I first set out to undertake a period of "atmospheric fieldwork" wherein, in much more novel and experimental ways, I would undertake "a deliberate attempt to attend to, experience and experiment with [geothermal-urban] relations" (McCormack 2010a, p.47). Tooth *et al.* suggest the arts may play a critical role in understanding geomorphology, noting that "Earth surface processes and landforms provide a kaleidoscope of perspectives, colours, textures, smells and sounds that can provoke aesthetic inspiration" (2016, p.1793). With thoughts similar to this in mind, combined with concerns for a more-than-human, more-than-representational approach, I engaged the geothermal "via experiential starting points from which...to 'dive in', to commence practicing to see what emerges" (Haseman 2006, pp.3–4). I spent six months 'becoming' geothermal, from February to July 2014, caught up in Reykjavík's use of geothermal heat and warmth from winter into summer. Using digital video and photography to engage, trace, and apprehend this period of attunement, I was later able to draw upon the experience and the materials generated in directing and focusing interviews, that would provide detailed understandings of geothermal urban phenomena. This section outlines the rationale for using video and photography to apprehend the geothermal urban (*a geothermal cinematics*), recounts and reflects on the practical process of elementally focused field exploration (*geothermal flânerie)*, and reviews the value of the field materials generated and how they shaped the on-going research (*digital elementality)*.

A geothermal cinematics

The use of video as a highly valuable method within contemporary geographical research, although still being developed, has become increasingly familiar and accepted terrain (see: Pink 2007a; Garrett 2010; Heath et al. 2010a; Lorimer 2010; Rose 2012; Koeck 2013; Richardson-Ngwenya 2014; Bates 2015; Harris 2016). Video as a tool has been turned to in order to explore the more-than-human on account of the "performative, haptic and affective dimensions to moving imagery" (Lorimer 2010, p.240). It has a capacity to be shaped by, capture, and resonate phenomena, in a manner that is

animated and contains within it a valuable vibrancy and vitality. Given the geothermal's pre-cognitive affective elemental capacities, the generation of field materials via a medium which has the potential to apprehend and resonate these qualities is pertinent. Video, as an extension of photography, provides "a means of witnessing" in a geologic and elemental direction, imbued with the potential of "how moving images evoke affect" (Ibid., p.242). The rationale for using video to explore the geothermal urban lies in its ability to provide rich animated field materials, to witness and capture dynamic phenomena like heat and urban landscapes in ways that audio recordings or writing can miss. Fieldwork that for example, produces audio-only recordings of the experience of walking through lava fields or swimming in a geothermally heated pol, would produce very different data to audio-visual recordings embroiled in the act. The former is firstly limited by only capturing the sonic aspects of phenomena. Second, whilst it stands to draw out detailed narrations of phenomena which are insightful, this reflective exercise (vocalising experience) forms from a cognitive interpretation of an event already passed and can miss valuable subtler details. The latter which merges the sonic and the visual, is able to capture more dimensions (sonic, temporal, visual, proprioceptive) of phenomena as they occur. Telling subtleties of the uneven placement of feet in navigation of a dynamic landscape, or the sensation of steam evaporating from a geothermal pool (which is highly visual and not notably sonic), stands to be lost through more limited mediums. Video has a capacity to be a tool for attuning to and being shaped by the geothermal urban, which facilitates the pre-cognitive, more-than-representational, more-than-human to be present within empirical materials.

Through my period of becoming geothermal, I used film and photography to produce a multitude of digital field sketches, which could "be more widely exploited for geomorphology's benefit, particularly by helping to communicate key concepts such as time, process, and material flux" (Tooth et al. 2016, p.1795) via a geothermal focus. Each day I had multiple engagements with the geothermal: I had heating on, I went to geothermal pools, I walked pavements free of snow and ice due to geothermal warmth, I passed by boreholes, I ran geothermally heated water from taps, I saw geothermal steam escape from pipes, I visited fumaroles, bubbling mud pits and hot springs, I walked over lava. These

experiences were captured at times by a necessary staged use of cameras[18] (a specific framed shot of a specific subject), but also - and predominantly - by the embodiment of cameras (a camera attached to my chest or shoe, just filming what happens), and bodies around cameras (placed to look out of a café window, the rhythms of geothermal urban life unfold and are apprehended): grasping the "melodic line of continuous variation" (Deleuze 1978, cited in Anderson 2014, p.80). The camera, much like myself, was also warmed by the geothermal. It went underwater, into steam; at times was overtly complicit in attempts to engage with a pipe, or a piece of lava, or hot-pot. One of the cameras, a GoPro, had no screen with which to see what you were shooting. This was particularly useful as it meant I was simply unable to frame shots, having to just wear the camera and let it capture what was happening. Overall, I produced 1 terabyte of materials, including thousands of images, and many hours of digital video, which were co-produced in events of technological, embodied, and geothermal urban relations; resulting in geothermally-cinematic vignettes.

This experimental, performative, embodied attunement was distinctly kinetic; geothermal urban "[l]ife *is* movement — geographic and existential kinesis" (Vannini 2015b, p.3, emphasis added). This required methodological attention "in terms of reflexively learning through bodily sensations and responses that occur inevitably as part of the embodied experiences of the researcher within different spatial contexts" (Crang 2003, p.499). Through an on-going thermoception[19] (see: Vannini & Taggart 2013a, pp.65–73) that was at times cognitive (driven by my conscious realisation of geothermal-heat-here) and at times pre-cognitive (just going-and-moving, and letting the geothermal urban unfold), there was a focus on the kinetic, the movement of bodies and heat. As "video tracks the multisensual fluidity and rhythms of everyday life" (Garrett 2010, p.522), it is a highly sensible tool to use in tracing phenomena which are also highly kinetic: the thermal and the urban. Digital video is a tool *of and for* kinetics (cinematics); "we engage with spaces and places in our daily life in ways that are essentially *cinematic*…the term *cinema* signifies…space in which we become part of a…system that allows us to perceive a sensation of *movement* and in which we are *moved*" *(Koeck 2013, p.5,*

[18] The cameras used were: a Panasonic V720 Full HD Camcorder, a GoPro Hero 3 Plus Camcorder, and a Cannon 450D digital SLR camera (with a Cannon portrait lens and a Tamron wide-angle lens). I used Scandisk ultra micro-SDXC memory cards and Western Digital portable hard-drives to record, store and back-up digital video and photographs.

[19] For Vannini & Taggart, "thermoception is both the capacity to be affected by one's environment, as well as the capacity to affect it by becoming involved in processes that result in the radiation of ambient heat, thermoception can be said to be a type of catalytic affect" (2013, pp.19–20).

emphasis in original). A cinematic method concerned as it is with movement, "captures the animic flux of life and especially an ontogenesis which undoes a dependence on the preformed subject" (Thrift 2007, p.5). Digital video and sequential photography engages a more-than-representational method by managing "to capture the 'onflow'" of the world (Ibid., p.5), and in that it "values the pre-cognitive as something more than an addendum to the cognitive" (Ibid., p.6). Digital recordings thus become "an index of the intensity and consistency of attending to and through the everyday" (Latham & McCormack 2009, p.256).

My rationale for using video was tied to an attempt to push on the cinematics of film, the city *and* the geothermal – the kinetic qualities of cinematic art forms (video, photography), urban life, *and* the dynamics of heat. In doing this, Koeck's (2013, p.160) suggestion that we might advance mise-en-scene within film studies towards a sense of "mise-en-urbanité"[20] can be developed, and extended to incorporate the geologic: a 'mise-en-élémentaire'. Hubbard, summarises how cinema is "*of* the city" and developed as an art form to "communicate the *pace* of modern urban life" (2006, p.135, *emphasis added*). What this overlooks is that cinema is of *movement*, and can be crafted in terms of other physical processes, any kinetic phenomena – such as the geothermal. The value here is in tracing the geothermal, its kinetic and affective qualities, and employing the related properties and capacities of video to apprehend the elemental. This returns to the examples of walking over a lava field or swimming within a geothermally heated pool. Proceeding with a sense of 'mise-en-élémentaire' is to use video to apprehend and articulate bodies traversing lava and steam rising - to make the elemental explicit. I deployed the video camera within a geothermal urban context as "a device for pursuing a kind of atmospheric fieldwork: that is, a device, by virtue of the cloud of constitutive affective relations in which it is immersed, which participates in the generation of an atmospheric sensing of something happening" (McCormack 2015a, p.91); performing and producing a geothermal cinematics as a way of exploring the elemental.

Geothermal flânerie

[20] This advances some notable techniques used within urban planning and urban design, which also informed my methodology: 'townscape analysis' developed by Lynch (1960) and 'serial vision' developed by Cullen (1961). Both of these approaches concern analysing urban spaces spatially and sensorially via the use of sketches or photography (and eventually video).

With video selected due to its potential to apprehend and resonate with geologic phenomena, as a medium capable of being caught up in the elementality of the geothermal, where, when, and how to use it still had to be considered. In selecting Reykjavík as a geothermal urban case study, I had drawn upon other accounts of its geothermal and urban qualities (see: Chapter 1 & Chapter 2), including academic, professional and tourist literature on Iceland, which permitted an informed speculation as to where and when the geothermal urban might be experienced. Turning to previous work on other geo-urban phenomena (Gandy 2002; Gandy 2004; Swyngedouw 2004; Kaika 2005; Vannini & Taggart 2013b; Gissen 2014; Starosielski 2015) directed me to seek out the geothermal urban through infrastructures, architectures and as experienced through human bodies. This was enhanced further following a one week visit to the city in 2013, for the Nordic Geographers' Meeting. Rather than just being conceptually aware of explicit loci of geothermal heat and junctures of the geosociotechnical (see previous chapter) such as pumping stations, storage tanks, swimming pools, buildings and pavements, I was able to actually witness them.

Whilst I found myself ready to commence fieldwork orientated to the Reykjavík Capital Area and mandated to seek-out and apprehend the geothermal urban everyday, I felt lost. This was in-part due a lack of familiarity with both Reykjavík and the geothermal, but also apprehensions and uncertainties about field working on more-than-representational terms. I found myself drawing upon previous familiarity with urban environments, pre-obtained knowledge of the Reykjavík district heating system, and my own bodily capacity for thermoception. I held an expectation that I would experience geothermal urbanism everywhere, so ubiquitous was the district heating system and lava-dominated landscape – and that there would be pockets where this was more explicit and conversely subtle. This set a direction for my own thermoception and attunements, wherein my approach treaded a line between being discursive and open to encounters, whilst maintaining a focus and objective. I produced a list of sites and spaces which were likely to emphasise the geothermal urban experience, qualities, and capacities for which I purposefully roamed. This proved to be a sensible and useful approach, as the geothermal proved to be both ubiquitous and fluid, and It allowed me to trace and experience the geothermal across a spectrum of sites and circumstances: the afore-mentioned swimming pools, pumping stations, radiators, sinks, pavements, homes and businesses. Crucially

these sites were all over Reykjavík; from the smallest nooks to open streets, the geothermal warmed the city. My task became to focus in on them, to attune to the geothermal following a sense of thermoception and allowing the phenomena to reveal itself.

To produce video and photographic accounts of the geothermal urban requires more than just operating a camera within these specific sites. The camera needs to be mobilised, and in doing so the embodied aspect of such methods is underlined. One of my first attempts at taking a camera with me to capture - and be a part of - the geothermal urban was in attaching it to my shoe (Fig. 3.2 & Fig. 3.3). I had become interested in how the way in which I walked about the suburb I was staying in varied based on geothermal heat. In some areas, but not all, the pavements are geothermally heated; meaning some sections are free from snow and ice whilst others are not. This results in alternating walking patterns: slow and cautious across non-heated pavements, faster and less-cautious over the heated sections. As my feet hit the pavement my rhythm and pace varied. My posture altered without conscious thought. Frictions were in flux, and with walking "an unconscious way of moving through urban space, enabling us to sense our bodies and the features of the environment" (Wunderlich 2008, p.125), it provided a valuable way into Reykjavík´s geothermal urban lifeworld. Walking as method, or a part of method, has long been established across the social sciences; specifically in geography, anthropology and urban studies (see: Edensor 2000; Careri 2002; Phillips 2005; Pinder 2005; Wylie 2005; Pink 2007b; Pink 2008; Spinney 2011; Vergunst & Ingold 2016) as a way of "unfolding stories" (Pinder 2011, p.672). In particular Jacobs (1961) in her volume key to urban planning, showed "how it's possible to learn from wandering around and engaging with people and places…[s]he suggested that being in…the city, by walking around and participating in it as best she could, she had learned things that official statistics and formal social science surveys often concealed or missed" (Phillips & Johns 2012, p.171).



Fig. 3.2. Walking on geothermally heated streets I, Vesturbær.



Fig. 3.3. Walking on geothermally heated streets II, Vesturbær.

My heading out into the geothermal urban also draws on the tradition of *flânerie* (strolling, walking, ambling). The *flâneur* emerged as a literary figure in early 19th century France, and through the work of Walter Benjamin (see: Benjamin 1999), when it was eventually published in the 1980s, became a concept of interest to academic disciplines concerned with urbanism. Shields (2006), for example, takes an interesting look at the idea of "Flânerie for Cyborgs", suggesting a kinship between the two terms and paving the way for a curious deployment of the cyborg as a geothermal *flâneur*. That is, tied to my cameras, I was experiencing biologically and technologically the geological. Bruno

approaches cinema as "geophysic exploration" (2002, p.15), drawing on the idea that cinema is a "imaginary form of *flânerie*" that is "in keeping with…kinetic origins" (Ibid.; pp.16–17). Of course, this is to think of cinema as a finished edited film, but in the case of digital video caught in and capturing the moments of walking a landscape, this is not imaginary but real. Geothermal *flânerie* proved to be an essential part of becoming and apprehending geothermal urban relations: "[w]alking and photographing is rhythmical and brings our bodies into 'conversation' with the environments we move through" (Yi'En 2013, p.3).

Along with *flânerie*, another approach is "rhythmanalysis" developed by Lefebvre (2004). Whilst *flânerie* is the process of the embodied travelling of a landscape, rhythm analysis is attending to the flows of (specifically urban) life. In advancing throughout Reykjavík as a geothermal *flâneur*, I was also attempting a rhythmanalysis which engaged urban rhythms tied to geothermal heat and warmth. My "discursive walking" (Wunderlich 2008, p.132) was only so because of the juxtaposed nature of the geothermal emerging here and there. Undertaking "a mediation of experience rather than a reflection on experience" (Garrett 2010, p.531), I found my wandering, when I really allowed myself to just go with the geothermal, was "not according to logical thought, but as a direct and felt response to [the] element[ality]" of the geothermal (Bolt 2004, p.8). This reflects a key difficulty of attuning to the geothermal and making the elemental explicit. The challenge was to balance a concern for actively tracking and tracing geothermal phenomena, with an acceptance that some subtleties might be serendipitously or unexpectedly encountered. My response to this was to allow myself to attune to and follow discrete geothermal phenomena within the Reykjavík Capital Area, but to also capture moments and encounters outwith the elementally distinct. This was to position myself to be open to the often less-obvious ubiquity of geothermal heat and to frame the geothermal urban context.

My experiences of geothermal *flânerie*, of undertaking the production of a geothermal cinematics, was not limited to urban walking – at least in terms of streets and roads. At times I ventured into undeveloped or semi-natural spaces. This was because the geothermal also revealed itself via the natural landscape: lava from past volcanic eruptions dominating parts the Reykjavík Capital Area. The

lava fields today have of course cooled, leaving behind distinctive rock formations that make up a portion of the city's natural spaces. One engagement with the lava field was in attending a piece of performance art titled "Sad Problems #15" by the artist Amy Howden-Chapman[21] (Fig. 3.4). Amy read out a poem on the site of a lava field in Garðabær that was being controversially removed to make way for a new road. Supporters of the road felt it was required to reduced travel times and improve traffic flows between two neighbouring suburbs. Opponents saw the road as unnecessary, and objected to what they felt was the destruction of a special and distinctive local landscape. Along with the rest of the audience, I followed Amy across the lava. This allowed a subconscious engagement with the lava, as I was focused on following the artist and listening to her words. In such a rugged landscape, quite different to pavements and roads, my steps were uneven and my trajectory arbitrary. I pointed my camera at Amy, recording her words, but also captured the character of the landscape and the experience of travelling across it. The distinction between the lava field and the nearby urban developments was stark: one of order and smoothness, one seemingly far more frenetic and disordered. I'd captured an interesting shift in the affective capacities of the landscape on my body. The camera juddered about and caught my feet haphazardly finding their way[22] - quite different to their gait on the geothermally heated pavements found in Vesturbær.



Fig. 3.4. On the lava at Garðabær.

[21] For more see: http://www.amyhowdenchapman.com/node/36.
[22] This observation echoed Lund's (2005) experiences of bodily movements across a mountain altering the view.

Another experience with lava in the landscape was in Hafnarfjörður. Here, a small group of students from the University of Iceland (one in Tourism and Geography, two others in Volcanology) joined me on a walk through the area's 'lava parks' (Fig. 3.5). Partly inspired by Gabrys' (2012) work concerning moss within urban spaces, I wanted to attend to the lava dotted about and highly characteristic of Hafnarfjörður. Some 'lava parks' contain play equipment and benches, others have pathways through them joining parts of the town, and some are just small bits of landscape between buildings. As with the lava field in Garðabær I filmed the experience of walking about amongst it all. This time, however, my direction was more conscious and deliberate. I didn't follow a guide, but instead led the group through the urban, weaving into and out of the lava. I hadn't pre-planned the route either, but instead knew roughly where the lava was and allowed myself to be drawn to it by sight. As we experienced the lava together, we noted how distinct it was in relation the built environment. The tactility of the contrasting, yet conjoined and interwoven, landscape varied. On paths and pavements walking was easy; on lava things became unsteady. My cameras enabled me to walk through these landscapes focusing on the experience and seeking out the geothermal (either as present-day warmth or cooled lava). There were alternative rhythms, changes in momentum, and variations of bearing that would have been difficult to apprehend via other mediums like sound recording or note-taking. Further, cameras enabled me to just get on with being in geothermal space. It was much less distracting to press a button or leave a camera attached to my body filming, rather than to stop and write, or sketch.



Fig. 3.5. Encountering urbanized lava in Hafnarfjörður.

Beyond attuning to the geothermal via cooled lava, another key location for an immersive geothermal cinematics was one which switched geothermal *flânerie* for geothermal swimming. Geothermal pools are both plentiful and popular in Iceland, with central Reykjavík being home to seven. As the GoPro camera could be placed into a waterproof casing it could be easily used in geothermal swimming pools to capture the movements and sensations of being in the geothermal water. On a trip to the pool I decided to bring my camera along; grasping it in my hands, I pointed it at bubbles, steam, the water's film, and vents[23]. Without any preview screen I was free to just experience the pool and capture the sensation of being in the water, creating abstract in-the-moment "durational" (Boyd 2017, pp.83–88) film clips (Fig. 3.6 & 3.7). These experiences, much like many others, highlighted how my method was also one of a 'sensuous geography' (Rodaway 1994; Stoller 1997; Paterson 2009). As "we do not know in what ways the world might express itself through us, how it might participate in our becoming otherwise" (McCormack 2010b, p.217), I had to reply on my own sense of thermoception to guide me towards the geothermal. As much as cameras were critical to apprehending the geothermal in such a way that I generated empirical materials, my body was also an essential instrument; "The sensuous – the experience of the senses – is the ground base on which a wider geographical understanding can be constructed" (Rodaway 1994, p.3).

[23] It should be noted that I sought permission to use a camera within the swimming pool from the management, and filmed only myself, my immediate group of willing participants, and non-human subjects.



Fig. 3.6. Checking the temperature, Vesturbærlaug.



Fig. 3.7. Geothermal heat escapes the pool as steam.

Paterson continues, "our first and foremost, most immediate and intimately *felt* geography is of the body, the site of emotional experience and expression *par excellence*" (2009, p.771, *emphasis in original*). In getting into the detail of the 'embodied-ness' of materiality, affect and our understanding of the world, Patterson clearly lays-out the importance of considering the haptic – and the value of it being embedded within methodological approaches and techniques. "The somatic senses generally work synergistically as part of the 'haptic system'…which includes kinaesthesia (the sense of movement), proprioception (felt muscular position) and the vestibular system (sense of balance[])' (Ibid.: 768). Experience *is* experiment. Or more bluntly, to experience (perform/live the geothermal) - especially through a methodological approach that is multi-sensual - is to engage in an

embodied way with the affective materialities of the world. The method for apprehending the geothermal urban, geothermal urbanism, and geothermal warmth, needed to take on-board seriously the haptic, kinetic, sensual, pre-cognitive, and performative:

> 'In its non-representational aspect, performative methodology is so much more than choice of method (video camera, interview, ethnography etc) and the standard of carrying out these methods, and much more about questioning how we are going to configure the world, and how we question in practice to what extent we are able to configure different worlds. In being affect-based, this methodological questioning is further complicated by no longer being scripted by disembodied contemplation but rather being apprehended by the very open sensations and connections of the body itself. Taken together, the object of study for performative research literally comes into being through being enacted in the practice of the research itself' (Ibid.: 324).

In undertaking varied geothermal attunements, there were practical challenges and difficulties which had to be navigated. These mainly concerned equipment, weather and personal safety. Cameras, memory cards, and hard-drives proved to be easy to operate and reliable. Prior to being in the field I had familiarised myself with the cameras' functions, and at the outset of fieldwork, undertook a number of equipment tests to ensure everything operated correctly. Throughout the fieldwork, there was only one noted case of a camera accidentally not filming part a visit to a geothermal pool, which was down to human error (as simple as the record button not being pressed properly). Icelander's are familiar with the expression 'there's no such thing as bad weather, just bad clothes'. For practical and safety reasons, my fieldwork periods had been chosen so as to not coincide with the worst winter weather, and whilst I frequently had to head out in snowy, icy, and wet conditions, I made sure to have the appropriate warm and waterproof layers. Iceland is also a very safe country, where serious crime (such as robbery or assault) is rare. A bigger concern was road safety (as a driver or pedestrian) and exposure to cold temperatures. Beyond ensuring appropriate clothing, I only drove hire-cars from reputable companies with the appropriate tyres, and made sure to stick to pavements and well-

lit streets at night – easy in urban Reykjavík. On longer or potentially more demanding trips, I would notify contacts in Reykjavík of my planned destinations and time-frames, and carried a mobile phone.

Whilst this period of geothermal urban attunement - 'becoming geothermal' - resulted in highly valuable insights and the production of elementally infused field materials, upon reflection, there were moments and aspects that fell short of the research questions I sought to answer. Whilst I was aware that "research is always a co-production" (Greenhough 2010, p.47) and "a form of performative material intervention" (Ibid., p.50) (see also: Whatmore 2003), I took this to concern my own experiences of a co-production with the geothermal urban. A tunnel-vision developed wherein my experiential and experimental concerns became dominated by an entirely personal encounter with the geothermal. At this time I felt I was being successfully "anti-biographical and preindividual" (Thrift 2007, p.7) by attempting to make the non-human geothermal the object of my experiential practice. It was not until I reviewed my materials that I realised that by adopting an approach almost entirely via my own embodied experience, I had been problematically autobiographic. Materials spoke of *my* engagement with geothermal heat and lava landscapes but did not open up to others' experiences. If my research was about "unfolding stories" (Pinder 2011, p.672) then it couldn't just be my story. Putting aside obvious criticisms that my single embodied experience as one researcher fails to in any way acknowledge the diversity and infinite variations of different bodies in the world; this ultimately lonely encounter produced materials that, whilst they did communicate affective embodied engagements, did not provide a broader view. I found that it was the materials I generated with others that spoke more of geothermal urbanism (as a collective social practice), and that I had to enter others' spaces and understand others' experiences of the geothermal urban. I might have involved others more in my attempts at producing more abstract, in-the-moment, affective geothermal cinematics.

Perhaps the leading factor in this were my insecurities as a researcher. It was the first piece of extended research work I had undertaken, it was my first ever attempt at more-than-representational methodologies, and in spite of some experience with amateur photography, film and filmmaking, I simply doubted myself too much. I felt more comfortable undertaking solo-experiments than

involving other participants because if the experiment went wrong it 'wouldn't matter so much'. It is important to note that, whilst these initial experiments fell short, they did build up my confidence as a researcher. This confidence saw me to return to the field with new skills and a clearer direction that eventually produced additional insightful and rich materials that spoke more directly to the questions I was seeking to answer. I kept in mind Dewsbury's advice to "fail again…fail better" (2010: 32) and crucially, that off-track moments are also useful, emphasising the value of more successful experience/experiment (McCormack 2010b).

Digital elementality

Be it digital video produced via a stationary camera positioned to capture flows within a geothermal urban scene, or through the embodied pursuit of geothermal heat and lava landscapes, "cinematic technique and visual composition…is understood as a sensational surface for the amplification of real-world…sensibilities" (Lorimer 2008, p.554). Bolt puts this slightly differently, stating there is "a mutual reflection and transmutation between imaging and reality…[and that] through the process of practice the outside world enters the work and the work casts its effects back into the world" (2004, p.150). The digital videos created, formed as a result of being exposed to the geothermal, can be understood in a more-than-representational sense as constituting a form of digital elementality. Carter & McCormack consider "film as an affective assemblage through which…sensibilities emerge and are amplified" (2006, p.228), and on these terms, the videos and photos created within the field continue within them an affective capacity which is distinctly geothermal. This is underlined by thinking for a moment about if different phenomena had been filmed: cows eating grass, a stormy sky, the aurora borealis, or experiences of burning oil for warmth. These materials, when re-viewed, would have a very different impact to their geothermally focused counterparts:

> "Things and people are made of the same atomic material, just as in the cinema they are made of the same celluloid material. . .celluloid takes on the animistic character of the atom, the single element that fashions the universe. Film images, including those of people, are things, and all things on celluloid are thereby reanimated and thus directly expressive."
>
> (Moore 2000, pp.68–69; cited in Thrift 2005, p.232)

Materials produced through an engagement with geothermal phenomena carry within them the affects of geothermal elementality, and "rather than ideological signs, cinematic images become refigured as bodies of affective intensity with the capacity to affect other kinds of bodies (Carter & McCormack 2006, pp.234–235)[24]. Via the process of engaging the geothermal, a geothermal cinematics has been created which is imbued with the affective capacities of the events with which they were made, "the outside world enters the work and the work casts its effects back into the world" (Bolt 2004, p.150). This connects with Starosielski's work which posits "thermal manipulation is critical to the transformation of the earth's raw materials into media" (2016, p.293). Digital elementality resonates "thermocultures of media…in which geologic matter's potentials are actualized as media" (Ibid.), and to the extent we might "begin to viscerally sense… [the geothermal] experience" (Lorimer 2010, p.243). For example, steam off-screen becomes steam on-screen, in that we experience it "catalyze complexly and dissipate unexpectedly" (Lorimer 2008, p.552). Thus, these materials carry with them not just representations of the geothermal urban, but are *crafted of* geothermal urban affects; "a taking up and extending of 'the excess of colors, forms, materials' generated by the earth itself" (Clark & Yusoff 2017, p.18, citing Grosz 2008, p.9).

Once produced, these materials must be reviewed and organised so as to reveal their empirical value. This begun whilst fieldwork was being conducted and was finished after the fieldwork was completed. Whilst in the field, the videos and photographs generated were assessed to gauge how effectively the geothermal urban was being captured, and to point towards aspects that were revealing, were of potential value, or that might not be quite as vibrant and explicit as was hoped. Concerned with capturing embodied engagements with geothermal warmth, I found that infrastructural and architectural sites provided the most explicit moments of contact and immersion. This led me to continue to trace the geothermal through pipes and buildings into my body: pumping stations, heated rooms, warmed water onto skin. However, I did not want to discount more subtle - or the potential for more subtle - apprehensions; thus, I also continued to explore Reykjavík in a manner that remained open to the less immediate and indirectly geothermal: steam escaping a pumping station

[24] There is a further connect here with what (Bergson 1988) terms 'external' images (specifically digital video and photography) and engaging them as "blocks of sensation with an affective intensity[…]their pre-signifying affective materiality is felt" (Latham & McCormack 2009, p.253, *emphasis removed*).

across a dual carriageway, little bits of lava decorating a front garden, a painting of a volcano in a café. Through this, I noted that the geothermal was revealing itself as had been anticipated as present-day warmth heating infrastructures, buildings, and people; and as past-geologic activity through lava landscapes which shape and inflect the urban experience within Reykjavík.

Once this period of fieldwork concluded, I reviewed my materials more fully and noted four emerging categories of interest. The first two concerned the two central engagements with the geothermal noted within the field; as present-day geothermal heat from within the Earth, and as past heat cooled as lava, pervading the urban as a distinct geologic *genius loci*. I labelled materials that spoke to these categories as 'energies, thermoception: heat' (direct engagements with present-day warmth) and 'landscapes, mobilities: lava' (engagements with, through and across, a geologic landscape). The other two categories concerned the articulation of the geothermal through the built environment. Materials that spoke to these categories were labelled 'infrastructures, architectures: geo-urban design' and 'performance, interventions: geo-urban shock'. The former concerned the built elements of Reykjavík that contained, channelled, and released geothermal heat; the latter turned to moments when the geothermal revealed itself through embodied actions. Many materials fell into more than one category. They confirmed infrastructures and architectures as a geologic-human, geothermal-urban interface; and signalled geothermal urbanism as tied up with acts and interventions that complicated human lives and bodies with the geological and geophysical. They also highlighted a value in tracing the geothermal from the ground into the Reykjavík district heating system and beyond. In doing so, they revealed within them a sense of the unique geothermal urban experience, but critically they did not yet fully answer my research questions. Whilst I could begin to unpack geothermal urban relations, the articulation of the elemental via urban forms, and establish places of geothermal urbanism; my materials and questions called for a more specific understanding of geothermal urban lives through shared and multiple practices, actions, and experiences.

3.3| Exploring geothermal urban lives

Following my initial period of 'becoming geothermal', at the end of the Icelandic winter during February and March 2015, I sought out conversations with Reykjavík´s residents within spaces of geothermal warmth. This was to specifically expand on my more personal engagements with the geothermal urban (that whilst illuminating, had been overly autobiographical), to broader and more varied empirical engagements with geothermal urban life. Every person I spoke to lived within the Reykjavík Capital Area and some worked directly within urban planning, architecture, geothermal engineering, and the management of swimming pools and other civic spaces. Overall, I completed 43 semi-structured interviews, or what may be better understood as 'geothermal chats', with 50 of the city's residents (on a few occasions two or three people were involved in the conversation – see: 'List of Interviewees', p.260). These chats told multiple Icelandic geothermal tales and formed a 'Jarðhiti saga'[25] that conveyed and enacted moments of everyday geothermal urban life. Drawing upon the notion that "an interview is in practice a local and immediate encounter" (McDowell 2010, p.159), they continued a process of attuning to the geothermal. They were an extension of the 'becoming geothermal' I had previously undertaken, although this time concerned with other's experiences of the geothermal urban. Vannini notes that "non-representational researchers conduct interviews" (2015b, p.11), and as such there was still a distinct interest in apprehending the elemental, and producing field materials that were "issuing forth novel reverberations" (Ibid., p.12). As "social scientists who undertake interviews to explore what is going on in particular places and circumstances draw on a range of other methods to check our interpretations" (McDowell 2010, p.158), geothermal interviews would complement, and be complemented by, my previous field explorations. This section explains the rationale for geothermally focused interviews (*geothermal interviews*), details the practical process of talking to others about their experiences of the geothermal urban (*geothermal talk*), and reflects upon the materials generated and how they were analysed so as to inform discussion of such phenomena (*warm words*).

[25] 'Geothermal saga'

Geothermal interviews

Interviews have been long established within geography as valuable methods for studying and understanding phenomena (see: Silverman 1997; Kitchin & Tate 2000; Phillips & Johns 2012; Hay 2016), in particular incorporating film and photography (see: Crawford & Turton 1992; Crang & Cook 2007; Pink 2007a; Mitchell 2011; Rose 2012). Building on work that has used interviews to look at experiences of heat and energy (such as: O'Neill et al. 2006; Harrison & Popke 2011; Hitchings & Day 2011), an approach in a similar vein to Vannini & Taggart's (2013a; 2013b) ethnographic approaches to off-grid living, utilising filmed interviews, was mirrored. Video had been a useful tool during my previous geothermal urban explorations, capturing the geothermal as a dynamic and vibrant phenomena in ways that audio recordings and written notes would have missed – puffs of steam, being in water, travelling across a lava field. I was still seeking to undertake "a deliberate attempt to attend to, experience and experiment with these relations" (McCormack 2010a, p.47), the affective and atmospheric elementality of Reykjavík´s urban experience. This led to a decision to also use video to record geothermal chats, primarily as I planned to conduct these discussions in and around geothermal warmth, and in thinking more-than-representationally, I wanted to be able to capture the setting of the conversations and their eventfulness and performance. Audio would not capture the embodiment of someone just tapping a radiator, warm water on their skin, or the spatial aspects of being in a geothermally heated room. Written notes might reflect these experiences, but would require the translation of talk into words, and practically I wanted the conversations to flow and not be interrupted by the slower pace of writing by hand. One other pragmatic consideration, was that the cameras had also proven to be easy to operate and reliable, not once malfunctioning or running out of power, and highly practical in their mobility and relative unobtrusiveness.

It was important to be able to enter geothermal spaces, talk to and move with participants, and be in the moment, becoming geothermal with them. This was an attempt at doing "the flipping over of 'participant observation' to 'observant participation' that Thrift (2000) made to emphasise the serious empirical involvement involved in non-representational theory's engagement with practices, embodiment and materiality" (Dewsbury 2010, pp.326–327; citing Thrift 2000). Digital video would not only collect the words, but actions, expressions, and body movement. A video camera could be

picked up and pointed at a shower, a tap, a heated floor, or capture an affirming grasp of a radiator. Video could follow and record spatially in ways notes could not. Video was a richer medium, more capable of apprehending the subtle in the moment without interrupting the moment, it permitted something of the geothermal ambience - atmosphere - to be captured. In addition to recording geothermal conversations on digital video, I also took a digital SLR camera to take additional pictures (of rooms, points of interest, exteriors of buildings), which served to help with my memory of the interviews and had the potential to further illustrate these encounters.

Critical to undertaking geothermal interviews was selecting who to speak to. It would clearly not be possible to speak to every person living within Reykjavík, and techniques that might engage a large number of respondents such as questionnaires, would not provide a deep or rich enough response. There were two types of lived experiences of the geothermal that seemed important to engage: the everyday experience of those simply dwelling and residing with geothermal heat, and those whom had an explicit part to play in its extraction, circulation, and delivery. I thus set out to speak to two main groups of people: one consisting of everyday residents whom encountered the geothermal through heating their homes, workplaces, municipal buildings and commercial premises as well as going about everyday activities within lava landscapes; and another consisting of geothermal and built environment professionals whom engaged the geologic in a much more analytic, conscious, and thoughtful way – geothermal engineers, swimming pool staff, urban planners, urban designers, and those concerned with construction.

I began with a small list of contacts I had accrued in my previous time in Reykjavík; calling, emailing, and simply speaking to people about my research and interest in geothermal heat. Whilst a few of these initial contacts were a little hard to track down, most were happy enough to meet and talk. I went about selecting my interviewees with an awareness that although it would not be possible to engage every possible experience of geothermal heat within Reykjavík, my intention was to be able to draw on distinct recurring themes that emerge from a sample which was not entirely homogenous. The most obvious factors to consider were age, gender, length of residency and location. On these factors I wanted to ensure a mixture of ages that extended from young adults to retirees, and that

there was not a significant gender imbalance. This was because I wanted there to be a spread of experiences to safeguard against pronounced bias that would limit the validity of any subsequent discussion. For example, only speaking to males aged 20-40 or females aged 60-70 would provide a very focused sample that would limit discussion and restrict any claims about the geothermal urban experience to these very specific groupings. With regards to length of residency and location, I remained open to hearing from those that were new to Iceland and the geothermal urban, but wanted to ensure a significant number of interviewees had a deep enough and longer-term relationship with the city and the geothermal. All interviewees had lived in Reykjavík for over a year, most for significant periods of time extending beyond five years. As to location, interviews were sought across the Reykjavík Capital Area, so as to ensure future analysis was not merely drawing from experiences fixed to one specific neighbourhood or resource. Income was less of a consideration due to Iceland's strong social welfare system and relatively limited economic disparity (see: Arter & Bill 2016; OECD 2018). Further, given the specific nature of the state-run geothermal heating system, and the high affordability of geothermal heat, it can be considered that income is not a problematic barrier to the geothermal urban experience. Equally, factors such as educational attainment, religion, ethnicity and sexuality did not play a part in significantly affecting access to, and experience of, the geothermal[26].

Specifically, there was a need to be aware of the limitations of undertaking geothermal interviews, mainly that they take time to organise, conduct and process, and this meant that not every perspective and experience could be explored. In consideration of, and in-line with, other relatable research (Bickerstaff & Walker 2001; Cupples et al. 2007; Hitchings & Day 2011; Fuller & Bulkeley 2013; Hitchings et al. 2014), a sample size of 40 interviewees was established so as to provide a volume of empirical materials that would be both rich and practical. The context of this research (in terms of the research questions posed and time and resource constraints) did not seek to undertake, or permit the delivery of, a statistically significant response as a proportion of Reykjavík´s population.

[26] Further, the possibility of speaking to those with different disabilities to provide a voice for someone who's experience of the geothermal may have been different, for example, due to sight loss or mobility issues was considered. However, the decision was eventually taken not to form such a sub-sample, as this would have begun to open-up and multiply research questions in such a way that would diverge from the research's primary aims.

Instead, a detailed and robust selection of interviews was required to appropriately explore and illustrate the geothermal urban within the Reykjavík Capital Area. In the field, owing to a positive response from willing participants, the sample size was extended to 50. This contained slightly more 'professionals' (28) than 'residents' (22), which was a result of it being easier to initially engage professionals on geothermal related research, and because there was a specific value to drawing upon the detailed knowledge of those that work directly with the geothermal. However, it is important to note that all professionals also resided within the Reykjavík Capital Area, so had as part of their geothermal urban experience their non-professional daily lives. It should also be noted that the 'professional' group contained more men to women (23 to 5) owing to a dominance of male employees within related sectors, but that the 'residents' group which could be more easily balance had slightly more women (12 to 10).

Whilst it is important to note these limitations, the final sample provided multiple and sufficiently detailed responses so as to robustly inform a subsequent discussion and findings. Notably, the distinction between residents and professionals was somewhat blurred, given the on-going experience of geothermal warmth. Professional accounts offered, understandably, more technical perspectives; whereas the accounts from residents drew almost exclusively on the more broadly lived aspects of geothermal urbanism. However, both residents and professionals contributed to an unfolding understanding of the practices and places of geothermal urbanism, and how the elementality of the geothermal is articulated through infrastructures, architectures, and bodies. Combined, these formed insights into lived experiences and detailed processes, which highlighted key emerging themes that would develop an understanding of the relation between the geothermal and the urban.

Geothermal talk

Considerable literature exists on the adaptable essentials of interview methods (see: Wengraf 2001a; 2001b; Bennett 2002; Kvale 2007; Secor 2010; Longhurst 2016), but these have yet to expand into more specific concerns for being more-than-representational, geologic agency, and attuning to heat

and warmth. My previous attempts at being more-than-representational had focused on being in phenomena, allowing it to unfold around me and attempting to produce materials more creatively within, tied-to, and as a part of the geothermal urban experience. In conducting interviews, I hoped to not just hear from others about their engagements with the geothermal in and around Reykjavík, but to partly share the experience with them. Much of what held with my previous time spent becoming geothermal still held; this was a continuation of that, now shared with others. More-than-representational interviews required little adaptation. Accordingly, I chose to hybridize and enhance, drawing on the fundamentals of more traditional interview practices and loosening up the frame to incorporate a more flexible, go-along, attuning chatter. I was focused on capturing the mundane that held within it a geothermal vitality – this was the simple adaptation, a practical flexibility and an awareness of the elemental unfolding all-around, which was tied to the eventfulness of geothermal urban moments. The camera was there to capture and partake in these geothermal encounters as opposed to merely record a conversation. Placing the camera on a table, framing a room, and able to be taken along if we moved through a space permitted events to simply unfold; allowing the interviews to be as much about the eventfulness of experiencing geothermal warmth as reflecting upon and narrating it.

It is important to emphasise the sheer ubiquitous nature of geothermal heat and provision within Reykjavík. It is truly the dominant heat source: speaking to anyone within a heated home or office, with a swimming pool or on a warmed pavement, is to be experiencing, explicitly the geothermal. Likewise, the distinct lava landscape is unmistakable, and the relative geologic youthfulness of lava fields is a notable motif in many neighbourhoods. Frequently in residential interviews, I was shown the inlet that connected to the district heating system, with geothermally warmed water rushing in and out. Within professional interviews I would be taken to inlets, heat exchangers, and pumps undertaking the very business of distributing and dissipating geothermal heat. Add to these encounters a line of conversation that directly engaged the geothermal, and there was no doubt that these discussions were within spaces of, and about, geothermal heat. Geothermal warmth is commonplace to Icelanders, and whilst they engage with it every day, it was interventions like

interview questions that allowed them to reflect, focus on, and articulate the specificities of experiencing geothermal warmth. The geothermal was there; it needed to be explored and captured by being in its warmth and acknowledging it through conversation and actions.

Interviews were conducted in English which is widely spoken in Iceland to a high standard. With professionals, their careers had taken them through training and qualifications that required an advanced level of English proficiency, meaning they were able to communicate complex and technical points clearly. With residents, conversations did not require an as advanced vocabulary, and discussions of everyday life, routines, and experiences of the geothermal were comfortably undertaken. The few Icelandic words or phrases relating to geothermal landscapes and experiences of geothermal warmth occasionally used were easily translatable. Difficulties could have arisen in discussion with older residents that may have been more likely to have spoken Danish as a second language to Icelandic, however, this did not prove to be problematic in the field. The interviews were all open, with a list of pre-planned questions to initiate the discussion, and a set of additional prompts to steer any conversation back on track and to conclude (Fig. 3.8). Questions were phrased so as not to assume a positive or negative experience or opinion from the outset. Generally, the interviews lasted an hour to an hour and a half, but they varied greatly as conversations do. The shortest chats were just under 30 minutes, whilst the longest lasted just over 2 hours. I spoke with people, being warmed, in living rooms, dining rooms, kitchens, bathrooms, basements, gardens, offices, studios, hospitals, restaurants, cultural spaces, swimming pools, power stations and boreholes. I found that the choice to use a camera to record these encounters suited the conversations: it was easy to take with me, it was unobtrusive (often sitting in a corner unless organically directly engaged with), it was easy to operate (and process materials), and it was a piece of equipment that was familiar and non-threatening to participants.

Opening Questions:
"Tell me about yourself: where you are from, how long you have been in Reykjavík for, what do you do?"
"How often you are in this space/place?"
"What do you do in this space/place?"
"Take me through an average day, let's produce a time-line."
"Thinking through your day, when do you encounter geothermal energy/lava?"

Steering Questions:
"Tell me more about how you use/encounter geothermal energy/this landscape."
"Tell me more about how you move in this space/travel this landscape."
"How does it feel to experience this energy/landscape?"
"When you engage with geothermal energy/a lava landscape, how do you manage/negotiate it?"
"How do you think this place would be if the energy/landscape was absent?"
"How do you think this place would be if the energy/landscape was heightened?"
"How do you think this place would be if the energy/landscape was greatly controlled?"
"How do you think this place would be if the energy/landscape was unaffected by human involvement?"

Concluding Questions:
"Do you think there is anything about the geothermal in this space/this landscape that we haven't had a chance to think about?"
"Do you have any additional comments?"

Fig. 3.8. Geothermal questions.

Chatting about the geothermal produced notably geothermal conversations. The informal style allowed for both the participants and I to warm, literally and metaphorically, and to attune to the circumstances of our warming. Briefer, or more structured conversations would have stifled this attunement – there would have been no rummaging in cupboards or turning on of taps (Fig. 3.9 and Fig. 3.10), which captured real moments of embodied geothermal engagement and living. Being flexible *in-situ* was also critical. A glance at a radiator or a sudden realisation that a floor was geothermally heated directed conversation as much as questions about daily routine and energy use.

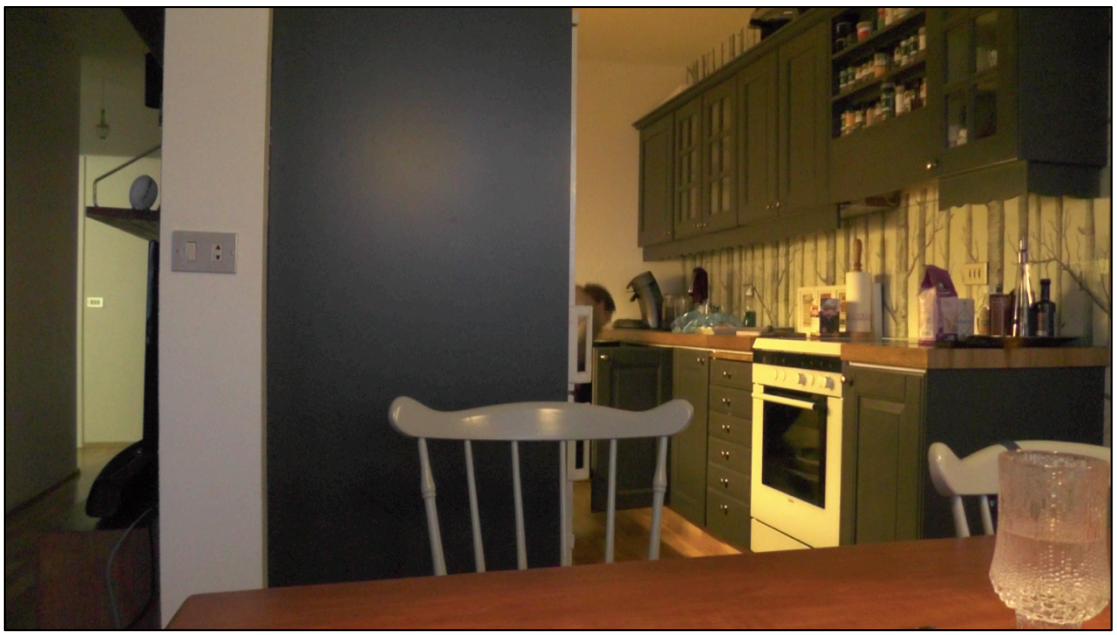

Fig. 3.9. Heiða in her Kitchen, peeping into a cupboard, mid conversation.



Fig. 3.10. Matthildur runs the warm tap.



Fig. 3.11. The camera comes along, Laugardalslaug.



Fig. 3.12. Not *just* talking at Orkuveita Reykjavíkur (OR).

As well as the interesting and telling - quick and subtle - moments, that might have been lost through more rigid encounters and an inability to note them down; chatting and video recording opened doors to other materials and spaces. I was free to follow my participants into basements or control rooms (Fig. 3.11), and extra materials like diagrams, plans, and maps were pulled-up, opened, and loaded (Fig. 3.12). There was a prevailing sense that, much like the heat with which I was trying to attune, the process of being a part of geothermal tales was at its most vibrant and vital when it was simply allowed to flow; moving, gathering, releasing.

I spoke with interviewees in the places and spaces in which they encountered the geothermal via heat of lava-dominated landscapes. This was useful and valuable for two key reasons. Firstly, it meant the conversation – by virtue of us being geothermally *in situ* could easily be focused or refocused onto the geothermal. Secondly, it meant that we got to experience being warmed by the geothermal within these locations together, which fed into the discussion and was recorded by my camera as we sat, or stood, or walked about. It was important that these interviews were actually more like conversations; an opportunity for experiencing geothermal warmth and talking about it. I was acutely aware of not wanting to lead the conversation to a point at which someone simply said what I wanted them to about the geothermal. I did, however need to steer and direct the conversation. This was in part, because like warmth coming and going, the conservation came and went: one moment talking about a radiator (Fig. 3.13), the next distracted by a bird that flies by the widow (Fig. 3.14). Thus, the conversation leaves heat (although our bodies are still warmed by it, and this all still captured on camera) and heads-off towards flight, holidays, and an anecdote. If it weren't for the occasional realignment of topic, the geothermal had a tendency to settle back into the background, ungraspable.



Fig. 3.13. Geothermal chatter is distracted by a bird (off camera) outside the window in Mosfellsbær.



Fig. 3.14. Anna's hand on her geothermally heated radiator.

Whilst I found my previous time spent 'becoming geothermal' required experimentation and a discursive, and at times hap-hazard and serendipitous approach, this was not the case undertaking geothermal interviews. The biggest challenges were obtaining interviewees and ensuring our chat remained on-track with the focus on the geothermal. The former gathered pace quite quickly, as word-of-mouth and a tenacity with emails and phone called paid-off. I had to remain aware of how the sample was taking shape and would occasionally follow-up specific potential contacts in an interest of maintaining some form of age and gender balance, but ultimately found myself speaking to more people than I had anticipated. With regards to the latter, I found guiding questions helpful, but the fact that our chats took place within the spaces of geothermal warmth and lava-dominated landscapes proved to sufficiently anchor discussions. The geothermal was always there, in the moments we directly and consciously engaged with and acknowledged it, and even when we did not. Video also proved to be a valuable medium, not least for its ability to be elementally infused and resonate an affective capacity after-the-fact. It captured something of the atmosphere of the conversations – a spatiality, temporality and animated embodiment - that audio recordings, notes and photography would have struggled with. Only two interviewees expressed a preference to remain off-camera, in which case the camera still acted as an audio recording device and was later used to film parts the space within which we had spoken, providing a still rich record. I decided to not

fully review my interviews whilst in the field, for two reasons. First, I did not want to find myself compromised by fixating on what others had or hadn't already said. Second, for practical reasons, I did not have the time to begin fully reviewing interviews in the field. I did, however, constantly check that equipment was working, and that video was being produced, stored and backed-up (using two separate external hard-drives). The final challenge presented by undertaking geothermal interviews was to then attend to these materials once I had completed my last conversation.

Warm words

I found myself, once my interviews were complete, with 'warm words'. By virtue of them being spoken and recorded within, directed toward and extracted from the lived experiences of geothermal heat; these words carry with them something of the geothermal's elementality. I had attended to a need to be "anti-biographical and preindividual" (Thrift 2007, p.7). Rather than only be about individual human subjects, interviews were also about the much broader geothermal experience, and the interactions between human bodies and heat. This is not to say that there weren't moments when interviews trailed off-topic, but given the sheer ubiquity of geothermal warmth these were still literally warm words, a display of everyday geothermal life: a reminder that "the background matters… a collectively lived and shaped condition" (Anderson & Ash 2015, p.34). The use of a video camera had proven to be truly freeing, and allowed this phase of fieldwork to "not concern…so much with representing lifeworlds as with issuing forth novel reverberations" (Vannini 2015b, p.12). The moments - the warm words - caught on camera, contained within them the elementality and experience of the geothermal everyday. I had concluded my interviews with an intention that the materials "ought to be viewed less as revelations and more as reverberations" (Vannini & Taggart 2013a, p.65) of geothermal energy and warmth.

I kept this is mind when then organising and analysing the video recordings and photos created during geothermal chats; mindful of the broader geothermal experience, the on-flowing elementality and ubiquity of the geothermal, that existed within and around the talking bodies. As these interviews held within them meandering and contextual accounts wherein the geothermal shifted between subtle background matter to explicit and immediately conscious it was clear that they would need to

be reviewed as a whole. For example, transcribing interviews and running a keyword analysis for mentions of the 'geothermal' would have provided nothing in respect to the rich lived experiences that had been captured. Turning back to the literature that had influenced the research design, and research questions, analysis needed to consider the relation between the geothermal and the urban, how the elementality of the geothermal was articulated, and the places and practices which existed. This required an exploratory, content-driven, thematic approach to organising and analysing the interview materials, drawing from adaptable qualitative data processes (see: Creswell 2002; Guest et al. 2012; Braun & Clarke 2013), applied to video (Heath et al. 2010b).

Analysis commenced by replaying interview videos, which permitted a re-attunement to the geothermal urban, echoing experiences and observations from the initial field period. Driven by the research questions and drawing on previous literature (see: Chapter 2), existing concepts and themes guided this analysis; which proceeded with a interest in and regard for emergent elemental geopower (Grosz 2008; Bennett 2010), the sociotechnical capacities and qualities of infrastructures (Graham & Marvin 2001; Starosielski 2015), gathered affective atmospheres (Ingold 2000b; Anderson 2009) and more-than-human hybridity (Haraway 1991; Whatmore 2002). From this, three key recurring themes were noted: the surfacing of geothermal heat (from the ground into buildings and bodies via a system of infrastructures and processes), atmospheres of warmth (spaces and places of focused and contained geothermal heat), and embodied practices that emerged in direct response to the geothermal (heated homes, taking showers, walking melted pathways, swimming). The visual dimension of the videos had captured the spaces of more intimate geothermal urban experience and proved to be valuable in placing me, as the researcher, back into the places our discussion had been in. Whilst they did not engage and highlight the palpable, kinetic, and visceral qualities of the geothermal as explicitly as the more creative videographic experiments had done, they effectively framed the spoken 'warm' words enhancing these revealing and descriptive accounts. Following the emerging three key recurring themes, interview materials were reviewed again, through which predominantly spoken aspects that resonated the elemental qualities and experiences of geothermal urbanism were identified. A process of transcription allowed these vocalised details to be further collated and organised, so as to convey explicit engagements with the geothermal. They revealed

distinct accounts of Reykjavík´s geothermal urban world tied to infrastructures, architectures, and bodies; which permitted a second layer of codification tied to sites. These foregrounded accounts were then cross-referenced with the recurring key themes of surfacing, atmospheres, and embodiment, to begin building the discussions that feature in the subsequent empirical chapters, with the transcribed words able to evidence and illustrate observations and arguments. At this point returning to field materials was becoming repetitive and redundant, wherein new insights were ceasing to be gained through further analysis. Understood as a point of data (inductive thematic) saturation (see: Saunders et al. 2018), the research process then moved on to discuss the themes and observations (see: Chapters 4, 5 & 6).

The interview materials proved to be highly valuable. They captured accounts of the geothermal urban that provided insights that facilitated detailed discussion of geothermal urban phenomena in Reykjavík. Curiously, in spite of deliberate attempts not to steer conversation in either direction and utilise neutral questions, these accounts were ultimately very positive. For such a geologically and geophysically active place, concerns regarding geothermal excess, or dissenting views did not emerge from geothermal interviews with any great significance. With regards to dissenting views, this may be connected to the socio-political context of Iceland, in which geothermal heat is successfully state owned and run, meaning the geothermal heat and energy is highly affordable, and is effectively monitored and maintained. Disruptions seem very rare and not flagged by respondents talking about their use of geothermal heat. A small number of professionals discussed occasional problems like burst pipes, but these were very much in passing and seemingly uncommon, and such is the system design they rarely caused any notable interruption to the on-going flow of heat. Using geothermal heat is also widely viewed as an environmentally friendly alternative to carbon burning heat and energy sources like coal, wood, oil and gas; or nuclear power. This might explain why there was a lack of environmentalist concern usually associated with energy and infrastructure provision. Indeed, the few voices that did raise concerns, were those appreciative of and wanting to protect lava fields from over-development - most notably highlighted through the piece of performance art “Sad Problems #15” by the artist Amy Howden-Chapman, on the site of a lava field in Garðabær that was being

controversially removed to make way for a new road. Concerns related to the catastrophic potential of volcanic eruptions and earthquakes also didn't feature. This doesn't mean they don't exist, but they didn't emerge as critical aspect of the geothermal urban experience, at least in Reykjavík. In conversation with Hafnarfjörður's urban planning team, the potential for such events briefly came up but held no immediate concern. It is possible that such apprehensions may have been more forthcoming in other places closer to current volcanic and seismic activity, that for those exact reasons, are less populated.

3.4| After elemental fieldwork

The previous sections have outlined two distinct ways of completing elementally focused fieldwork, undertaken to engage and understand the geothermal, geologic, and elemental in an urban context. Both a process of geothermal attunement - the first was a performative, immersed, and embodied engagement with the geothermal urban world; the second, the completion of geothermally focused conversations, exploring geothermal urban lives. This final section turns to the period after elemental fieldwork. First, it considers the complexities, difficulties and challenges of incorporating more-than-representational and elementally imbued materials into a written thesis (*retaining warmth*). Finally, an assessment of the value and effectiveness of the field methods used offers some reflections and direction for other research agendas that may seek to explore the geologic, elemental or more-than-human phenomena (*other attunements*).

Retaining warmth

Experimental encounters with geothermal heat, *in-situ* geothermal chats, more-than-representational geothermal cinematics, and warm words: geothermally attuning fieldwork was elementally illuminating, and whilst the videographic materials created can be reviewed and analysed within that medium, they are required to go through a process of extraction and translation to form a part of a written discussion. Video may accompany written accounts by either being embedded aside written content in online publications or hosted separately online and linked to in footnotes. The former is not possible with printed text that takes the form of a book (like a thesis), and whilst the latter is

possible it relies heavily on factors such as online access, the maintenance of web sites, having the appropriate software and hardware, and can come at an on-going financial cost. For this research, two key questions drove a decision to utilise transcription, description, and still images of geothermal urban phenomena within the subsequent discussion chapters. The first was to consider where the vitality and elementality of videographic materials were most important. The richness of these materials was most essential during analysis, where an afore-mentioned ability for video to place myself as a researcher back into geothermal spaces facilitated a reconnection with the everyday elementality of these encounters. This is not to suggest that the videographic materials would not also be highly effective at relaying the geothermal urban experience to others, but nonetheless led to a second question; asking if the vitality and elementality of videographic materials could be effectively translated into written form so as to evidence discussion.

Videographic materials could inform and illustrate a written discussion of the geothermal urban, but would need to be engaged in such a way that I did not find I had "literally 'written out' the agency of non-human others" (Greenhough 2010, p.51) through my work. This raises challenges about how to go about communicating the experience of phenomena captured in one medium through to another. It threatens to strip-out the spatial, kinetic, animate vibrancy that digital video offered over audio recording and written notes. For Springer (2017) the solution is to engage with a metaphorical 'Earth writing' which draws out a 'geopoetics', which I interpret as being descriptively "acute and cute" (Dewsbury 2010, p.332) in my writing and allowing words-as-spoken to fill the page. Spoken words can be transcribed; scenes, settings and experiences can be described; videographic accounts can have stills extracted and juxtaposed, overlaid and montaged in such a way that an inherent affective elementality continues to resonate. This is an effort towards ensuring my "accounts fairly suggest their partial-ness and moment-ness whilst still saying something interesting and useful about the world they describe" (Latham 2003, p.2007), in which "a poetic sensibility meets a sensuous disposition" (Paterson 2009, p.785).

Whereas the videographic materials did need to be engaged as produced in the field to inform my analysis, they did not necessarily need to be directly included within the written discussion. The wider academy is increasingly turning to ways of including such materials within, aside, and supplementary to written accounts; however, in the context of a written thesis the adaptation of these materials is both pragmatic and upholds the vigour of any discussion or argument. In working with these materials, it became clear that the transcribed interviews and descriptive accounts of the geothermal urban experience were highly effective in illustrating and evidencing the unfolding discussion. As a result, the interview material, which was also of great value for its exploration of plural experiences of geothermal urbanism, features more prominently in the following chapters. As such, this thesis proceeds with a sense of *ekphrasis*, "translating one art form into another" (Boyd 2017, p.62; see also: Krieger 1991), allowing my discussion and accounts to be warmed by geothermal words and geothermal images (Fig. 3.15).



Fig. 3.15. An ekphrastic geothermal urban montage.

Other attunements

Through undertaking elemental fieldwork under the methodological direction of attunement, there are a number of points worth highlighting that speak to other research agendas. These relate to attempts to undertake creative and performative fieldwork (especially using video), an interest in exploring the elementality of wider phenomena, and most broadly an emerging interest in approaching more-than-human subjects with a concern for being more-than-representational. With regards to creative and performative approaches to fieldwork, two critical notes might be taken forward. The first is not to be shy in being experimental and taking risks to generate expressive, animate and vibrant field materials. In a follow-up attempt to attune to the geothermal, for example, it would be worthwhile not holding back and being more unrestrained in the use of video to uncover a kinetic and visceral elementality. It may be of value to have been creative, more as an artist following a personal sense of thermoception and less as a geographer with a research agenda, also underlining the potential for engaging with interdisciplinary research practice. Second, performative and creative approaches to fieldwork may be more suited to and require more creative research outputs. It is possible to make use of and include non-textual field materials within accounts and discussions, and there is an increasing interest in non-text-based research outputs - still empirical, informative and robust (for example: Butler 2007; Duffy & Boyd 2012; Boyd 2013)[27].

In terms of research that might have an interest in other aspects of the geological, it is worth noting the use of video in this research not just to capture the experience of present-day heat but also past geophysical events that echo through cooled lava fields. Video was able to capture the embodied experience of moving across and through these lava landscapes, and thus presents as a tool easily adaptable to apprehending the affective elementality present in experiencing other geologic forms. Finally, it is useful to highlight the value of a broader methodological line of enquiry in connection to the use of more-than-representational thinking for exploring other more-than-human phenomena. Approaching the geothermal urban through a methodological direction tied to the need to trace, apprehend, and attune to the subject phenomena facilitated a focus on the more-than-human. A

[27] The Creative Agency, "a community of creative makers, academics, industry professionals and organisations[…]a virtual and material co-share workspace" points to the potential of online digital materials (www.creativeresearchhub.com).

more restrictive approach would have risked the production of less detailed field materials and limited the empirical value of the research. The potential for video in particular, has been demonstrated, its value as a tool for attending to and understanding other landscapes and phenomena underlined. Recent attempts to begin to map out the more-than-human research via a practice of "engaged witnessing as a way of attending to the performative and creative nature of encounters with non-humans" (Bell et al. 2017, p.136) can draw directly from fieldwork like this which demonstrates that "moving images have much to offer more-than-human geographies" (Lorimer 2010, p.251). This research employed a methodological approach that was "to undertake…'undefined investigations'…which is to say, investigations that do not begin by *defining* their phenomenon, but seek instead to learn from the investigation what defining, describing, proving, caring, observing, sharing, encountering…might be" (Laurier & Philo 2006, p.353). This is to highlight the value of commencing fieldwork with an initial immersive component; which can attune a researcher to phenomena and to approach follow-up methods and analysis with enhanced and enhancing sensitivities. Other research agendas might proceed with a similar approach, not only open to how phenomena might be understood, but open to how phenomena might be encountered through bolder adaptable methodologies.

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This chapter has examined a methodology tied to the idea of attuning to phenomena, attempts to produce more-than-representational affective field materials, and has considered some of the complexities and difficulties of undertaking such work. It has also outlined how videographic methods are especially valuable ways of attending to a kinetic world and are able to produce vibrant and lively research 'data', suggesting that film in particular has a capacity to become digitally elemental. Critically, it has outlined that in engaging with the geologic, although there is a value to individual experiences with the non-human, there is a need for multiplicity in order to fully understand such phenomena. It carries a warning that attempts at attuning to the world and experiences of the more-than-human need to be undertaken with a care for being open to the different ways different bodies might attend to phenomena; to move beyond the scope of the individual researcher and towards multiple and shared attunements. Overall, it has shown how a

willingness to experiment and engage in a sense of the performative, which can be successfully combined with established practices, can yield rich field experiences and materials. Beyond a warning against stunting individualism, it is a call for methodological attunements to go further and push the creative boundaries of fieldwork and methods in getting caught up in, and being able to capture, the eventfulness of life. This thesis now turns to these 'warm' materials in analysing and thinking through the geothermal urban relations within which they are made, and figuring an understanding of geothermal urban phenomena.

- vignette iii -





Hands.

Washing dishes.

Geothermal heat.

Detergent.

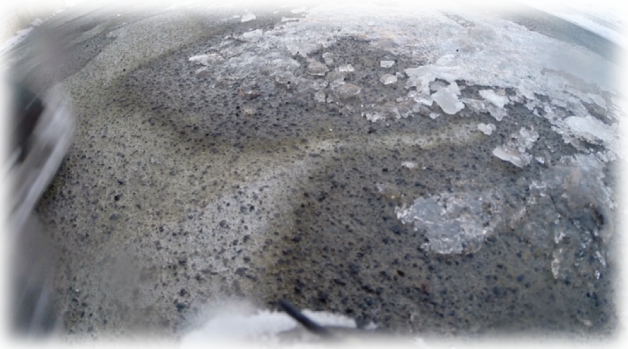
Feet.

Walking the street.

Geothermal heat.

Melt.





4| Infrastructures

"Normally people don't believe, don't understand when I say, I drill to the earth"
- Kristin Rafnsson, Production Manager, Orka Náttúrunnar (ON)

"In the cities…you don't see the pipes of the pumping stations or anything like that…I think the average Icelander doesn't notice"
- Guðni Axelsson, Director of Geothermal Training & Senior Geothermal Reservoir Engineer, Íslenskar Orkurannsóknir (ÍSOR)

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Reykjavík has been outlined as a unique 'maelstrom'[28] of the geothermal and the urban, surrounded by geophysical activity and geothermal heat that the city is constructed on top of, within, under, around and from. An abundance of heat, and in particular geothermal heat, is critical to Reykjavík's existence given its northern latitude and cold climate. This chapter commences a more detailed examination of the geothermal urban, and does so via the infrastructures that enable the exploration, extraction, and distribution – utilization – of geothermal heat within Reykjavík. In particular, this is by focusing on the Reykjavík district heating system; its components, processes, and contextualising its spatio-temporalities. Unpacking and understanding geothermal urbanism is a complex task; if you take only the most immediate observations, it presents as an intricate network of geothermal urban spacetimes, with varied geothermal urban relations occurring simultaneously - a unique spatial arrangement which forms geothermally embedded places. These places are bound-up in human technologies and social orderings resulting in a distinct geothermal urban lifeworld, and there is a deeper complexity that lies just under the surface – not just the surface of the earth, but under the linear, contained, and controlled facade of the geothermal urban machine.

Geothermal heat has been outlined thus far as thermal energy with subterranean origins and drawn into the process of homeostasis. This chapter begins by turning to the forces (pressures, flows, heat) and structures (infrastructures, objects, social organisation) that are critical to geothermal urbanism. It draws out their transformative and processual capacities and provides evidence for an geosociotechnical understanding of geothermal urbanism, by following geothermal heat as it is

[28] I employ this term here after Thrift (2004, p.57), specifically regarding the geothermal as "continually on the boil, rising here, subsiding there". The usage here implies, but temporarily eschews, affective qualities (the intention of the original that will be drawn out in later chapters).

extracted from the ground via a network of complex infrastructures, transferring through objects and physical mediums (primarily water, but also air) and flowing into constructed human spaces. As Gandy (2004, p.374) notes, "[b]y focusing on the flow of water through urban space we can begin to disentangle the nexus of social and technological structures that constitute everyday life in the modern city and the creation of a viable public realm". Similar to water, and also within water, geothermal energy flows around Reykjavík. As it is followed, multiple geothermal urban milieu are illustrated through vignettes drawn from field encounters. These encounters relay distinctive aspects of Reykjavík's geothermal urban lifeworld bound up with and articulated through its geothermal infrastructures, infrastructures that themselves make the geothermal more explicit. This permits the remainder of the chapter to focus on "surfacing"; that is, surfacing as geothermal heat leaving the ground, the surfacing (or the un-surfacing, burying) of geothermal urban objects, and the surfaces that are crossed through geothermal heat transfer. It positions geothermal urbanism as emergent, as something which is in flux, has a varying consistency, and that itself must surface.

4.1| Forces and structures

Forces

Pressures, flows, heat. Each of these is central to the geothermal and is caught-up in geothermal processes as both caused and causal. Ultimately, the geothermal originates with residual heat from the formation of the planet Earth (involving great gravitational and kinetic forces) combined with the existence of radioactive isotopes concentrated in the Earth's upper crust (Garnish & Brown 2012; see also Kruger & Otte 1973, Glassley 2010, pp.11–20). From here it is a composition-in-flux, as temperatures and pressures shift to form flows, and flows cause temperatures and pressures to shift. Flows of heat and pressure that are transferred through, transferred by, and are transformative of subterranean materialities. It is important to recall that "materiality does not just designate brute matter" (Latham et al. 2009, p.62), however within the confines of the inner Earth the materiality of

the geothermal is explicitly physical: heat conducts, convects and radiates[29], pressures mobilise, matter flows. The geothermal, then, has an innate materiality bound up within forces – powers – that derive from and are productive of pressures, flows and heat. It is also an innate materiality bound up within the atoms, particles and waves of energy amassed at the centre of the planet. Within the Earth, then, the geothermal is already mobile and processual; and further, what constitutes the geothermal is the materiality of heat and pressure coursing through different mediums – a swarming multiplicity of atoms, heat waves, and energised particles. In turn, this processual materiality has a temporality and a spatiality – temporalities stretch back to the formation of the Earth and through to the present, whilst spatialities concern definable points in spacetime, and the locus of the 'core', 'mantle' and 'crust' of the planet.

What is so central to the geothermal urban is that these forces are not confined to within the Earth, that is the under-ground, and as hidden phenomena solely of the core and mantle. The pressures, flow, and heat of the geothermal extend into, and merge with, the above-ground through explicitly human processes (rather than via fumaroles, hot springs, mud pool, geysers and volcanoes). This way they are, initially, bound up within pipes and storage tanks. The innate materiality of the geothermal is complicated as it also becomes entangled up with the human – human materialities, spatialities and temporalities – through which a geothermal urban lifeworld emerges. Geothermal forces (pressures, flows, heat) – powers – maintain their innate geothermal properties but also become a part of a wider whole, a geothermal urban whole in which they combine with urban properties: "The relations between the earth and its various forces, and living beings and their not always distinguishable forces, are forms of geopower, if power is to be conceived as the engagement of clashing, competing forces" (Yusoff et al. 2012, p.975).

The forces at work (pressure, heat and flow), all continue to exist within pipes, storage tanks, radiators, and swimming pools. What is critical to note, also, is how these forces wax and wane. In

[29] As (Glassley 2010) outlines (i) 'Conduction occurs via a transfer of energy between atoms (and electrons) of a material' which are 'in [direct] physical contact with each other' (p.15), (ii) The 'combined process of heat being transferred by both mass movement and heat conduction in called convection' (p.19), and (iii) 'Heat can be transferred radiatively by the emission and absorption of thermal photons…similar to light photons (380-750 nanometers), but fall at the longer wavelength (approximately 700 to beyond 15,000 nanometers) infared portion of the electromagnetic spectrum'.

spite of attempts to contain and maintain them within man-made systems that are impenetrable and hermetically sealed, they escape. Heat transfers away through human materials, pressures drop over distance as elevation increases and gravities take effect, flows slow as a result with frictions also playing their part. This means that there must be an intervention in order to maintain the geothermal heat which relies upon pressures and flows – interventions external to the centre of the Earth, superterranean rather than subterranean. That is for example, human-made pressures from pumps, or flows enabled by raised piping engaging gravity, that maintain the flow of geothermal water above ground. Thus, the forces involved in the geothermal urban are geocentric (that is, of the Earth's core and the original process of geothermal creation) and anthropocentric (that is, of the pressures and flows added by human intervention which occur above ground). This heat still retains a distinctly geothermal composition, but it is nonetheless altered by its elevation to the surface. Through this, a key aspect of the geothermal urban is encountered and underlined: the human. Human forces are a critical part of the geothermal urban: "The earth, the world, the universe is made up not only of objects but above all of forces, forces that interact, clash, and coexist, creating both stable, predictable orders of organisation—objects and their relations—*and* zones of indeterminability—events and their singularities" (Yusoff et al. 2012, p.975). Human engagements with geo-forces result in the predictability of a tap which delivers geothermal water onto hands (Gandy 2002; Kaika 2005; Swyngedouw 2014); conversely, when they break down (Graham & Thrift 2007; Graham & Marvin 2001), they result in the event of a burst pipe with geothermal water spraying into the sky and untamed heat escaping away. This underlines the critical role of non-human (in this case geologic, geothermal) agency in maintaining a geosociotechnical networked infrastructure.

Structures

Infrastructures, objects, social organisation. The geothermal urban is being revealed as an assemblage, a "multiplicity of networks" (Bender 2010, p.306), of various actors, human and non-human, tangible and intangible, forces and structures: "rather than seeking to explain phenomena as either natural or social…an actor-network approach, explor[es] the relationships between different human and nonhuman actors that co-produce a particular phenomenon" (Greenhough 2009, p.207). Whilst the geothermal urban might be considered an assemblage, there is a need to think further

than a flat ontology, "[t]here is…a danger that by purging scale too hastily its replacement will remain within the metaphysical circuit, and within the spatial structuralism, from which it seeks to escape" (Collinge 2006, p.251). By this, what is meant in terms of the geothermal urban is that there needs to be an allowance for understanding the role of forces and structures, as part of a geosociotechnical process. The geothermal and urban are not separate spheres but co-formed, in which "the *actor* is a number of different *things* – perhaps human, perhaps nonhuman; maybe conscious maybe unconscious – and always embodies *action*" (Allen 2011, p.278).

With the urban being a distinctly anthropocentrically inflected entity, to imply that humans are a part of the geothermal urban is an incredibly obvious statement. What has not been so obvious, and has just been encountered above, is how the human is not only added into an equation with geologic and anthropologic components, but is bound up *within the geo*. It may be assumed that the geo(thermal) complicates the urban, flowing into the city, heating objects, human (and other) bodies, and transforming human places – but what must also be noted is the way in which the human complicates the geo(thermal) through the simple processes of elevating it to the Earth's surface[30]. This dependence upon a geo human co-forming of the geothermal urban draws out a distinct rejection of a nature-human dichotomy and the value of conceptualizing the geothermal urban more relationally: a "rejection of ontological binarism is intended as an encouragement to think *relationally*, in terms of associations rather than separations" (Castree 2002, p.118).

It is geothermal urban assemblages that form the instrument with which humans (with their physical objects and social organisation) impact upon forces (that is; pressure, heat and flow) and forces impact upon humans. The geothermal is complicated within these assemblages in two ways: as transformed and innate. Firstly, transformed, initially wholly non-urban geo structures like lava chambers and geothermal fields are complicated and become geothermal urban with human intervention (for example, when a geothermal well is drilled into a geothermal field, the field transforms from a wholly non-urban geo structure to one that is geothermal urban). This applies the

[30] This is not to ignore the Anthropocene thesis, which implies direct human involvement in the geological from a species-wide, temporally broadened, global perspective; but is to focus on the more localised, specific, human connection to the geothermal.

other way, in which a non geothermal wholly urban object like a pipe becomes geothermal urban as it is exposed to geothermal energy. Transformed structures are those that are explicitly *folded into* geothermal urban assemblages having been enhanced and previously existed in an alternative state. Secondly, are innate structures, such as the Reykjavík district heating system (that consists of physical structures like pipes and social structures like management teams) all bound-up with geothermal forces. These structures are deeply entangled with, and span, both the geo and human aspects of the geothermal urban and cannot be assigned to just one or another. Innate structures are those that *come into being* within geothermal urban assemblage having not previously existed in an alternative state. These transformed and innate structures might be understood as two forms of hybrids (Whatmore 2002), both with a distinct geologic elemental emphasis.

This thinking can be developed by unpacking these structures a little further. Whilst structures may be understood as transformed and innate, they may also be perceived as tangible or social. Geothermal urban structures exist as physical entities such as pumping stations and storage tanks – infrastructures, but they also exist as social entities (for example bodies like ÍSOR and legal documents like plans) - organisational. To understand the role of structures further, there are four points to consider. Firstly, physical infrastructures are conduits of heat and pressure. They enable the geothermal to flow within the urban and facilitate a mobility of heat that is also critical to the geothermal urban assemblage. Further, these physical infrastructures are the machinery of complicating the wholly geothermal into the geothermal urban (instruments of transformation). Secondly, in spite of this urban complexity, the geothermal is still key. Whilst pumps and pipes alter the pressures and flows of the geothermal, maintaining its heat but also transforming it into something more-than-geothermal, the inherent geothermal qualities are maintained. These geothermal qualities are themselves then transformative – transforming the otherwise merely urban as it is folded into a geothermal urban assemblage. Thirdly, the physical aspect of structures can extend beyond directly networked infrastructures into a web of other enabling objects (to invoke Latour (1991) and the social as any set of associations). This may include maps, test tubes, drills, white boards, notepads and so on. These objects allow the marking out, monitoring, extracting and utilization of the geothermal. They are implicit and contingent in the geothermal urban, embroiled in

its formation and a part of it. Fourthly, is human social organisation, which is itself a significant structure that underpins the physical infrastructures and web of afore-mentioned 'other enabling objects'. These structures become evident through company and organisation charts, in the successful building and running of a district heating system, and is evidenced in design documents, network plans and planning documents: "It is as if we might call technology the moment when social assemblages gain stability by aligning actors and observers" (Latour 1991, p.129). The geothermal urban can be viewed as a social organisation of natural materials through organisational structures, but also as the coming together of tangible and intangible forces and objects. As Kaika & Swyngedouw note (2000, p.136), "[t]he dialectic of the environment and urbanization consolidates a particular set of social relations through 'an ecological transformation which requires the reproduction of those relations in order to sustain it (Harvey 1996)'".

4.2| Exploration

"You never know these fields exactly"
- Guðni Axelsson, Interview, 16th February 2015

To 'follow' geothermal heat as it leaves the ground prior to the building of the Reykjavík district heating system would have been naturogenic (Vilkka 1992, pp.99–100), but now in certain locales, to follow geothermal heat would lead in directions naturogenic, anthropogenic and hybridized (Whatmore 2002, pp.160–167). What is presented and narrated here is one following of the transfer and circulation of heat through multiple geothermal-human (geothermal-urban) loci: the Reykjavík District Heating System. Whilst there is an over-arching linear spatio-temporality, geothermal heat is divided, turns and loops. It also escapes, drifts and radiates away. As such there are diversions, multiple endings (and beginnings) and moments where threads are lost and re-emerge. Whilst it is geothermal heat that is followed, it is revealed and made palpable – framed – through human infrastructures, and as with geothermal heat, the various human infrastructural components (socio-political, physical) also fade in and out, emerge and dissipate, exist in the background and suddenly –

or not so suddenly – appear immediately apparent. Herein is an approach both arboreal and rhizomatic, and to commence there is a return back to the origins of geothermal heat within the ground, but through a heated office in central Reykjavík. Just as thermometers were first used in 18th Century France to take initial readings of the warm subterranean world, modern day geothermal utilization starts with similar exploration and attempts to 'know' the geothermal underground.

ÍSOR

On yet another cold winter's afternoon, with snow falling from the sky scattered about by a bitter wind, I was glad to walk into the warmth of ÍSOR (Íslenskar Orkurannsóknir), the Icelandic Geo-survey. The building that houses the organisation responsible for detecting and monitoring geothermal activity in the ground, itself of course, heated by that very geothermal energy: walls, computers, maps, cups, chairs, people. Once through reception to the first floor of the building (Fig. 4.1), I was greeted by Guðni Axelsson, Director of Geothermal Training and Senior Geothermal Reservoir Engineer, "Practically all buildings [in Reykjavík] are heated with geothermal heating" he later tells me [P7-54.00] (See Fig. 4.2). Guðni had been with ÍSOR (including the organisation's predecessor, The Geoscience Division of the National Energy Authority of Iceland, Orkustofnun) since 1985, whilst the organisation's roots go as far back as 1945 as a part of the electricity regulation office (ÍSOR 2015). Guðni explains:

> "…we've been involved in most of the, if not more-or-less all, the research, which we call exploration, which is done prior to any drilling. Research people [are] first to locate where are the most promising resources [and] resource areas. So, I think we have carried out most of that, maybe a little by universities and a bit by the engineering firms… 95% has been done by us"
>
> [P7-07.00].



Fig. 4.1. *The internal entrance to ÍSOR. A large geological map of Southwest Iceland welcomes visitors - highlighting lava fields, lava channels, warm springs, fumaroles, craters, calderas and faults.*

Whilst the structure of the organisation has been fluid over the years, as of March 2015 ÍSOR has two main divisions: geoscience and geothermal engineering, each with just over twenty employees and focused on individual projects. The organisation is owned by the state but self-funds by charging for it services – with an increasingly non-domestic client list as they provide training and expertise as far as mainland Europe, Kenya, China, Central America and The Philippines. ÍSOR's involvement in the provision of geothermal energy can be seen to revolve around five main steps. Firstly, the exploration or pre-feasibility stage, wherein before any drilling is begun geological mapping is used to determine where geothermally heated water and steam might be found. Secondly and thirdly, the geochemistry and geophysics of any location is studied. This involves taking samples of geothermal fluid to try and understand the temperature of a system and the use of physical methods to look into the ground to gather the size of any reservoir. Following these stages, fourthly, wells are drilled and tested. Then, fifthly, comes reservoir physics and engineering - wherein heat may then be extracted on a regular basis and a programme of systems maintenance enacted. Such work involves teams that consist of a mixture of people with varying expertise: "People are used to working together on these projects, they are not isolated in the corner…it helps understand this phenomena underground that you cannot really see or access or measure directly" [P7-11.00].

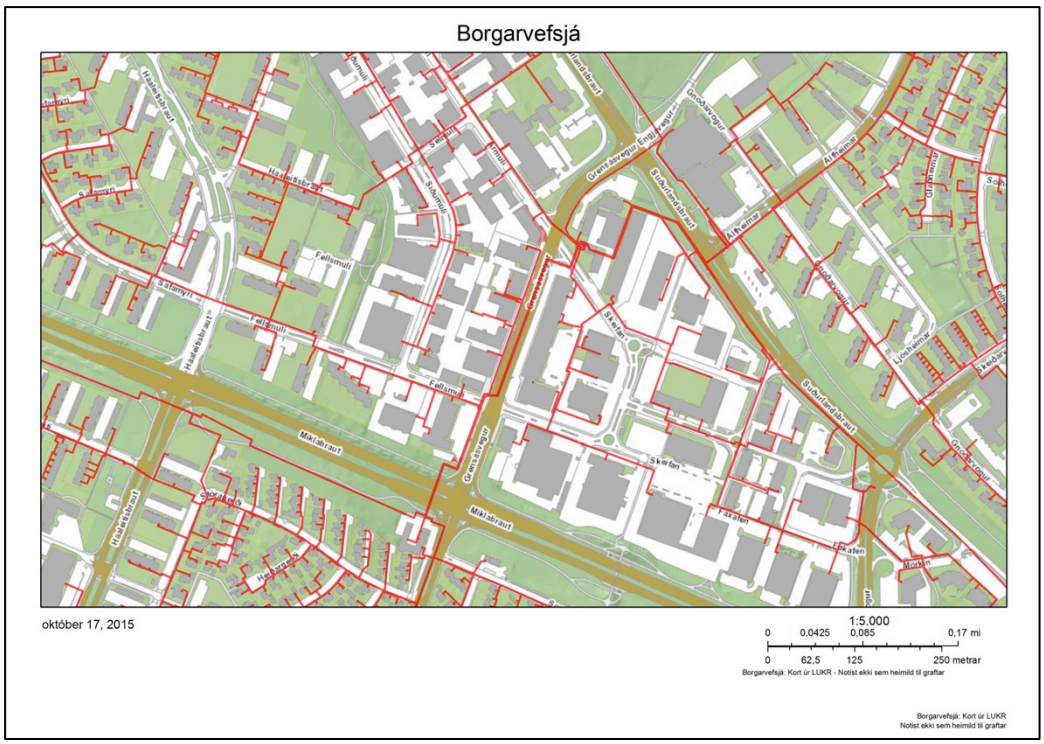

Fig. 4.2. *ÍSOR lies at the centre of this map on Grensasvegur, the red lines are the pipes of the geothermal district heating system (Borgarvefsjá 2015)*[31].

Mapping Geothermal Iceland has a long history, from the Saga's of approximately 1000 years ago, to the commencement of geothermal drilling in Reykjavík in 1928 (see chapter 2). However, mapping the potential locations of geothermal utility with scientific rigour has been a more recent endeavour, and for ÍSOR and South-west Iceland this really started in the early part of the 20th century with a peak of exploration in the 1960's and 1970's [P7-11.00]. The methods used to read, map, and probe the environment have developed since the early 1900's and the process – of exploration and developing exploration methods - is on-going; "People are continuously drilling more of these geothermal wells, and the research that we can do, each new well provides more new information…a new piece in the puzzle. It's on-going, even if we have a geothermal field where there is a power plant operating, they still need to drill occasionally" [P7-13.00]. The ways in which geothermal energies are uncovered varies, but Guðni explains them as essentially falling into three approaches. Firstly geological mapping, looking for surface evidence of geothermal activity such as cracks in the ground and escaping steam, gases or hot water. The second approach is micro-seismicity, monitoring small

[31] For more information on the maps from Borgarvefsjá see: http://reykjavik.is/borgarvefsja-english-manual

earthquakes that occur in active areas that are more likely to be high-temperature geothermal zones. This requires the placement and monitoring of multiple seismographs, and there is an existing network that covers the whole of Iceland - but it is sparse, so usually special networks of more densely placed seismographs are deployed to study a specific geothermal field with more accuracy. Third is the geophysical method, looking at the electrical resistivity of the ground. It is regarded as the most successful method and exploits a relationship between electrical resistivity, water and heat; where you have both water and heat underground, there tends to be a lower electrical resistivity indicating a location suitable for further evaluation. This method has been used since the 1950's, Guðni informs, wherein a current is run from point A to point B to reveal details about rock types, water and heat. Today, it is linked with also looking at the magnetic field of the Earth, wherein induced currents can now obtain information on resistivity to greater depths, 10 to 30km deep. Whilst the deeper you go the less clear the picture is, most geothermal wells are only 2.5 to 3km deep, so the information provided is fairly comprehensive – however, "There are always surprises…from the surface we can not always see things accurately down there" [P7-20.00].

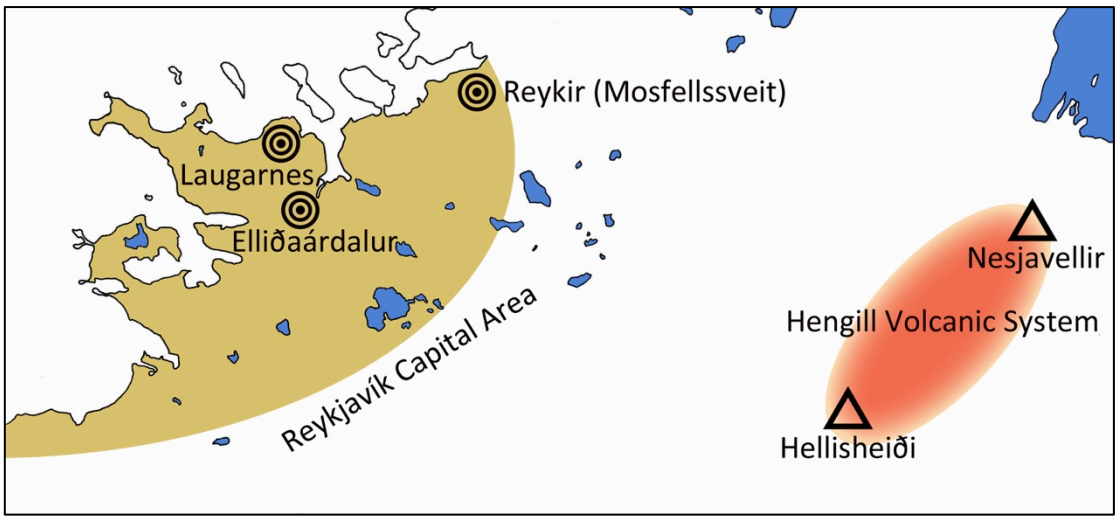

Fig. 4.3. *The approximate locations of the geothermal fields Reykir (Mosfellssveit), Laugarnes and Elliðaárdalur within the Reykjavík Capital Area (yellow); the Hengill volcanic system (red); and the nearby Hellisheiði and Nesjavellir geothermal power plants.*

What is "down there" are three key low-temperature geothermal fields[32] in and around Reykjavík that provide the source heat for the city's district heating system. They are Mosfellssveit (split into Reykir to the south-west, under the suburb of Mosfellsbær, and Reykjahlid to the immediate north-east of Reykir), Laugarnes and Elliðaárdalur (Fig. 4.3) (see: Tómasson et al. 1875; Arnórsson 1995; Franzson et al. 2010). There is a "[m]uch higher concentration of geothermal activity, geothermal resources [in Iceland, than elsewhere]" [P7-42.00], Guðni highlights, and when asked how different things might be if the localised geophysical processes were subtler or more passive the response is that, "The simple answer is Iceland wouldn't be here, you know, this would just be ocean… This volcanic activity has kept us on our toes…It is quite a unique place" [P7-58.00]. Guðni speaks with a sense of clarity when he expresses his view that without geothermal energy Iceland as a nation-state, as a human-urban experience, or as land at all, would be completely different, and that the cheap abundant heat plays a critical part in maintaining positive 'living standards' [P7-56.00] having an impact economically, in that coal and oil need not be imported nor burnt (which would also leave smoke, soot and dust in the air). Actualising the utilization of this cheap and abundant geothermal energy requires much more than simply knowing where it is (or perhaps more to the point, where it might be), however. Once fields have been located, probed, read and explored, they must next be drilled.

[32] "Enthalpy is defined as the heat content of a substance per unit mass, and is a function of pressure and volume as well as temperature. Geothermal resources are usually classified as 'high enthalpy' (water and steam at temperatures above about 180-200 °c),'medium enthalpy' (about 100-180 °c) and 'low enthalpy' (<100 °c). The term 'enthalpy' is used because temperature alone is not sufficient to define the useful energy content of a steam/water mixture. A mass of steam at a given temperature and pressure can provide much more energy than the same mass of water under the same conditions. The distinction is important to geothermal practitioners so the term has entered general use" (Garnish & Brown 2012, pp.409–410).

4.3| Extraction



Fig. 4.4. *The front entrance to Hellisheiði power plant - sleek, orderly and calm – in contrast to the frenetic forces it processes and the fractured lava landscape in which it sits.*

Hellisheiði

The Hengill volcanic system lies just to the East of the Reykjavík Capital Area, and at its southern most plateau is Hellisheiði (Fig. 4.4), the location of the third largest geothermal power station in the world and the biggest provider of geothermally heated water to Reykjavík (DiPippo 2012, pp.384–387), occupying a site of approximately 5km². The landscape is one of lava rock and pipes; in summer, with the green of occasional moss, and in winter covered in snow and ice. Given the temperatures and pressures involved, geothermal heat leaves the ground as both a gas and a liquid. This steam and fluid will vary in make-up depending on the geology of the geothermal field but it is not merely H_20 (water), and will contain a mixture of minerals and gases (for example carbonates, sulphates or chlorides, Garnish & Brown 2012, p.426). This energy is still underground, when at Hellisheiði via steam or fluid, it first enters a pipe that has been dropped down the shaft of a borehole. At approximately 300°c it then rises through the borehole which is connected to a muffler (Fig. 4.5 & Fig. 4.6). The muffler enables the pressure with which the steam and fluid is surfacing to drop so that it can then flow through steam separators. From here the now separated geothermal water, called

'separated water' flows into heat exchangers whilst geothermal steam is diverted for use in electricity production.



Fig. 4.5. *Geothermal steam and fluid rises up through boreholes at Hellisheiði - the borehole housing, a muffler, escaping steam and pipes are visible here.*

Meanwhile, fresh cold ground water (at about 5°c) is pumped into a large storage tank and then up into a steam condenser. Whilst in the steam condenser this cold ground water is used to create a pressure differential with geothermal steam that enables the production of electricity with turbines, however, this water is also heated by the geothermal steam and leaves the steam condenser at about 50°c. The ground water does not come into direct contact with the geothermal steam, however, and the geothermal steam flows around a closed circuit of pipes carrying the cold water: the geothermal heat transfers into the cold ground water via conduction through the pipes. The 50°c ground water then arrives at the heat exchanger in a 'double segregated pipe system', wherein the same manner as the steam condenser, the much hotter 'separated water' extracted from the borehole flows around the ground water heating it up further via additional conduction through the pipes. From here the now cooled 'separated water' (from the geothermal borehole) is returned underground and the warmed ground water (now referred to as 'heated utility water') travels to Reykjavík. It does so via gas-extractors and approximately 22km of pipes, and under the power of gravity, but with the aid of (geothermally powered) electrical pumps. Eventually it is stored in one of a number of large hot

water storage tanks ready to distribute and use within the urban area – here this water is 82°c, only 1°c cooler than when leaving Hellisheiði[33].

Ancillary to the directly geothermal infrastructure is a central building which houses a critical monitoring station, as well as a reception, visitor's centre, other offices, maintenance rooms and other amenities. The plant is curious in that it manages to be both large but navigable. It also seems awash with workers but the number is perhaps lower than might be expected. I'm informed by Kristin Rafnsson, Production Manager at ON, whom has worked at Hellisheiði since it opened in October 2005 that there are about 20-30 workers at the plant, consisting of around 8 electricians, 8 engineers and 15 maintenance staff (numbers varying due to contractors that are not always required). Building work began in 2004 and before that the area was known for a (still existing) farm and as a skiing area in winter. There was uncertainty from Kristin as we talked over when the first borehole was drilled – for exploratory purposes – but he was of the thinking that it was most likely in the 1970s. Production began in 2006 when the first turbine began generating electricity from geothermal steam (at that time 22-27 boreholes had been drilled). Then, in 2010, hot water production began. Over 50 boreholes have been drilled today with approximately 36 in use. The power station can produce up to 303 megawatts per hour of electricity and 500 litres per second of hot water. Amongst all this infrastructure, technology and heat, one thing is for certain in spite of being hidden under snow and ice in winter, "There's…lava here, it is…lava" [P19-04.00]. The landscape is undoubtedly volcanic, awash with frenetic chthonic energies being extracted from the ground – a mixture of lava rock and steam, of the strong vibrations of equipment whirring and the hum of a network of physical infrastructure breaking the surface, sorting, propelling.

[33] A detailed animated description of the production cycle for geothermally heated water at Hellisheiði can be found on the OR website: https://www.or.is/vinnsluras.



Fig. 4.6. *Above a borehole, the main pipe descends into the ground, geothermal steam and fluid flowing up into the pipes that link to mufflers and the rest of the plant's network of components.*

As with ÍSOR the operations that allow for the extraction and processing of geothermal energy are housed in a building heated by that very energy. It´s hovering around 0°c outside but we are comfortable in a side meeting room, geothermal heat flowing around us. As we talk our conversation jumps about, just like the geothermal heat that is one moment underground, the next in a heat exchanger, that is at the same time conducting into another medium and escaping through a hood or muffler. This is because the plant is a complex arrangement of different processes and objects, of balances and checks, of physical infrastructures and systems of management that, for their deviations and chaotic natures, form a coherent and functional whole. Talking with Kristin reveals how the successful extraction of geothermal energy is a matter of managing the energy, and managing the objects and organisational processes that enable the energy to be utilized. It also reveals how embedded the ground, the landscape, geothermal energies and the built form are within each other, and how overtly so for someone working directly with heat production. Having begun by telling me about the history of the site (outlined above), we quickly turn to the landscape itself: how we are on top of lava (albeit thousands of years old) and how there aren't many natural (steam) vents in the

immediate area but a short way along the road at Hveragerði (a small town about 45km east of Reykjavík) things are more visually visceral (notably the Reykjadalur hot spring valley and large geothermally warmed greenhouses) . From there we drift into talk of geothermal heat as a resource that must be used sustainably: as the geothermal fluid and steam is extracted the water-table, and pressure, drops. Kristin explains:

> "Yes we monitor, and in our license… we have to, we have a scale, there is a scale that we have to be in. There's a frame that we cannot go out-side. We have to work in that frame, how much we take the water down and how much steam we can take up from the area, and er, we monitor this. Each week we go on every bore-hole, measure the pressure, and er, if it is not monitoring automatically in the, in the, computer system, then we go each week, measure the pressure of the, of the boreholes. And then we['re] regularly measuring the, where the water level is in the ground. The cold water [too], we, this is monitor[ed] automatically on each borehole. The water level in the cold water area. So, yes, we monitor it very well."
>
> [P19-07.00]

Every 3 months resistivity of the ground is used to check the water level, much identical to the methods used by ÍSOR during the exploration of geothermal fields. Indeed, ÍSOR are involved in the monitoring of the boreholes, "there is a company, it's called ÍSOR, and they regularly, they sen[d] down special tubes to measure the heat, the pressure and the level of the water…we are doing that regularly, maybe once a year or [every] two years" [P19-10.00]. Along with monitoring boreholes, the monitoring of existing consumption of geothermal heat is also a central part of the utilization of geothermal energy – and planning for its continued use. Kristin tells me that there are plans underway to expand the steam supply in the next few years, where they will start taking geothermal heat from a new area within the Hellisheiði site – a reminder that of the 50 drilled boreholes, 14 were so far unused. Amongst all the pipes, vents, hoods and pumps lay wires and sensors. Computers (Fig. 4.7) and computerised sensors are a critical part of the plant's infrastructures and play a vital role in monitoring and controlling the extraction of geothermal energy as well as its distribution: "We have thousands of measurements, we see it in the measurements mostly…We have a set point, and… we have low alarms and high alarms and that is the best way to find out[…]everything is working

correct[ly]" [P19-55.00]. This "set point" is a mixture of many measurements – with low and high limits within which pressures, heat and water levels are ideally maintained.



Fig. 4.7. *The main control room at Hellisheiði, computerised monitoring of the plant's processes and a view of the heat exchangers.*

Again our conversation drifts, as we continue to tour the power station. Kristin moves to telling me about the temperature of geothermal water as it travels the system (outlined above), and then is reminded of one use for it, at the 'end' of its journey – at about 30°c, seeping into small pipes directly under pavements to melt frost, snow and ice, before heading into the waste system and out into the sea. With this, Kristin is then reminded about a difference between geothermally heated water coming from Hellisheiði and geothermal water coming from, for example, Mosfellssveit. The difference is precisely that, at Hellisheiði geothermal heat is used to warm up cold ground water – it is this warmed ground water that then gets piped to Reykjavík. From Mosfellssveit it is the geothermal water itself that is pumped directly into people´s homes. The main reason for heating up cold fresh-water is that it has a different chemical composition to geothermal water. Due to the heat and pressures underground, geothermal water absorbs extra minerals that can cause scaling in pipes. Using heated fresh water means these pipes do not block up as easily and last much longer, saving on maintenance costs. A number of homes also have their own heat exchangers, wherein a closed loop

of fluid runs around the building. This fluid is heated up by either geothermal water or geothermally heated water and carries geothermal heat around the building in pipes. This means that in some buildings in Reykjavík, the geothermal heat has been through two transfers; firstly at heat exchangers at Hellisheiði warming cold fresh water, and then at a destination's own heat exchanger where this heated fresh water heats up a closed loop of fluid that runs around the building. In other cases, though, the geothermal is direct. In these cases the composition of the water is fine for it to enter pipes and then be directly utilized for heating or washing. It may still encounter a heat exchanger at a property, but in some cases it comes literally from the ground into domestic usage: onto skin and into transferring into bodies. This is the case with water that comes from Mosfellssveit, and whilst geothermal water and geothermally heated fresh water are not directly mixed, the flow in a pipe occasionally switches from one to another as the source is alternated depending on production, demand, and (sometimes) maintenance.

4.4| Distribution

OR

While an incalculable length[34] of pipes transport geothermal and geothermally heated water to, across, within, and from Reykjavík – as with the Hellisheiði power station – there is a room from which all this is overseen. At the headquarters of OR on Bæjarhálsi in Árbær (East Reykjavík), is the main control room for overseeing the distribution of hot water. It is simply impossible to monitor every millimetre of every pipe every moment, but sensors placed at key points send back information digitally in either real-time of at specific intervals providing a live snapshot of the district heating system's circulatory. The main control room at OR conveys the status of the network through a collection of monitors – but also phone lines, notes and readings from on-site observations, and marks and scribbles on white boards and system diagrams. It is a room abuzz with the 'health' of not

[34] Whilst the lengths of individual pipes are known by OR, such as the main pipes from pumping stations to storage tanks, and the details of smaller pipes (for example in homes) were marked-up (and occasionally still are) on architect's plans, the sheer number of pipes along with varied ownership, inaccessibility and – almost undoubtedly – the simple fact that some have been forgotten or 'lost' means that knowing the actual length of the entire combined network is incalculable.

only the hot water system but also geothermally produced electric power, constantly overlooked by a number of workers from OR. This human involvement is crucial as "computers can't make decisions" [P6-41.00], Sigurður Steinþorsson, a mechanical engineer at OR explains. Whilst the computers can process and relay a vast amount of data on the current operation and status of the geothermal circulatory – and enact changes to it by allowing engineers to remotely alter valves, pressures, output and so on – it takes the minds of trained engineers to interpret what exactly is going on in the context of the wider system and make any relevant alterations to ensure its continued stable operation.

Beyond computer systems and human minds, there is also the now familiar backbone of brute matter (see: Ingold 2011, p.31) – heated water, physical infrastructures such as (even more) pipes, valves, and housing units for components. In a meeting room Sigurður accesses the organisations computer system and presents an overview of the distribution of geothermal water across the Reykjavík Capital Area. The first thing to note is – once again – overlap. To mark exactly where distribution begins and ends is complicated, and the explanation commences once more underground. Sigurður retraces steps, pointing out the locations of wells and boreholes in and around Reykjavík, and reinforcing just how much a large-scale, monitored, and heavily-relied upon system can contain so much disorder - that the order with which the system is perceived is very much in flux, has blurred boundaries and is chaotic (not just under the physical surface, but past the mirage or order). As an example, Sigurður is quick to point-out that the heat with which water and steam leaves the ground "varies a lot, we have up to 130 °c in some areas…down to 70°c" [P6-00.00].

Scanning a system map the scale of the district heating system is made clear; "How does it work? Well, it begins in the wells, it begins in the power plants, the water we have here comes from many different locations" [P6-18.00]. Sigurður uses the technical maps to zoom into one of the main pumping stations in Mosfellsbær, Reykjahliðarstöð (Fig. 4.8), which "takes all the water from the wells and sends it into pipes 700 to 800 millimetres [in] diameter, [on]to the [rest of the] Reykjavik area" [P6-20.00]. Indeed, in some parts of Reykjavik geothermal water flows directly from the ground, up through boreholes, through pumps and into homes (where it may or may not meet a heat exchanger). For the water that isn't used as directly, this is sent to large geothermal storage tanks such as those at

Grafarholt or Öskjuhlíð, and then from there into homes, pools and buildings where the premises are connected by a steel pipe fitted by OR, the internal plumbing of the building fitted and managed by separately contracted plumbers.

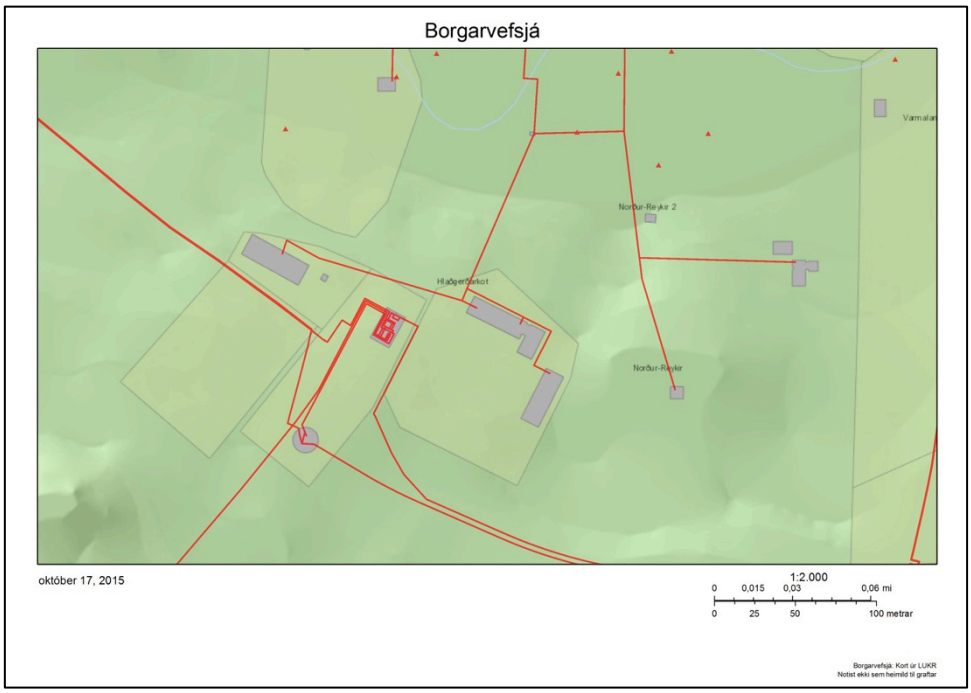

Fig. 4.8. *Geothermal pipes come into and out of a pumping station and storage tank at Reykjahliðarstöð in Mosfellsbær (Borgarvefsjá 2015).*

Water often arrives at homes at around 80°c, which in line with newer regulations in place to safeguard users following accidents in the past, means these homes then need a heat exchanger to bring the temperature down slightly to make it safer to use. We then zoom out from Mosfellsbær and into the main pipe that allows hot water to flow from there into central Reykjavík:

> "The town is divided into two parts, half is using this energy from Mosfellssveit, and we mix it with [water from wells in Laugarnes]...we can mix these two types of water [from different wells]...so that means, well, some part of the city is from the geothermal wells we drill and the rest is from the power plants."

[P6-24.00]

Sigurður clarifies:

> "We don't mix the two types of water [geothermal and geothermally heated], we take the water we get from the wells in Reykjavik and Mosfellssveit...we can mix those two type[s] and run them in the piping systems, but we have to divide the piping systems into two parts...the other part...is the west side of the city...we keep that only on the water from the power plants, because if you mix water which is heated up, cold water heated up, and the other one from wells, it gives problems... so we don't do it... it blocks the pipes, because of silica [build up]"
>
> [P6-26.00].

Whilst the network of pipes undergoes maintenance, and a number of new pipes have been added to the system over the past 10 years, a lot of the infrastructure is dated. "We run it over fifty years, some parts of it...and the oldest parts are even older, so in some areas it's difficult...replacing them...for the new pipes we're putting down now…fifty years we want them to be running properly" [P6-27.00]. This long life-span is beneficial economically, however, there are problems with older components - "We have asbestos pipes for instance...they break down, due to changes in pressure, they just break like shells [P6-29.00]. Modern pipes are made of different materials and are manufactured in Iceland by a company called SET Ehf, "It's steel, it's normal steel...we have insulation of foam, polyurethane foam, and we have [a] polyethylene coating around it" [P6-30.00]. Nearly all of the pipes, old and new, are underground – about 70cm. This serves to protect the pipes somewhat, with them less exposed to adverse weather conditions, and also serves a practical and aesthetic purpose, in that it is tidier and more convenient to have the pipes out of the way underground, rather than crossing over streets in sight and in a potentially haphazard manner. There are exceptions however, with the (older) main pipe from Mosfellsbær above ground, encased in a concrete box (Fig 4.9 & Fig. 4.10).

With that in mind, Sigurður returns to the geothermal source at Mosfellssveit, and points out that all the wells are clustered along a line on the map, he explains that the reason for this is that they are

placed along a crack in the ground from which the geothermal energy surfaces. Sigurður goes on to explain that the output of the boreholes and the water table are stable, bringing up a record of the amount of water pumped over the previous year. Much more water is used in winter compared to summer, which highlights a temporal/season variance in geothermal usage.



Fig. 4.9. *The main geothermal pipeline above ground in Mosfellsbær.*



Fig. 4.10. *The same main geothermal pipeline in central Reykjavík has become a pavement.*

This may lead to the assumption that Reykjavík is less overtly geothermal in the summer. Whilst usage is down, small streams of steam still appear from pumping stations in the city, albeit in a reduced capacity as pumps are temporarily switched off. Hot water is still used for cleaning and bathing, and the lava fields that echo under-worldly volcanic and geothermal processes continue to surround, infiltrate and literally form the foundations of the urban. Moreover the lava fields become more apparent during the summer as they no longer lie under a blanket of snow and ice.

Our discussion refocuses again and returns to the control and running of the geothermal system:

> "There are many wells, and we just turn them on you know, we just turn on the pumps which are deep in the boreholes. We start the pumps and in the summertime we might be using only 5 of 12 [wells]… we use the ones that are not as sensitive, shall we say, use the ones that are always full."
>
> [P6-40.00]

With the pumps sometimes extracting geothermal water and sometimes not, how does the earth respond to this human process? "Well", say the engineers. The water table recovers when geothermal fluids are withdrawn from underground; and "If we turn off the pumps and the wells, take out the houses, take the equipment away, and close it…then it [the geothermal water] just, stays [in the ground]" [P6-40.00]. Be it with human geothermal infrastructures or geothermal energy, there is an underlying familiarity with geothermal heat and the everyday, a sense that resonates when Sigurður later adds: "We know how it works, it's always the same…It's…been running stable for almost a century now and…there's no reason why things should change, because…the heat has been in the ground for so many centuries, it's stable." [P6- 87.00]. Human geothermal infrastructures, technologies, and actions, are directly responsible for some geothermal energy surfacing or not surfacing – as Sigurður continues:

> "We can always turn off and turn on a pump – a borehole – from the centre here, that's no problem, it's easy… but generally we use our scientists, and the people who know how to run

the systems, we use the 'story', the computers can't make decisions, like you know, which boreholes are being used."

[P6-41.00]

Whilst a network of sensors allows the engineers to remotely overview the entire geothermal heating system, there is still a need to inspect the system directly. "We can do it from here [the control room] if we want to, but, er, we go to the boreholes anyway to have a look and check it, if [there's] something we can't see" [P6-41.00]. The health of the geothermal system is very important as Icelanders rely on the warmth it generates to live. It is not just pools and living rooms that are made comfortable by the heat, but hospitals, retirement homes and schools provide vital shelter and community services that would cease to function properly should the heating stop. Thus, engineers are constantly looking out for any problems:

"There are many ways of knowing, if the pressure drops rapidly, and they see it at the control station…something is happening. But, for the hot water, we always get steam coming up from [the ground], almost always, so we can know that there is something happening, if there is a small leak they always get bigger…it's not like the cold water, the cold water can be very sneaky…"

[P6-74.00]

Again, whilst sensors provide critical information remotely, the biggest indicator of a problem with the system is seeing steam escaping from a pipe or the ground (the heat and pressure causing such a distinct visual indicator). Sigurður explains further:

"in the old days, we put them [the pipes] in, in like a cement box, like a coffin, and on top of it there's a lid, and the lid is cement as well, and er, where these came together there is always a crack, there is always a way for the water to come down, and it drips on top of the pipe, which…we have rock-wool insulation around it so there is no plastic coating like a polyethene coating, so this rock-wool get wet, and through the years it [precipitation] leaks

> down, and the water coming down in this area, is dripping on the pipe, and slowly it forms…slowly, it starts rusting and in the end there is a hole, and the water comes out, through a very small hole at high pressure, and we have like a…big steam coming up around it. What we do, we take of the lid, we turn of the pumps, we, sometimes we have to cut out a part of the pipe or something, sometimes we simply…just fix it like this [patch it up], in most cases we just take out to part and weld"
>
> [P6-70.00]

On the rare occasions that there is no hot water: "Mostly we know what's happening and we tell them [users] as soon as we can. We use sms a lot, you know, just to send an sms to all the people in the area, and then we put it in the press and er, on the website, the official website, to tell people what's going on " [P6-72.00]. In such a way, be it in the sending and receiving of emails or making and taking of phone calls in the control centre, or in the use of the press and the internet in communicating with consumers, the geothermal heating system is also interconnection with other systems or networks, such as those of communications and electricity. Furthermore, the successful running of the district heating system relies on working with other departments and organisations: "Well usually…just for heating a pavement, it could be, the city who is responsible for the pavement and for the road…we provide hot water, we sell the hot water…they have to work with us to do it" [P6-66.00]. Geothermal energy is tightly intermingled with the broader urban environment within the Reykjavik Capital Area, through physical objects, and through systems of social organisation, politics and economics.

4.5| Geothermal surfacing

Surfacing

The preceding sections have revealed that central to the geothermal urban is the surfacing of geothermal forces. These forces (pressures, heat, flows) are drawn upwards where they are maintained and modified by human processes and enter a distinctly geothermal urban assemblage.

In doing so they are transformed and the wholly geothermal becomes geothermal urban whilst simultaneously the wholly urban, too, becomes geothermal urban. Moreover, the process of geothermal utilization is deeply interconnected with the surfacing of this energy and the interface between surfaces as heat transfers from medium to medium and object/body to object/body. The surfacing of geothermal energy is enabled by geothermal infrastructures and crucially by flows, the flow of geothermal waters and the flow of human processes. This surfacing is also enabled through and complicated by interfaces, that is, the interaction between, across, over, under and through surfaces. Surfacing is also complicated by, and highlighted as having, a socio-technical dimension and socio-economic value, in the commodification of the geothermal as a chargeable resource.

Surfacing is embroiled within and complicates the geothermal urban in distinctive and complex ways. Geographers have attended to the concept 'surface' in different ways, "whether figured as material interfaces, natural structures, aesthetic phenomena, geometric projection, or fetishistic distractions…[s]urfaces may be sculpted, calculated, smoothed, camouflaged, magnified, represented, sensed or commodifed" (Forsyth et al. 2013, p.1013). Indeed, surfaces have been engaged as physical entities to be pulled up, pulled open or pushed through, and likewise metaphorical surfaces have been considered for the same treatment – in both cases to reveal depths previously unknown. Surfaces have also been engaged in themselves, the focus not on depth, but on breadth and the immediate. What is interesting about the geothermal urban is that the surface of the earth, a considerable boundary, is side-lined - "[t]he scholar's neglect and suspicion of surface phenomena is a consequence of a dichotomy in western thought between surface and depth, sensory appreciations and intellectual understanding, with bias against the first two terms" (Tuan 1989, p.233). Perceptions of the geothermal urban are preoccupied with the subterranean and the superterranean, with energy 'down there' and then energy 'up here'. When Guðni Axelsson commented that "[i]n the cities…you don't see the pipes of the pumping stations or anything like that…I think the average Icelander doesn't notice", this summarised not just an aesthetic preference, but a mind-set in which the fact of breaking the surface is covered up, or buried: "[b]urying the flow of water via subterranean and often distant pinpointed technological mediations (dams, purification plants, pumping stations) facilitates and contributes to masking the social relations through which the

metabolic urbanization of water takes place" (Kaika & Swyngedouw 2000, p.121). There is appreciation for the task of initially drilling through the crust and pumping up geothermal fluid and steam, but thereafter the idea of breaking the surface, surfacing, is eschewed to the background. However, the entire geothermal urban nexus is dependant upon geothermal energy continually surfacing. If it were to stay 'down there', the would be none 'up here'. The geothermal urban would cease. In essence, the geothermal urban is reliant upon a continual surfacing; and this continual surfacing means that the surface is critical: "The structures of many earthly things become visible when they surface or are surfaced" (Forsyth et al. 2013, p.1014).

In turning to how surfacing is critically engaged with the geothermal urban, there are eight key observations to be taken from Reykjavík. Firstly, it is continuous. Or at least, the surfacing of geothermal energy must be continuous in order to sustain the geothermal urban assemblage. Should geothermal energy cease to be excavated from underground, heat would no longer occupy the pipes and storage tanks of the district heating system and Reykjavík would (literally) freeze, unless it turned to other energy sources. In addition to this, and what must be reminded, is that this surfacing of geothermal energy does not just occur at one fixed location. This continuous surfacing happens across multiple sites and at varying intervals. At any one moment and number of boreholes may be in operation. The second observation, then, is that this continuity is based around multiple surfacings, all of which combine to fill storage tanks and heat Reykjavík. It is multiple and simultaneous.

Thirdly, it is processual. The geothermal must elevate, and in ascending from the ground through the surface and into the district heating system it is part of a process – extraction. The geothermal does not just appear in-situ, it is cultivated, coerced, and transported. The pumping of geothermal heat from boreholes into hot tubs is part of a grand enactment, the process of geothermal utilization. That it is processual is also related to it being continuous, multiple and simultaneous. Fourthly, it is formative and transformative. As previously mentioned the wholly geothermal transforms the urban into the geothermal urban and the in turn the wholly urban transforms the geothermal into the geothermal urban. To underline this, we can turn to any number of geothermal boreholes or storage facilities. Without geothermal heat they are mere urban objects, with geothermal heat, they are

transformed into something greater – the geothermal-urban, warm with heat. This transformation isn't merely semantic or metaphysical – it is literal – as pipes expand and atoms vibrate at a higher rate, excited by heat. Further, innate geothermal urban structures come into being through the act of surfacing. Here we might turn again to organisations like ÍSOR and OR or the act of swimming in a geothermally heated pool – phenomena that does not precede a geothermal urban lifeworld. It is surfacing which enables this formation and transformation to happen.

Fifthly, it is not limited to the geothermal urban. It is important to remember that the surfacing of geothermal energies also occurs without – in fact predominantly without – human involvement. None-the-less non-human surfacing can still impact upon the urban and form a part of the geothermal urban. An example of this is the Laugarnes geothermal field directly underneath Reykjavík. Mostly, its heat is drawn up through boreholes, however, it still lies directly under the urban with heat naturally transferring into the ground and up into the urban. Sixth, it is not limited to liquid and steam. Surfacing of the geothermal is not exclusively water and gas. Heat transfer allows heat to radiate, convect and conduct through rock – linking here with the previous observation. Further, the geothermal has previously surfaced via volcanic eruptions – most notably through molten rock, or lava. This previously surfaced geothermal heat, now in a solidified cooled form, dominates the landscape (aesthetically, sensorially) in certain parts of the Reykjavík Capital Area (mainly Hafnarfjörður and Garðabær). Whilst the physical surfacing of geothermal heat has long since concluded, the geothermal continues to 'surface' as the echoes of its former thermal qualities are encountered in the present. In a sense, the geothermal surfaces, is revealed, through the lack of its thermal qualities.

This leads on the seventh observation, that it invokes distinct materialities, temporalities and spatialities. These might be non-linear, immediate, muted, limited, bounded, frenetic, or overt, but are distinctly geothermal and are in permanent flux. This is specifically interesting as it is these distinct qualities and capacities of the geothermal urban, which can be drawn as material, temporal and spatial, that delineate distinct, palpable, geothermal urban spaces and places. The geothermally heated city's infrastructures are tied to its own rhythms that differ from the coal, wood-heated,

nuclear or gas-heated cities. Finally, eighth, surfacing is reversible. As critical as the surfacing of geothermal heat is to the geothermal urban assemblage, so is its un-surfacing[35]. Practically, geothermal energy must un-surface in order to facilitate its flow through the urban in pipes (there is the pragmatic issue of not having pipes across roads and streets for example, but also that these pipes are less likely to be damaged by the elements and the geothermal heat cooled by snow, ice and wind). Further, geothermal heat eventually unsurfaces when left-over heat returns to the ground – either via conducting from buildings or pipes, or through waste-water which carries what heat remains back into the Earth, rejoining the water table and eventually reheated to return to the surface: geothermal "…materialities… are still elementally prejudiced to a metaphysics which enframes the *geo* as a crust from which we raise our constructions (Irigarary 1999); the point is how we delineate the terms and meanings of the multivariate crust" (Jackson & Fannin 2011, p.436). Should we fail to acknowledge un-surfacing as well as surfacing, the processual and emergent nature of the geothermal urban assemblage appears linear, rather than cyclical; fixed, rather than falling in and out of formation.

Surfaces

Whilst surfacing has been drawn out above as central to the geothermal urban assemblage, so too, are surfaces, "commonly associated with planar phenomena or with the edges or limits of things, whether solid materials, liquids, or other molecular substances" (Forsyth et al. 2013, p.1014). The surfaces of the geothermal urban are multiple; they can be caught-up in the assemblage as a direct part of the physical district heating system (the ground at boreholes, the film of a geothermal swimming pool, the side of a radiator), or they can be caught-up indirectly (how the surface of a spoon heats up on a table in a room that is geothermally heated, or for that matter the table too, or even a body). The Oxford English Dictionary (2016) describes surfacing as "[t]hat rises to the surface". This definition has now been extended upon, moved on from only concerning ascent to the crossing of boundaries. The connection here, is that for surfacing to occur there must be surfaces, and that these surfaces are boundaries to be crossed – or indeed transformed; "[s]urfaces *matter*, and in many

[35] I prefer to use the term 'un-surfacing' here, instead of 'burying', as it works to better illustrate the manner in which such practice *opposes* surfacing.

senses it is their function as limits of matter and as spaces of material exchange which draws the attention of scholars" (Forsyth et al. 2013, p.1014).

As with surfacing, some key observations can be made as to the way in which surfaces are fundamental aspects of the geothermal urban assemblage. Firstly, surfaces are multiple, just as there are multiple surfacings. There needs to be a surface from which heat is coming and another surface to which it is going. This may be from geothermal fluid into a pipe, or from a heated floor into the air within a room. Secondly, surfaces are simultaneously complicated, as with surfacing. The heated floor may heat air whilst the air heats objects within a room, or the same heated floor may be heating the air whilst it also heats a rug and a sleeping cat. Thirdly, surfaces are also transformative and innate. They have the capacity to be transformed by geothermal heat transfer but also to then transform other surfaces – for example the geothermal heat that warms the surface of a pavement which then melts snow and ice. They are also formed of the geothermal urban assemblage itself: the film of a geothermal pool. Fourthly, as with surfacing, surfaces are processual - the very nature of a surface either being transformed, transforming another surface, or forming is also a process. Here, though, the process is not necessarily one of surfacing (ascent), but one of multi-directional heat transfer, a process of enveloping new surfaces without the need to break ground, but still with the character of crossing material boundaries. These observations, and those made earlier regarding surfacing, position the geothermal urban as emergent – that is, as something which is in flux, has a varying consistency or frequency, and that itself must surface. The geothermal urban is surface phenomena, and it is also surfacing phenomena. As Sigurður Steinþorsson commented, "If we turn off the pumps and the wells, take out the houses, take the equipment away, and close it…then it [the geothermal water] just, stays [in the ground]". Without the geothermal surfacing and transforming surfaces, the geothermal urban assemblage fails to form; and without boreholes, pipes, and pumps to draw up this energy, the geothermal fails to surface in such a way that it can be utilised within the urban scale.

The geosociotechnical surfaces

Through an analysis of the Reykjavík district heating system, the geothermal urban assemblage can be understood as forming of and possessing several key features: 1) Forces (pressure, heat, and flow) which are innate within the geothermal but which are complicated by human intervention; 2) Structures, both physical and social, infrastructural and organisational – the instruments through which the geothermal urban forms; and 3) Surfacing and Surfaces, the geothermal urban fails to take shape without the process of surfacing nor the existence of surfaces which geothermal heat forms and transforms. These features have their own materialities, spatialities and temporalities (of –forces, –structures, –surfacing and surfaces) and, together, form distinct and unique broader actor-networks of materialities, spatialities and temporalities: a geothermal urban assemblage. This requires an advancement of the sociotechnical (Graham & Marvin 2001) to incorporate the geo (Clark & Yusoff 2017a) and processual capacity of its agency (Bennett 2010; Grosz 2008). Take, for example, the merging of pipes and transfer of heat at Hellisheiði power plant overseen by geothermal engineers. This single vignette incorporates geothermal heat (forces, geo), social organisation and physical infrastructures (structures, socio, technical). The role of non-human, geologic, geothermal agency was further underlined when Sigurður commented that mixing geothermal and non-geothermal water in a pipe "gives problems" [P6-26.00], the distinct capacity of the geo upon the sociotechnical in action. Building on this it is possible to make two more observations. Firstly that the earth itself is infrastructural. Earlier in this chapter, although both considered aspects of a geothermal urban assemblage, forces (geo) where separated from structures (sociotechnical). However, the earth itself may be viewed as structural, infrastructural, organisational: it contains and controls geothermal heat before it extends into pipes and storage tanks. Surfacing, as a process, draws together the geosociotechnical and allows the geosociotechnical to be understood in enriched terms attending to its elemental capacities, structural qualities, and blurring the lines between separate geo and urban distinctions. Secondly, surfacing allows for the non-fixed nature of the geosociotechnical. Any consideration of the geothermal urban assemblage must also consider it to be processual, emergent, constantly in production (and un-production). Whilst components might be set (a pipeline into a borehole, a storage tank upon a hill), and have a quality of (at least semi) permanence, they are a part of a larger slow-moving (and sometimes frenetic) machinic composition.

Surfacing permits the varied temporality (and spatiality) of the geologic (Clark 2011) to also be explicitly included. Geothermal heat will flow and cease, pipes will expand and contract, human managerial decisions will alter and shift. When Sigurður commented that the geothermal heat had "been running stable for almost a century now" [P6- 87.00] he reflects upon the fluctuating, emergent, and processual features of the geosociotechnical.

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This chapter has embarked on initial attempts to understand what the geothermal urban is by focusing on the Reykjavík district heating system, a vast infrastructure that draws geothermal heat from the Earth towards the surface and into the built environment. It has been identified that the geothermal urban consists of complicated and fluctuating materialities, spatialities, and temporalities. It has also been identified that the geothermal urban can be understood as possessing three key features: forces, structures, and surfacing/surfaces. Further, the geothermal urban assemblage is reliant upon the elevation of the geothermal from the subterranean to the superterranean. This surfacing of the geothermal into the urban is transformative in two ways. Firstly, it is transformative of the geothermal heat itself which becomes complicated by forces and materialities external to its subterranean origins. Although this heat retains a distinctive geothermal quality, it becomes geohuman, or geothermal urban. Secondly, it is transformative of the surfaces it transfers into, through, and over. Through its transformational quality, it is underlined that the geothermal urban is not only complicated, but complicates. This is a critical aspect of the geothermal urban, and is facilitated by and understood through surfacing. This reveals other key aspects of the geothermal urban, that it is processual, emergent, and relational. These observations, instead of answering the question as to what consists the geothermal urban, open it up - "rather than simply being space- and time- transcending technologies, infrastructure networks actually act as technological networks within which new spaces and times, and new forms of human interaction, control and organisation are continually (re)constructed" (Graham & Marvin 2001, p.187). It is necessary to examine further geothermal urban lifeworlds - the geothermal urban interface and experience of geothermal urban dwelling - in order to continue to understand what the geothermal urban *is*. "Technological networks…are constitutive parts of the urban…[t]hey are mediators through which the perpetual

process of transformation of Nature into City takes place" (Kaika & Swyngedouw 2000, p.120), however, "ANT establishes the first principles of interconnectedness and distributed agency, but then how life feels and functions for bodies and networks, and the kinds of spaces, places and experiences they find themselves in need to be dealt with" (Jones 2009, p.302).

- vignette iv -

Containment/Release









5| Architectures

A Haircut.
Friendly chitchat through the door following an episode in which I was
a day early the previous afternoon. A modern salon, rather than barbers, chairs
along the left side with mirrors running the stretch. The owner's dog sniffing around.
Through to the back where the basins are. A quick hair-wash before the cut.
Out of the tap, onto my scalp, *geothermal waters.*
More chatter: a wedding in Lithuania. A visit to London.

A Coffee.
Stofan had moved. Along the road and around the corner to a new 'house'.
The pictures of Icelandic mountains, volcanic, survive in new positions.
A bigger space, familiar faces, talk about a new chai latte.
One is ordered. Locals and tourists come and go.
I write a birthday card. Head to the bathroom.
Out of the tap, onto my hands, *geothermal waters.*
60's music plays on the stereo. I check my emails.

- Field Notes, 3rd June 2014

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In the preceding chapter the complexities of the Reykjavík district heating system were explored, with the geothermal identified as present, absorbed, and transported within an assemblage; as frenetic energy direct from the ground, and traceable through cooled lava within the landscape. It is revealed through physical objects (boreholes, pipes, valves, roads, pavements) and through intangible human processes (geothermal exploration, national planning policy, local municipal operations, individual human actions), drawing out the interplay of forces, structures, and process of surfacing, fundamental to the geothermal urban and which complicate any notion of a binary materiality. The geothermal is at once chthonic, surfacing, and surfaced, and is both acutely and subtly framed and engaged with via the built form. Geothermal forces are distinctly elemental, with heat engaging rock, water and air. This led to a suggestion that the qualities of geothermal urbanism are to be further understood in encountering and exploring the lived everyday realties of geothermal utilization. Here, this is explored, through a discussion and explanation of the envelopes of geothermal heat that form around the architectures, objects, and machinery of the geothermal urban lifeworld.

This chapter develops the concept of 'thermospheres'[36], with envelopes of geothermal heat understood as more specific 'geothermospheres'. There is a connect in this naming to the urban "mechanosphere" put forward by Amin & Thrift (2002, p.78), in this case underling the geothermal component of a "machinic assemblage" (Ibid.). Thermospheres can be seen to exist as specific envelopes of warmth or coldness in relation to an alternative background temperature. Crucially, it is argued, what Reykjavík possesses - and what contributes to its unique sense of place - is a vast number of *geo*thermospheres: thermospheres that are either directly or indirectly the result of geothermal heat. This chapter will explore how these geothermospheres are distinct and possess their own unique formation, function, engagement, and dissolution; and continue to draw out the geothermal urban's elemental qualities and capacities. Firstly, this chapter will journey through ethnographic vignettes that illustrate different examples of geothermospheres, each augmented by the geosociotechnical assemblage of infrastructures, architectures, and geothermal heat. Secondly, geothermospheres are outlined in more detail as distinct, palpable, unique, and elemental spacetimes gathered by and emergent from territorializing-deterritorializing (DeLanda 2006) capacities and processes. This chapter then concludes by turning to the discreet atmospheric qualities of the geosociotechnical assemblage which are amplified within and via geothermospheres and especially caught up in geothermal architectures. The geothermal urban is further understood as an articulation of the elemental through the built environment, constructive of distinct affective atmospheres which resonate to form an explicit geothermal urban place.

5.1| Perlan (The Pearl)

Living within geothermal tanks

In the exploration, extraction and distribution of geothermal energy, geothermal energy has already been used: heating the offices from which ÍSOR plans and analyses geothermal exploration, turning

[36] The 'thermosphere' suggested here is notably different to the version identified within aeronomy as a layer of the Earth's atmosphere. Curiously aeronomy's 'thermosphere' is shaped-by the, and in some cases argued to be, extra-terrestrial. This is almost in direct opposition to the distinctly earth-bound application of the term in this chapter, formed of surfaced geothermal heat.

turbines that generate electricity which is then used to run pumps that draw up geothermal fluid and steam, and melting the snow on the pavement that surrounds the six hot water storage tanks at Öskjuhlíð (Fig. 5.1). This blurring between the process of providing geothermal heat and its use is made all the more apparent at Öskjuhlíð as, whilst five of the storage tanks are used to store geothermally heated water, one is used as a cultural space. Here, the infrastructures that enable the geothermal heating system are themselves directly involved in providing built spaces within which everyday urban life is able to flourish. So it is not just the geothermal heat that supports everyday life, but the buildings which are central to its distribution and storage; buildings which are there because of the heat. The site at Öskjuhlíð is a clear example of how geothermal infrastructures facilitate heat to create places for human dwelling that would either not exist, or would do so very differently if they were not present.

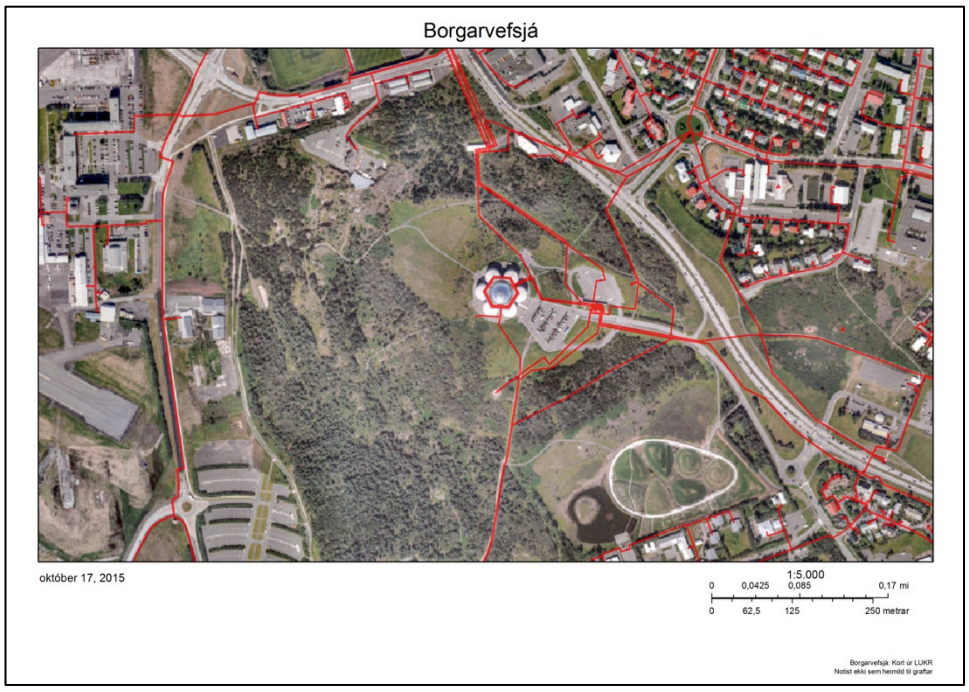

Fig. 5.1. *An aerial view of Perlan (centre), with geothermal pipes overlaid in red (Borgarvefsjá 2015).*

The storage tanks upon Öskjuhlíð are better known by the name given to the cultural space, 'Perlan' (The Pearl). Perlan (Fig. 5.2) utilises the spare geothermal storage tank, but also the space between and on top of the tanks: a central atrium provides additional room, whilst a large dome sits upon the

six tanks. It opened in 1991, and Stefán Sigurðsson, the current manager whom has been there since it opened, greeted me in one of the offices above the tanks:

> "In the beginning, when we started using geothermal water, the first tank was built up here, and the reason [it] was up here was to get the pressure to get the hot water into downtown Reykjavik. And the first building that got the hot water was a school… and they didn't believe it when the hot water came into the school and the caretaker, he burned his hand! But, er, eventually the people in downtown Reykjavik, they looked up to Öskjuhlíð with gasps as they were getting hot water from the tank. Very soon there came the idea 'why don't we build a restaurant up there'"
>
> [P23-01.00]



Fig. 5.2. *Perlan.*

The Pearl was designed by Architect Ingimundur Sveinsson and based on an idea by Icelandic 'master artist' Jóhannes Kjarval. Kjarval's idea was that "The sides...should be covered with mirrors, so the northern lights can approach the feet of men – the roof should be decorated with crystal of every colour and floodlights should be in the eaves to illuminate the whole area. It should answer to the

light of the day and the symbols of the night"[37]. It may well be accepted that Perlan connects those who visit the site with the northern sky, specifically through the domed roof made from hundreds of glass pieces and with the lighting used to illuminate the building and its surrounds. However, it can also be suggested that the building much more directly succeeds in connecting visitors with the subterranean, the geothermal; given the functional nature of the site's connection to geothermal utilization, the way in which geothermal infrastructures form the skeleton of the building, and the geothermal heat that traverses the building inside and out. Indeed, unique to Perlan, geothermal water is pumped through its metal framework to keep it warm in cooler months rather than just into radiators. "[T]hey are taking it from the pipelines" notes Stefán, whom confirms the importance of having the building heated during winter, something that could only be achieved with cost-effective geothermal heat given the building's volume of 20,000m^3. Six tonnes of hot water alone is required to melt snow from the glass each winter's day. Perlan is simultaneously both geothermal infrastructure (the structures of pipes, tanks, human planning, the forces of geothermal heat) and geothermal place (in the sense of a defined location, with cultural meaning, and human use). Stefán comments, "The lobby is just an open space, the space between the tanks, you could say the tanks make the space" [P23-10.00]. By extension, it is perhaps the tanks, the geothermal heat and the cultural everyday uses within the site that makes the space, or place, of The Pearl.

Whilst the sites original function was to use its height to build up enough pressure so that hot water could be provided to the higher levels of buildings in the nearby area, today the purpose is purely to provide a back-up reservoir for when demand peaks, and each geothermal storage tank can hold up to four million litres of hot water:

> "Today…[the tanks] have not the same purpose as they had in the old days, today they are storage, so the water, the left-over water comes into the tanks and there is a pipeline with 130°c hot water, that is maintaining the heat. The heat is always around 84°c, 84°c to 86°c. When it gets very much frost, then they will need this water… it's a reserve. Because all the

[37] This quote, attributed to Jóhannes Kjarval, is frequently refernced in promotional material for Perlan - both in print and online (see: http://www.perlan.is/saga-perlunnar/?lang=en).

> hot waters are drilled straight to the houses from the pipelines, so this is just left over waters, and when they need it they will take it"
>
> [P23-04.00].

Stefán Sigurðsson continues, explaining why the additional tank was allowed for non-geothermal use, but not demolished:

> "At that time, the heating company could see that they didn't have a use for it…this is in 1996, and er, the city is always getting bigger so they are starting to look at the tank, that
>
> they will probably need to put it in function again, especially if you are going to build a new hospital then you will definitely need that tank".
>
> [P23-04.00].

He resumes, "In 1996 they saw that they could 'give one', it was a couple of years later that the Saga Museum came into the tank". Indeed, the spare tank's first occupancy was the Icelandic Saga museum, and for a brief period, Iceland's human history – entwined as it is with the geothermal – was literally being recounted inside a geothermal water tank. In addition to the cultural space, there are offices, a restaurant (Fig. 5.3), a café, a bar, kitchens, amenities and a conference room and Stefán rounds the number of employees to around 90 people. Given its prominent location atop Öskjuhlíð (which rises to 61 metres above sea level) Perlan has joined Hallgrímskirkja (the nearby Lutheran cathedral) as a memorable part of the city's skyline; "The Pearl is a landmark in Reykjavik, it was, instantly it was, everybody talked about this building" [p23-13.00]. Furthermore, Perlan's status as a landmark is not just affirmed as a visual anchor within the cityscape, but through its vital role in the city's geothermal heating system:

> "…the water tanks will always be here, because, when it get minus ten [degrees celsius] or more, then, er, the pipelines are not enough, so they need more water, that's why they are here [the tanks], and that's why you have also, if you look at the hill up there, you can see,

you can see water tanks [additional geothermal water storage at Grafarholt] – it's the same reason"

[p23-41.00].

Perlan is a standout part of Reykjavik's geothermal heating system, but with one simple gesture, Stefán reminds that it is only a part of a much larger and complicated network. Its ability to be defined against the wider environment, atop Öskjuhlíð, makes its status as a geothermosphere stand out. The Pearl is a containment of geothermal heat which facilitates human lives.



Fig. 5.3. *The restaurant inside the top of the dome at Perlan.*

5.2| Heimilið (The Home)

Mosfellsbær - Varmá

In and around Mosfellsbær, a peri-urban suburb to the north-east of Reykjavík, precipitation filters through the ground and collects at the Mosfellssveit low-temperature geothermal field. The geothermal field at Mosfellssveit is between 85°c and 95°c (Gunnlaugsson, Frimannson, et al. 2000, p.2089), a result of the Earth's geophysical processes transferring heat up towards the surface via the mid-Atlantic ridge that crosses Iceland (Ibid. p.2087). This heat then transfers into the groundwater,

eventually escaping upwards as hot water and steam, through permeable rock, gaps and cracks. Anna was born in Reykjavík and lived near Hlemmur, the central bus station, for most of her life. Following stints in Breiðholt and London, she now lives in Mosfellsbær with her family. Anna runs a small locally based travel business: offering tours of Mosfellsbær to tourists and telling them about the geothermal landscape, hot water and area's human history. "I'm making a living from it" [R1-08.00], she tells me as we talk in her home on a cold February afternoon. Indeed, just before our chat, I had joined her and one of her guests on the tour – taking in a geothermal pumping station, a walk up and around the local Varmá ("Thermal") River and finishing in the cosy warmth of her home (originally built in the 1920's as a farm house, today an enlarged modernised suburban/peri-urban dwelling), treated to pancakes, salmon on rye bread and coffee. "I cannot imagine life without geothermal heating" [R1-05.00] she tells me just as we start conversing and Anna recalls her daily routine. Hot water forms a bookend to her day, starting with a hot shower in the morning and/or a hot bath in the evening (the heated water, of course, geothermal). In addition to this, the family also own a hot tub – not uncommon in Iceland given the cheap cost of hot water: "I'm just used to...hot water is endless…and we don't pay much for it…it's one of the advantages we have living here…the hot water" [R1-07.00]. Our conversation flutters about, touching on heat here and there, mirroring the nuances with which the geothermal is present within Anna's everyday lifeworld.



Fig. 5.4. *The geothermal borehole in Anna's garden is in the trapezoid-shaped building to the right (photo courtesy of Anna).*

When we talk about heating, there is clarity and confusion. Central heating based on geothermal energy was installed at some point in the 1970's, alongside a borehole that sits in the garden (Fig. 5.4). There is a clear understanding of where the heat is coming from and the basics of how it can be controlled to keep her home comfortable, but the details are hazy: in making the interface with the geothermal as 'user friendly' as possible a more detailed, conscious connection, with both the energy and the technologies that contain it is lost. When asked how the temperature of the radiators is controlled, Anna responds: "…if you have it maybe on two-and-a-half, then this oven [radiator] finds the balance… but I cannot describe it in more detail" [R1-10.00]. On each radiator is an analogue thermostat (most commonly the Danish brand 'Danfoss') which is used to control heat from a scale of 1 to 5 – as is that case in Anna's home. Much as the brand 'Hoover' has come to mean 'vacuum cleaner' in British English, the 'Danfoss' brand has come to mean 'thermostat' in Iceland. As such the techno-language of plumbing has been simplified and conversations about heating and heating control refer to a refined 1 to 5 scale of the 'Danfoss' and 'ovens' (radiators), rather than degrees celsius and complex components of an engineered system. This extends to conceptions of Reykjavik's district heating system more generally: "[geothermal water]…comes from somewhere underground, some pipe, some borehole…in the basement, if I open this door, then you will see all kinds of things…everything regarding the hot water, that's in the cellar" [R1-12.00]. To a regular user of geothermal heat in Reykjavík, there is a mysterious world of technology and geophysical nature hidden just behind walls, in cupboards or cellars, or just underfoot. The geothermal is surfacing but it is masked. This may well be the case with various alternative infrastructures and heat sources in other locations, but nonetheless it underlines in particular the back-grounding of the geothermal, which extends across entire neighbourhoods:

> "If you were here this summer, you would see with your own eyes, because they are building new houses here, and digging big holes, and all this is for [sewage], the [heated and cold] water, the electricity… and it all sort of goes along and…I don't even think about it! I just do this (Anna turns on the tap in her kitchen) and I get water, hot and cold"
>
> [R1-14.00].

Even so, as we walk about the house with Anna showing me her shower (a point of conscious connection to geothermal heat), pipes that carry hot water are pointed out. This is a less common feature, as the heating was retro-engineered into the house (in more modern buildings all the pipes are behind walls or under floors). Anna touches one of the radiators (which is on) and remarks whist signalling towards the conduits of heat, "I like to see [the pipes]" [R1-20.00] (Fig. 5.5).

For Anna, having geothermal energy in her home is not simply a result of technologies and physical infrastructures. A meter in the cellar counts how many litres of water she uses, and occasionally, representatives of OR (Orkuveita Reykjavíkur – 'Reykjavík Energy') visit to read the meter, although Anna can't recall how often – implying their visits are infrequent. This rare direct interaction, though, is a window onto the complicated human system that is as essential to ensuring a warm home as the infrastructures and energy itself. "They have to do a good job, they do it properly" [R1-27.00] is Anna's short trusting review. As we take a tour around Mosfellsbær, Anna points out the local river, Varma (meaning "thermal"). "The stream disappeared and the river got cold, because they took away all the heat that you could see with your eyes" [R1-29.00], she later explains in her home. As the geothermal heat has been diverted into buildings and away from Mosfellsbær, it has left the natural landscape. The river today is cold, and the steam that once rose from it is no more – a visual dimension of the landscape which has changed - whilst geothermal heat now escapes steaming from hot-tubs and showers.



Fig. 5.5. *The radiator in Anna's kitchen sits under the window.*

Mosfellsbær - Utan inni

Another building in Mosfellsbær shows us a different architectural arrangement of geothermal inhabitation: in this case, the outside is inside. "Utan inni" is what they call it, Svava tells me as her husband Olafur nods in agreement beside her. They live in a unique home (Fig. 5.6) - the entire dwelling is encased in a giant glass-house - and have done for nineteen years, since it was completed. Geothermal heat warms radiators and a concrete patio, trapped by the glass that surrounds the entire dwelling – rooms and open spaces, which also captures solar radiation. Olafur is a retired architect having studied in Germany and then worked in Iceland, the idea for the house was his:

> "You never know, you never know where these ideas come from...when I was fifteen years old, I was working at the summer time in Hveragerði, in the [geothermal] greenhouses there, in the gardening school maybe, that was a very good time, and I was just fifteen years old and I was there one summer, maybe, I don't know"
>
> (R11-02.00).



Fig. 5.6. *'Arcadia' in Mosfellsbær.*

Arriving at Arcadia (the name for their the home) is a very different experience to walking up the driveway of most other homes in Reykjavík. It is clearly different from the modern vernacular architecture of the other dwellings in this part of Mosfellsbær and may at first suggest a garden centre or small commercial green house operation. My visit was in March, during which the Icelandic winter is still in full-swing and as with other experiences of the geothermal the snow, ice, frost and cold air highlighted the capacity of geothermal heat: melt, dryness, warmth. Indeed, the driveway was snow-covered, icy and frosty but approaching the front door the warmth from the inside was apparent, the transparency of the glass revealing visually a dry interior that was inviting. In through the main entrance a left takes you into a garage, whilst a right will take you to the main dwelling space. A central collection of single storey rooms (100m^2) is surrounded by a large patio (500m^2) that contains plants, outdoor seating, and art (see Fig. 5.7 below). You are 'outside inside', and warm: a thermostat controls openings in the roof and walls that aims to maintain heat at 20°c in the central dwelling space. A glance at the couple's thermometer revealed the temperature on the patio to be 10°c, significantly higher that the temperature outside the structure (at approximately 1°c)[38].

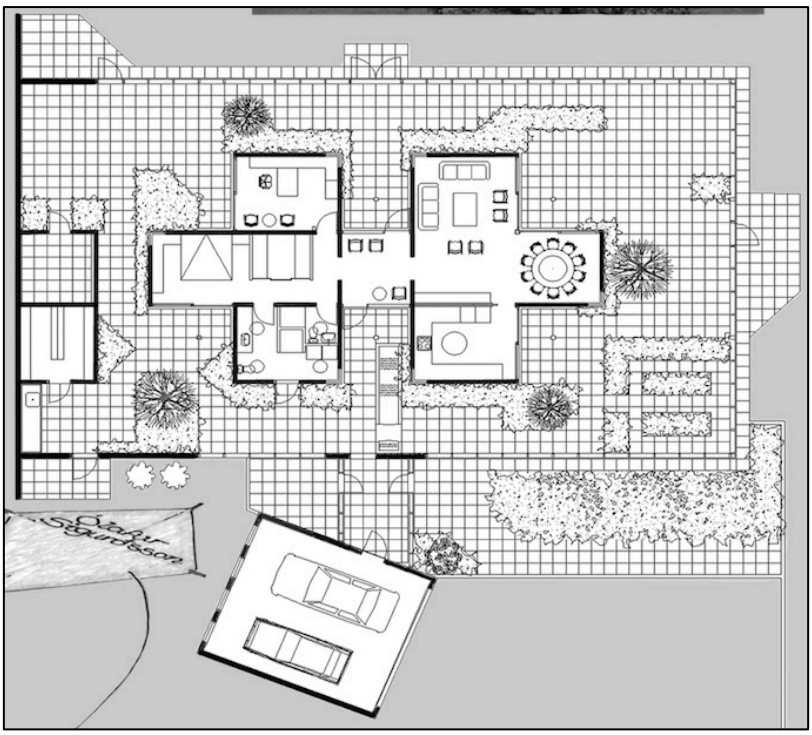

Fig. 5.7. *Arcadia plan (© Olafur Sigurðsson).*

[38] This outdoor temperature is based on the recorded observation for Reykjavík at the time of the interview, compiled and kindly provided by the Icelandic Meteorological Office.

Olafur and Svava lived in another Reykjavík suburb, Kópavogur, before coming to Mosfellsbær. That home was built in the 1960's at a time where geothermal energy hadn't yet been rolled-out on the scale it is today, and they relied on burning oil for heating:

> "We had a heater, a heater for water, and three children, and then we had to decide 'who is going to shower next and how long' and things like that. And that's the thing that you never have to think of here [with geothermal energy]"
>
> [R12-06.00].

After three or so years in Kópavogur, however, geothermal pipes were laid and heating installed. If the first seeds of the idea for living in a giant green house came from working in a commercial enterprise in Hveragerði, then the first attempt at realising the idea was in Kópavogur, where they built a small connecting 'greenhouse' linking the living quarters and the garage – this, without geothermal heating underfoot but protection from the elements, where they "could always come into shelter" [R12-04.00]. Olafur provided more insight into the time it took to come up with his plans:

> "It took a long time [to design the house]. First of all, I was designing this for just two people, us two, children are gone…so we just needed for us two. Thus we made this house 100m^2, we have these rooms here for the daily purpose and then a bedroom and a workroom over there. And then, when this house [was] designed, I had to build a huge glass house to cover that and the only thing I wanted that was [there was] at least three meters from the house to the glass…and that we could walk around it too [the house within the glass].
>
> [R11-09.00].

Ten years passed in finding the land and obtaining the correct permissions to build Arcadia. Initially they had hoped to build elsewhere in Reykjavík but stricter planning rules and more conservative approaches to town planning meant they could not find both land and permission. In fact, they found that due to the need to use a lot of glass, they had to secure a bigger plot, so there was no safety risk to neighbours should a piece come loose during a storm, with normal wear over time or even through

an earthquake. Ultimately, permission was granted and a suitable plot found in Mosfellsbær. Building began in 1991 and they moved-in during the Spring of 1996, with some work still outstanding. The process of getting hot water into the house was particularly straight forward however, with OR having already laid the main hot water pipes that simply required connecting to the house's system. Heat exchangers are used for the heating, mainly in order to save pipes from silica build-up, however hot water used in the bathroom and kitchen is directly geothermal; "You just get the water when you get the plot, it's normal, nothing special for us" [R11-31.00].



Fig. 5.8. *The 'outside inside' at Arcadia.*

Here, dwelling is acutely highlighted as a product of geothermal heat, infrastructures, technologies, human systems and other materialities – glass and solar radiation. "The walls are just 15cm thick, and no insulation", Olafur tells me. Pumice, a type of volcanic rock formed during eruptions from lava with high water and gas content, was chosen as the material from which to make concrete that filled wooden frames to make the internal walls. Pumice is extremely porous, so geothermal (and solar) heat transfers through the walls with ease. Indeed the 'outside inside' (Fig. 5.8) requires very little geothermal heat to stay warm, "It is very little from the geothermal, because that is just ten degrees (celsius), the heat, that's throw-away heat from in the house. But it is… at least five degrees warmer in this glass house than outside" [R11-14.00]. The reason behind the space is simple, "I was hoping to

have [a] longer time outside, and we have at least two months in the spring and two months in the autumn longer than the rest of the fellows here [other residents]. We could even sit outside now" [R11-14.00]. Although the temperature is now comfortable, it took a little adjusting at first, "How do we warm it up, and is that enough? It was not enough" [R11-24.00]. This is interesting as it points out that the geothermosphere is penetrable by other forms of heat (and vice versa). Olafur and Svava have cultivated in a unique way is a geothermosphere, but one which is also engaged in part with a solarthermosphere (sharing the qualities of any greenhouse). This is an important observation, as the geothermosphere is reliant on there being geothermal heat, and is defined by tracing the extent of that heat. However, geothermospheres can flow into and overlap with other forms of heat co-creating broader thermospheres. Each geothermosphere so far encountered, for example, envelopes people and thus 'homeothermospheres'. This does not mean that the geothermal can't be foregrounded, but does require the acknowledgment that in its tracing the geothermal will merge, envelop, and transform with other forms of heat.

After initially hoping to rely on only geothermal heat rising from under the floor to top-up any solar warmth coming through the glass, Olafur and Svava had to add radiators so that more geothermal heat was coming into the space; "When you have floor heating, it's not as quick to respond to the difference from the heat outside, it's slower, and then we could be freezing…things like that you can't predict" [R11-24.00]. This led on to considering if the ability to heat the space related to decisions about its size - "we don't think about it, we have lots of heat" [R11-38.00] is Olafur's conclusion, if heat was more expensive they "…probably wouldn't have built it at all" [R11-38.00] he says. The affordability of geothermal energy was a significant factor in making Arcadia possible. Today, the geothermal heat flows into and out of their home, hidden under the floor or in walls, the only visible internal components a few radiators. Furthermore, the connection into the house, and controls for the heating are tucked into an outhouse ('out' of the main living area, but within the outer shell). Svava used to note the temperature and daily usage, but had not done so for a long time. The controls, too, somewhat forgotten, with the heating system running in the background unnoticed except for the warmth they provide; "Yes we have lots of controls but we never move them" [R11-60.00]. Svava pauses a moment to think about the geothermal heat flowing around their home: "We

are so used to having hot water by now we don't think about it – we take it for granted… it could change, you never know when it gets colder down there" [R12-71.00]. Should it 'get colder down there' their forecast isn't optimistic - without heat, they say, "we wouldn't be here probably" [R12-74.00].

Hlíðar

Þhorsteinn lives in a common style of Reykjavík apartment (Fig. 5.9 & Fig. 5.10); a large detached concrete town house with a basement and three or four more storeys. The buildings are usually split into three or four apartments and Þhorsteinn occupies the top floor of his building. The home he shares with his partner is arranged across the one floor with a hallway, kitchen, living room, bedroom and bathroom, and the basement space is shared with all the other residents. As we sit in his kitchen, the heating on in the house and keeping it very comfortable, he tells me about his daily routine. He gets up, going to the gym three times a week, and then has breakfast at home. He then goes to work and usually returns straight home once the workday is over. The heating is on "24/7", "it's very nice to… go into the bathroom and stand on the warm floor, and that's basically it…[i]t's very nice to wake up in a warm house, especially during winter… it's very pleasant only being cold for five minutes…[and then getting into a warm building]" [R4-04.00]. Þhorsteinn's comments highlight here that there is something about being briefly exposed to the cold and then entering geothermal warmth that underlines its sensed beneficial qualities of warmth and comfort. Þhorsteinn underscores this further when he shows me the "cold cupboard" in his kitchen. This is essentially a pantry that is accessed through a door in the kitchen that is against the external wall of the house and isn't heated by geothermal energy. Quickly popping in it is noticeably colder, and the warmth of the kitchen is felt all that much more when you leave and come back into the room. Þhorsteinn says that neither he nor is partner like going in there much because of the unpleasantness of the brief exposure to the cold – as much as the cold of the cupboard highlights the warmth of the kitchen, the warmth of the kitchen intensifies the feeling of coldness in the cupboard.



Fig. 5.9. *Þhorsteinn's apartment is on the top floor, the driveway is clear of snow and ice as it is heated by geothermal waste water.*

Our conversation moves on and we find ourselves talking specifically about the heating of rooms:

> "What you need to watch out for is that you don't have the windows open for too long, because the heating system adjusts to the heat in the room, and usually the radiators [are] below the windows, so if you leave the windows open…like in the living room or the bedroom you are not supposed to have the window open, because it will actually heat the house up a little bit more… other than that, you don't really think about it"
>
> [R4-07.00].

Here, Þhorsteinn is referring to the almost complete automation of heating for many Icelanders – that each radiator has its own thermostat ("Danfoss") which the user usually leaves on a specific setting, set quite some time ago and forgotten. If a room gets too hot, rather than turn the heating down, a window is opened to let in some cool air. However, if not monitored, and not only done briefly, the thermostats register a drop in temperate and increase the flow of hot water through the radiator, causing them to heat up and the room to actually get hotter. The same happens when a room is stuffy and a window is opened to aerate the space - – "you really do not think about the bill at all" [R4-08.00] Þhorsteinn adds, underlining how geothermal heat is used without too much thought as to

its cost. Indeed for Þhorsteinn, and as is a common practice, the cost of heating is included in his rent, so he never has to consider how much the heating is costing. Þhorsteinn had also spent some time living in Denmark and draws a distinction between non-geothermal heating there and geothermal heating in Reykjavík: "this is a distinct difference between living in Denmark and Reykjavik, you know, you think about every single minute you have the radiator on [in Denmark], and you never even start thinking about it [here]" [R4-09.00].

In spite of this prevailing nonchalance, there are distinct moments when geothermal heat is noticed. Þhorsteinn's experiences of geothermal living are accented by moments of failure that highlight geothermal heat through either lack or excess in comparison to the normality of the system. "The was even a problem this autumn with the floor in the bathroom being too hot" [R4-09.00], he explains:

> "I felt it was confortable having this extreme heat in the bathroom, but my girlfriend didn't like it, so we had a discussion about turning the heat just a bit down in the bathroom because it was inconvenient for us to have it so hot. But we weren't really thinking about it in economical terms"
>
> [R4-09.00].

There is also sometimes a problem with the taps at the sink in his kitchen, the "calibration can be off" [R4-13.00], so it can be harder to get a smooth hot to cold transition and comfortable temperature by mixing hot and cold water through the faucet; "finding the exact point where you can wash the dishes but it is still hot enough to deal with the fats…and not too hot for you to handle the dishes" [R4-14.00]. This "calibration" issue can of course happen in situations where the heat is not geothermal, but it is that more acute for Þhorsteinn given the high temperature of geothermal water and the immediacy of the heat (for example, there is no waiting for a boiler to heat up the water, so there is no lag or cross-over where the water goes from cold to tepid to warm to hot). "It's so hot, the extremely hot water, that if you burn yourself once, you never do it again, it's just extremely hot" [R4-15.00], he says. Þhorsteinn does not just use hot water for heating his home and washing dishes. The

hot water pipes come into the building via the basement - a communal space - that also heats up with the warmth used to dry clothes. He also uses geothermal hot water in the bathroom to bathe in, and then the entire building's waste-water is put to use melting snow outside on the driveway and pavement – "it's very convenient, it's very cosy not to have to wade through large piles of snow" [R4-25.00].

Other than routine uses, and the sensation of feeling geothermal warmth, our conversations also touch upon the other ways in which geothermal heat is sensed. "Because of the water tasting like it is, the hot water, you tend to heat cold water on the stove" [R4-04.00], Þhorsteinn had mentioned at the start of our talk. Here he is referring to a distinct sulphuric taste that comes with directly geothermally heated water, a result of minerals dissolving into the water. Whilst not problematic for heating or cleaning, it can be an unpleasant taste, so fresh cold water is heated on a stove or in an electric kettle for making hot drinks like tea or coffee. As well as a sulphuric taste, direct geothermally heated water also has a sulphuric smell – "like you're boiling eggs" [R4-16.00]. "[It] doesn't really change anything for me, if you grew up in this warm water condition, you actually just, just feels nice I guess, feels like home" [R4-16.00] Þhorsteinn comments. He continues:

> "One reason also being that the water is very soft in Iceland, so you kind of feel [a] connection between the smell and you know, hot and soft water…that I haven't experienced anywhere else in the world. It's a very pleasant feeling, coming out of the shower and you're...you feel like, a little bit more at home when you smell this sulphur…in the hot water".
>
> [R4-16.00]

For Þhorsteinn, the taste and smell of geothermal heat is as entwined in the experience of using and living with it as the warmth itself. These sensed aspects of geothermal energy are not immediately noted as they are not the identified beneficial outcomes of geothermal utilization, however they are a distinct part of a geothermal-urban lifeworld and are not found in non-geothermal heating systems, even notably removed in homes in Reykjavík that use heat exchangers. As our conversation

continues Þhorsteinn also draws out another way in which geothermal energy is sensed for him: visually. This is not just in the steam that comes from hot water taps or hot-pots at his local swimming pool. Þhorsteinn wears glasses. They cool down when he goes outside, and when he then enters a warm building the contrast between his cold glasses and the warm air causes condensation to temporarily form on the lenses: "it gets foggy, a layer of mist forms on your glasses… you are completely blind for the first minute or so" [R4-28.00]. Of course, this can happen in a situation with any heat-source, but in a setting like Reykjavík with a particularly cold outside and particularly warm inside, it is that bit more frequent. It is also a direct conscious reminder of the geothermal energies that permeate the city unique to a spectacle wearer. Next, Þhorsteinn points out a very modern benefit to geothermal heating, that it enables the use of technology – especially smart phones. "[Y]ou are very addicted to your smart phone" he says, "you can take your gloves off right away in a warm building and use your smart phone" [R4-30.00]. Here he is referring to the fact that many modern smart phones use touch-screens to be operated. If a user's fingers – or indeed the screen – are too cold it will not work properly. The abundance of heat in and around Reykjavík´s buildings means that both his phone and hands warm up quicker when he returns indoors, enabling certain smart devices to be used more easily and freely. He has quicker access to his personal mobile technology as a result of the geothermal heat warming devices and bodies up quicker than would otherwise be the case.



Fig. 5.10. *Þhorsteinn's living-room, where two radiators heat the space.*

Towards the end of our conversation, we turn to talking more broadly about the benefits of geothermally heated water in the context of his day-to-day life and experience of the urban, in particular, Reykjavík without geothermal energy:

> "I think it wouldn't be that nice, one of the benefits of having hot water of course is that we get to have like something similar to the experience of having a town square in the swimming pools. That's a very important thing in our social experience of the city, that's one thing that once you've grasped the concept of having a social gathering place for the community and the importance of that, you understand the social value of having the swimming pools, and that's, you know, you'd have nine months of having no social meeting points other than just plain boring buildings that would have to have some sort of an event or something for people to meet. But instead we have the swimming pools and you would probably use it more when you retire, we have a very you know, a very strong culture, or it's a strong cultural phenomenon for older people, maybe when you start going into your 50's, to wake up early, go visit the pool, talk to people in the pool about, you know, politics, news and current affairs, things like that, and then you go to work. You have a feeling of belonging somewhere in the society, you hear about a lot of people, they have to go to the tub before they go to work, it's a part of the ritual, and that's something that we simply wouldn't have [without geothermal heat], there's a lot of social interaction associated with the heat that we have".
>
> [R4-39.00].

Even for Þhorsteinn, whom identifies himself as not much of a pool user, geothermally heated swimming pools are seen as both hugely important in enabling a good quality of day-to-day life and are key signifiers of the geothermal heat that is critical to Reykjavík. In many respects, geothermal swimming pools have become the primary way in which residents of Reykjavík consciously engage with and talk about geothermal heat.

From this, though, Þhorsteinn moves on to consider buildings more generally:

> "…the hot buildings…they make life very much more bearable, because it's extremely cold and dark for many months in Iceland, and you kind of want to get depressed but it´s hard because it's very cosy and almost all Icelandic apartments, they're all very warm and roomy and, you know, of course it has affected a lot how we build buildings in Iceland, they can be very spacious without costing too much money to heat up for example, something simply impossible if you don't have quite cheap energy".
>
> [R4-41.00]

He continues to reflect that without heat, there would "[p]robably [be] smaller houses, and it has changed a lot with central heating" [R4-42.00], he continues:

> "I have two older uncles that are like great uncles, and they always tell me about one of the best things happening in Iceland was this central heating system with hot water, because, actually, when that came into their – they were raised on a farm – when that happened on their farm, they felt a relief because they wouldn't have to breathe the contaminated air that was associated with burning coal in the apartment. With regards to cleaning and feeling healthy and the feeling of cleanliness in the space you lived in, the differences were immense, a positive impact on how people felt about themselves and their homes in Iceland".
>
> [R4-42.00]

For many living in Reykjavík the benefits of geothermal heating are not just seen as the abundance of heat, the comfort of ubiquitous warmth and the low cost, but also the clean air that comes with not having to burn wood or coal.

Finally, we turn to the cityscape and urban experience: "I think also the architecture would definitely be different, we don't have small apartments in Iceland, I mean most apartments are very big" [R4-44.00]. By this, Þhorsteinn means that the affordability of geothermal water means that Icelanders

can have much larger houses as they can heat them up. Without geothermal energy homes would need to be smaller and less-open plan, so they are cheaper to heat up:

> "I would say the hot water is a very important aspect of raising the living standards in Reykjavik, most definitely, it's terrific to take the opportunity, you know, that's one of the greater things, that you have the opportunity to take longer showers and you have extreme heat in your house if you want to have it…[a]nd also, you know, the fact that you never ever feel guilty about over using this, you know, overusing the hot water".
>
> [R4-51.00]

Our conversation concludes as Þhorsteinn echoes the thoughts of many others:

> "I think [without geothermal energy] first of all, they would have never settled here. There is no way anyone would have just stopped right in Reykjavik and said 'this is a beautiful place and I'm going to stay here, I'm gonna be the first settler and you know, stay for the rest of my life', that would be, like, a first. There would definitely not be a city in Reykjavik [without geothermal energy]".
>
> [R4-46.00]

Þhorsteinn outlines the importance of geothermal heat to everyday human life. In doing so he connects geothermal energy right through to homeostasis and underlines the role geothermospheres play in establishing Reykjavik's geothermal urban lifeworld. Geothermospheres would not form and gather as such distinct envelopes, and not become immersed in human lives, if it were not for infrastructures and architectures containing them. Once geothermal heat has surfaced, it is bounded by surfaces within human maintained and manipulated geothermospheres, which go almost entirely unnoticed. "You take it [geothermal heat] for granted, most definitely" [R4-52.00], Þhorsteinn concludes, "Usually, like, I would say [I] probably spend 99.99 per cent of my day not noticing the heated environment and the benefits of having hot water, running around everywhere, heating everything up" [R4-52.00].

5.3| Sundlauginn (The Swimming Pool)



Fig. 5.11. *Grafarvogslaug*.

Grafarvogur

In Grafarvogur, north-east Reykjavík,"Korpúlfar" or the "River Wolves" can be found frequenting the local pool, Grafarvogslaug (Fig. 5.11). Korpúlfar is a social group of older citizens founded in 1989. Ragnar, a member for 3 years, explains that the group started with ten members but has expanded to have around eight-hundred today. Ragnar, Dóra and Eyrun have all come to Grafarvogslaug to attend one of the groups twice-weekly exercise classes. They take place in the morning, at 0930, and for half an hour an instructor runs the group through movements and stretches all undertaken in the main heated pool. Most of the group enjoy free access to the pool and classes, as the municipality covers the cost for senior users, and socialise afterwards (Fig. 5.12). Ragnar usually comes to the pool thirty minutes before the exercise class to use the hot-pots where he can both warm up his muscles and catch up with friends. He is uncertain of the exact temperature of the hot-pot he uses but for him it is a mixture of "the right temperature and the right people" [R18-07.00]. For Ragnar the other hot-pots are too hot, and this one has the biggest social pull, in that it is the biggest and busiest. "I don't move around [in the hot-pot]", he explains, most users sit still in the warm water, allowing the heat to sink into their bodies. "I will not do it in cold water…When the body warms up, everything is [better], relaxing" [R18-08.00]. For Ragnar, "it is not normal to be quick, it has to be at fifteen minutes minimum [in the hot-pot]", something reflected when observing most pool users. The use of the hot-

pot is directly (although not solely) connected to heating the body, the geothermal energy transferring from the warm water into tissue, muscles, blood and bones. It is not something that can be achieved in moments, but takes minutes: "I feel different, lighter" [R18-08.00]. The hot-pots at Grafarvogslaug are open-air, so when in one the body can experience two temperatures at once. Most of the body will be in the warm geothermal water, usually up to the neck (although sometimes just the waist), with the head (and sometimes shoulders and arms – extended outwards) in the cooler air. "One of the best things is when there is a snow storm outside and you are in the hot[-pot]", Ragnar shares, "It feels very strange, you are in hot water almost naked, and have a snow storm in the face" [R18-12.00]. The difference in mediums and temperatures highlights the comforting qualities of geothermal water compared to a cold wind.

When Ragnar refers to being "almost naked" he highlights just how direct the experience of the geothermal is in pools. The heat is in direct contact with the body, mostly without any barrier, bar swimsuits which the water (and heat) easily permeates. Furthermore, the experience of using an Icelandic swimming pool begins with taking a shower naked. This is for hygiene reasons and is strictly enforced, mainly through multi-lingual signs reminding users of (or introducing) the policy at the entrance to changing rooms and showers but also through verbal reminders as you purchase a ticket (specifically if not a regular face or a non-Icelandic speaker – the assumption that this implies you may not know about the rule). This means, that for all pool users, there is a very personal introduction to geothermal energies through using the showers in the changing room; warm geothermal water meets human bodies without the barrier of clothing and is directly engaged through the embodied conscious process of washing and cleaning. "We undress, and take our swim suit to the shower, and soap our skin and clean [ourselves]", Eyrun an 82 year-old member of Korpúlfar voices, "and then we put the swim suit on, and we go up straight to the pool – start swimming…[a]fter we have swum, or whatever…then we go to the hot pool..[a]nd then we relax" [R17-02.00]. Eyrun has been coming to Grafarvogslaug for that past 12 years and she comes regularly with her 89 year husband "for our wellbeing…we keep fitter, we feel we keep fit by coming here" [R17-01.00]. As with Ragnar, Eyrun joins in with the exercise ("It's very nice…[g]ood for thirty-something minutes" [R17-03.00]), and the socialising ("Other than swim and have a chat…that's the main focus" [R17-03.00]). Eyrun is equally

as enthusiastic about the hot-pots, "…we have got three hot pots...[o]ne is very hot and I don't think it's very healthy to stay for too long [a] time, but there is one – that's the biggest one – and most people mostly go there" [R17-05.00], she points out. "It's about… 42/43 [degrees celsius]… [we] [t]alk about politics, the weather, mostly the weather" [R17-05.00]. Eyrun also echoes Ragnar's comments about how long is needed in a hot-pot, although also implying that too much heat can be problematic (many will warn of possible fainting if you get too warm): "Mostly, ten, fifteen minutes, we think it's the limit, because I don't get happy then… you have to watch out" [R17-06.00]. Eyrun continues, "You feel more relaxed after you come here…you simmer in [a hot-pot]… but it's not good to be in too hot hot-pots, something in the middle…the middle thing is best in everything" [R17-07.00]. Although access to geothermal water has perhaps become second nature to Icelanders, and the geothermal origins of the heat pushed to the subconscious there is a gratefulness for the resource any moment it is reflected upon. "Going to the swimming pool is just very very nice, wonderful – a big part of our life" [R17-08.00], notes Eyrun, "This is a lifestyle and we are very happy, and will try to enjoy [it] as long as we can" [R17-12.00] – and when pushed on the idea of what life would be like without geothermal water?:

> "Terrible… Of course… We are very rich with hot water, in our houses and of course we shower every day and that would be a problem [with no geothermal water]. But… we would miss it. But, if you never knew, er, if you were never acquainted with hot water, swimming pools, you wouldn't miss it. The things you don't know, you don't miss them."
>
> [R17-08.00]



Fig. 5.12. *Inside Grafarvogslaug, the tables where Korpúlfar members enjoy a post-swim coffee.*

Dóra is also a member of Korpúlfar and had been coming to Grafarvogslaug for nine years. She swims every weekday and also has her own routine, starting with the compulsory shower, through to warming up in a hot-pot and either swimming or joining the exercise class. "If I start in the hot pots I might stay there and not swim" she explains, "you just melt, soften up…have it cosy and talk" [R19-03.00]. For Dóra, too, taking time to allow the heat to sink into her body is very important, "You have to stay in for some time, you have to get the heat in the whole body, you don't get the relaxation in two minutes" [R19-10.00]. In her view it is also better to keep people happy and healthy through having access to geothermal pools, they "need less medicine" as she puts it [R19-08.00]; "It helps so much, I hear them talking about how much better they feel… the heat, the motion… it's relaxing… you feel like you have someone to comfort you". Dóra continues, "You get energy by doing this, you get more energy, you can do a lot more, I can do a lot more if I go into the swimming pool" [R19-14.00].

The social connection is very strong, "It is very good to warm up the body and to speak to others" [R19-05.00] comments Ragnar. If he moved to another area of Reykjavík, he explains, he would still come to this pool. This a sentiment echoed across various pool users, within Korpúlfar and elsewhere, that there is a strong personal connection to the social familiarity of the pools and users remain – to a point – 'loyal'. Dóra underlines the social connection with geothermal pools when she comments, "our communication goes through the hot tubs" [R19-10.00]. When asked if swimming

pools would still be enjoyable to use without geothermal water, Ragnar replies decisively, "If the water was cold, surely not" [R18-12.00]. For Dóra, "We would not live here, nobody would live here, because it's so important, it's our life, the hot water" [R19-13.00]. Towards the end of our talk she adds, "It's [geothermal heat is] one of the main [things], just as important to eat even… to have quality of life" [R19-18.00]. Earlier, Dóra had mentioned how much visitors from abroad enjoy the geothermal pools when they are in Iceland, they tell her "we miss the hot-pots" [R19-05.00] when they leave.

For both Icelanders and foreign visitors geothermal energy, specifically as experienced through geothermal water and geothermal pools, is perceived as something unique and special to the island. Whilst the geothermal heat must exist and be accessible in the first place, without infrastructures to capture and process this heat, and points of utilization and contact with which to encounter it, it would not be a part of the urban everyday. Reykjavík consists a mass of technologies, processes and objects that focuses and frames geothermal heat. This facilitates the urban everyday to become fundamentally geothermal urban, a spacetime of geothermal energy and human urbanization, and to form a place of geothermal urban process rather than passing.

5.4| Thermospheres

Geothermally infused architectures, whether they form cultural spaces, social spaces, homes or offices may seem at first to concern the "outside" and the "inside", existing primarily as shelters from weather and climatic extremes. Whist these constructions offer shelter from rain, wind and snow, they are more about defining spaces of "hot" and "cold" rather than of the outside and the inside. Svava and Olafur's "utan inni" highlights this very well in spite of the fact that, "[f]or all its fascinating potential, few Icelandic architects have taken interest in taking the idea of the arctic greenhouse further" (Schmal 2011, p.41). It does so because its purpose is explicitly one of forming an envelope of heat that contrasts against the cold, rather than to demarcate a specific "outside" and "inside". Notably, this envelope is one that extends beyond traditional notions of an "outside" and an "inside" as complicated by their "utan inni". So it is not that the intention of the architectural design is to

form a recognisable outside and inside, but that this is incidental, formed and distinguishable as a result of a process primarily concerned with hot and cold. Perhaps another key example is that of geothermally heated pavements or driveways. These exist not to differentiate an "outside" and an "inside" but to facilitate an envelope of geothermal heat that demarks spaces of heat and spaces of coldness; hotter spaces where snow and ice melt, colder spaces where snow and ice remain. Further, these envelopes need not be of a set temperature or temperatures, but are relational – that is whether they are to be perceived as hot or cold is dependant upon the broader but immediate temperatures within which they sit. As with Reykjavík's geothermospheres, these are demarcated out of a direct oppositional relation to the wider, cooler, non-geothermally heated world. Markedly, these geothermospheres are of a higher temperature than the general world that surrounds them.

Another critical example of Reykjavík´s geothermospheres are its swimming pools – most notably the open-air pools and hot pots. Many of Reykjavík´s geothermal swimming pools have either external hot pots or an outside pool. Here the difference in heat, between the geothermosphere and the atmosphere, is overt. Each hotpot is at varying temperatures, or geothermal intensities, and as such they each form their own geothermosphere which may be perceived as hot, very hot or cooler in relation to one another, the inside temperatures of a leisure centre, or the outside. These geothermospheres are also demarcated out of a direct oppositional relation to the cooler non-geothermally heated world within which they sit. As Ragnar shared, "One of the best things is when there is a snow storm outside and you are in the hot [water]…It feels very strange, you are in hot water almost naked, and have a snow storm in the face" [R18-12.00]. Here the geothermosphere is clearly perceptible, contained within the hot water within the hot pot, extending into Ragnar's body and dissipating into the air – visualised through steam. It is in stark contrast to the cooler general surrounding space, and of objects and organisms which have lost their heat or failed to gain it – enter the geothermosphere – in the first place. What is clear from this encounter too, then, is that the geothermosphere is relational. It is discernable in the context of the cooler dominant temperature that surrounds it, clearly a distinct envelope of geothermal heat that takes shape and forms around geothermal architectures, infrastructures, and objects of the swimming pool: "…buildings…imbued with the power to make a difference to their inhabitants" note Kraftl & Adey (2008, p.213).

Geothermospheres are distinctive in relation to envelopes of other heat, and are of and possess their own unique formation, function, engagement and dissolution. Firstly, their formation is unique in the way in which they are embroiled in the geothermal heat that surfaces via human activity. This formation is further unique, in the way in which it is maintained by human intervention, causing the heat and infrastructures to become identifiably geothermal urban (as outlined in the previous chapter). Geothermospheres, are then, critical as a part of the palpable culmination of the geothermal urban. Once heat has entered human infrastructures and transforms into the geothermal urban, the geothermal urban then collects at and within these spheres. This is connected to the second point regarding their function. Geothermospheres exist either so that humans may make use of geothermal energy (swimming pools), or, they exist as a by-product of the process through which geothermal energy surfaces (areas of heat and melt around pipes and boreholes for example). Either way, geothermospheres are a result of design and intentional human processes: "Our thermoregulatory advantage is both physical and mental…our ability to control heat is also the basis for the subsequent development of human culture, technology and society" (Ong 2012, p.10). What is key to note, however, is that although thermospheres are designed, any sense of anthropocentric primacy is false. Thermospheres are spaces of a geothermal urban assemblage, defined as much by the qualities of geothermal heat as by the ways humans respond and try to manipulate this heat.

The point here is that geo-thermospheres have a distinct and unique function which responds to the extraction and distribution of the geothermal (or indeed, geothermal urban) heat. This function is the creation of realms of relative heat that warm the world, expanding and contracting in response to the processes that form them – forces and structures. Thirdly, then, geothermospheres have a distinct mode of engagement with the world. Where function relates to what the geothermosphere does (warm), engagement refers to how they exist through the human and non-human (interface). This interface is complicated: "Physicists, engineers, designers, architects, physical geographers, and others have focused…on understanding the complex processes occurring at the interface of…materials and surfaces, and human geographers are increasingly rediscovering such surface phenomena as friction and turbulence – whether literally or metaphorically (Cresswell 2013; Cresswell & Martin 2012)" (Forsyth et al. 2013, p.1017). It can be understood in more traditional

terms, as the point at which two surfaces connect (where geothermal heat engages the non-geothermal within a definable sphere – direct interactions – e.g. geothermally heated water pouring onto skin); or as the way in which devices are used to alter and adjust geothermal heat (indirect interactions – e.g. thermostats, the 'Danfoss' in Icelandic homes). Geothermospheres, much like geothermal heat, must surface. Fourthly, geothermospheres are distinct in their dissolution. They cease to exist as geothermal energy stops surfacing, either naturally or as human intervention prevents or redirects flows of heat. They also cease to exist as the external world, non-human channels, warmed bodies, and objects carry it away, or they dissipate through intentionally designed conduits: drains, waste pipes, and the afore-mentioned heated driveways and pavements.

Geothermospheres are "here" and "there". They are multiple and simultaneous, identifiable (spatially, temporally, materially) and relational (positioned as envelopes of a specific geothermal heat against a non-geothermal background). This relational aspect is very interesting, in particular, in observing how geothermospheres form through a relational mobilisation and immobilisation of geothermal heat: flow. Geothermospheres form from the temporary storing, gathering, of geothermal heat. Geothermospheres take shape from a positioning, a positioning that critically engages both "hot" and "cold" and "flow" and "stall" – "here" and "there". Geothermospheres define edges – surfaces – which either are or are not geothermal urban, that may or may not have been or become geothermal urban. It is Manuel DeLanda (2006) that draws out the idea of 'territorializing' and 'de-territorializing' in his work on assemblage theory - from "Deleuze and Guattari translate[d]…into a vocabulary that re-codes emergence and becoming, namely, (de/re-) territorialisation (Venn 2006, p.107):

> "The concept of territorialisation must be first of all understood literally. Face-to-face conversations always occur in a particular place (a street corner, a pub, a church), and once the participants have ratified one another the conversation acquires well-defined spatial boundaries"
>
> (DeLanda 2006, p.13)

Geothermospheres are territorialized via geothermal heat, water, pipes, buildings and people – all in relation. What DeLanda draws out, is that relations are dependant upon forces that cause entities to take shape either by the coming together or coming apart of constituent elements. Here a direct connection may be made to the relational, assembled, nature of geothermospheres and geothermal urbanism. They result from territorializing forces and structures and dissipate through de-territorializing processes. Geothermospheres are dependant upon the relational, territorializing/de-territorializing qualities of "hot" and "cold", "flow" and "stall" and capacities of elemental forces - "…there are territorialising functions at play in place…[s]imilarly there are de-territorialising forces at play in place that erode, replace or dissipate elements" (Cresswell 2011, p.240). This relational emergence creates distinct geo-thermospheres, "…place…forms and reforms daily through the connections and flows that partly constitute it" (Ibid., p.242). In additional to this, it should be noted that geothermospheres are far from binary – indeed, "not all boundaries create their regulatory effects through 'us-them' partitions" (Sparke 2009, p.55). Geothermospheres are found along a gradient of heat (not just hot and cold but lukewarm, tepid and boiling), a juxtaposition of spatial and temporal positioning (not just here and there, but both and neither, not just now and then, and together and never), and are of relations that are territorialising and de-territorialising. Geo-thermospheres hold "a series of opposites – presence and absence, materiality and ideality, definite and indefinite, singularity and generality – [but critically] in a relation of tension" (Anderson 2009, p.80). Further, this may be connected to the concepts of affect and atmosphere, "atmospheres are circumvented and circulate…are a kind of indeterminate affective 'excess' through which intensive space–times can be created" (Anderson 2009, p.80). Geothermospheres, through their emergence and dissolution, their territorializing and de-territorializing, possess an affective capacity and produce distinct atmospheres, form and reform place (Cresswell 2011, p.242).

5.5| Geothermal atmospheres

Cresswell (Ibid., p.226) notes that "[a]rchitecture is essentially a way of predetermining what we are 'thrown together' with (Massey 2005)". In being 'thrown together' with the geothermal, the architectures and infrastructures contained within a geothermosphere exercise a kind of affective

capacity – one of the geothermal through the human. It is perhaps possible to think of Bennett's (2010) **"**thing-power" which "gestures toward the strange ability of ordinary, man-made items to exceed their status as objects and to manifest traces of independence or aliveness, constituting the outside of our own experience" (p.xvi). Massumi (2002) points out the 'half a second' before a reaction to affect, before it becomes a feeling or emotion. This half a second is present within geothermospheres as the moment just before geothermal warmth is registered by the body:

> 'It is within the pre-cognitive that the dynamic concept of 'affect' can be found…Affect, in non-representational terms, is considered transpersonal, fluid and mobile, and, importantly, always 'inexpressible: unable to be brought in to representation' (Pile 2010, p.8). This conceptualisation of affect is commonly aligned with the various readings of Spinoza and Deleuze that have surfaced within Human Geography…Affect thus becomes something akin to atmosphere – invisible but sensed within our bodies, as feelings, and understood and expressed, as emotions: while the three (affect, feelings and emotion) are interrelated and all work together, they are never quite the same (McCormack 2010, p.643; see also Anderson 2006)'.
>
> (Waterton 2012)

Reykjavík´s geothermospheres are affective envelopes of geothermal potential - "In the world of Spinoza and Deleuze, affect is the capacity of interaction that is akin to a natural force of emergence" (Thrift 2004a, p.64). Here, this natural force of emergence is entangled with the natural force of geothermal heat – it's affective capacities surfacing through the felt dimensions of warmth in the same way the heat itself surfaces from within the earth. Crucially, whilst these affective capacities may be registered by the human body – that is, cognitively: "Affect refers to the force of intensive rationality – intensities that are felt but not personal; visceral but not confined to an individuated body" (Whatmore 2006, p.604).

Another way to think observable geothermospheres is through the concept of urban heat islands – those which "form in urban and suburban areas because many common construction materials

absorb and retain more of the sun's heat than natural materials in less-developed rural areas" (Gartland 2008, p.1) - albeit differently constituted. In essence, geothermospheres may well be considered 'islands' of heat and Reykjavík viewed as unique for having a *geothermal* heat island effect. Generally, the heat island is seen as a problematic heating of urban areas, but in the case of Iceland's northerly latitude and cold climate it becomes beneficial and desirable – something to be designed in rather than designed out:

> "The urban heat island effect is the most obvious atmospheric modification attributable to urbanization. The replacement of natural surfaces by those characteristic of a city radically alters the aerodynamic, radiative, thermal, and moisture properties in the urban region"
>
> (Oke & Maxwell 1975, p.191)

It is important to connect this thinking back with what has been covered in the previous chapter - that is, the geothermal urban as an emergent geosociotechnical process – but also as affective. Geothermospheres emerge as a result of human infrastructures and the surfacing and maintenance of geothermal forces. It was these constituent infrastructures, transformed by the geothermal heat that they carry (and the geothermal heat transformed by the infrastructures it courses through) that were outlined as *the materialities* of the geothermal urban. Geothermospheres, which gather from and around these, are *the lifeworlds* of the geothermal urban – the lived, actualised manifestation of the geothermal urban assemblage as a palpable entity. They are born of and comprise geothermal forces and human structures which are both social and technological. More, these geothermospheres are full of affective capacities and resonance, which are just as much a part of geothermal urban materiality. The geothermosphere is differently constituted to the 'urban heat island' (as typically understood) for its distinctive geothermally affective qualities. Geothermospheres produce envelopes – islands – of heat which have distinctly different spacetimes and affects. The geothermal hot-tub, the geothermal hot water tap, resonates with a different vibrancy, an alternative vitalism (connecting back Bennett 2010), to the solar or the carbon heated urban.

If thermospheres are envelopes of heat, and ones with affective capacities, they might also be thought of as forming, being, possessing or emitting distinct atmospheres of the geothermal-urban:

> "[W]e may walk into the room and ''feel the atmosphere,'' but what we may feel depends on the angle of our arrival. Or we might say that the atmosphere is already angled…[h]aving read the atmosphere, one can become tense, which in turn affects what happens, how things move along."
>
> (Ahmed 2010, p.37)

When you walk into a geothermosphere you feel its atmosphere. Atmospheres of geothermal affect permeate Reykjavík, resonating from the envelopes of heat that gather around architectures and infrastructures. Atmopsheres are seen in a wisp of steam escaping a borehole, felt through the grip of a pavement when the snow has melted and are enacted in the turning on of taps. These affective geothermal atmospheres are also fittingly described through "a relational account of affect in which shared structures of feeling bubble up within particular constellations of people, technologies, and other nonhumans" (Lorimer 2015, p.45). The geothermal urban bubbles with "an affect, a set of affects, a kinetic determination" (Deleuze 1988b). Multiple, varied, but shared, geothermospheres 'bubble up' through affective compositions of people, pumps and warm water: the pool, the geothermally heated school, a bathroom: geothermospheres, geothermal "atmospheres may interrupt, perturb and haunt fixed persons, places or things" (Anderson 2009, p.78). Atmospheres also "emerge, according to Böhme (1993, p.119), as an intermediate position between subject and object, or rather as a unity of subject and object, which is fundamentally characterised by their co-presence (Böhme 2001, pp.56–57)" (Sørensen 2014, p.2). Within the geothermospheres, affective geothermal urban atmospheres perhaps do not just "bubble up" but also forms bubbles around compromised and constituent actants: the body in a hot tub is not merely a conduit of geothermal urban affect but is within it, an affective atmospheric resonance existing around as well as through the swimmer, the water, and the immediate air into which geothermal heat dissipates.

Geothermospheres - thermospheres - are interesting, not least because they allow for a breaking away from "the logic of the corpse…the already passed" (Thrift 2004b, p.83). In "a world in which the event is primary" (Ibid., p.85), they are one way in which we might "think of the work of the world as a set of dynamic intensities that produce different spatial and temporal, intelligibilities – territories of becoming that produce new potentials" (Ibid, p.88). What geothermospheres also show, is that the geothermal urban consists of a unique *a priori* materiality which in turn resonates with distinct geothermal urban affect forming palpable geothermal urban atmospheres (which indeed may be understood as geothermal urbanism): "matter stands for that which is prior to – and forms a basis for – human experience, perception and knowledge" (Kearnes 2003, p.144). Moreover, geothermospheres (geothermal urban atmospheres, geothermal urban affect) are distinctly, palpably and uniquely formed of these materialities (Ahmed 2010; see also Deleuze 1988, p.124).

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This chapter has drawn out further an understanding of the geothermal urban by attending to the spaces and envelopes of geothermal utilisation. It has highlighted how these envelopes of heat gather at the sites of geothermal urban architectures, objects and machinery to form distinct thermal spaces that enable human dwelling - "consolidat[ing] man-made reality vis-a-vis the elementary powers of nature" (Engels-Schwarzpaul 2007, p.525). It may be understood, that these geothermospheres create "a spatial grammar for an environmentalized vision of a present and future" (Gissen 2014, p.182). That is, a present and future that is possible due to geothermal warmth. However, these geothermospheres are in flux, contingent and relational: "they move, combine and recompose as they encounter other bodies, revealing a vitality that is present at every imaginable spatial and temporal scale…[, m]oreover, they move us and move in us" (Braun 2011, p.390). Indeed, the geothermal urban assemblage, magnified via geothermospheres, has been unveiled as a contextual, relational, materiality; formative of gathered, elementally infused, palpable affective atmospheres:

> "[A]rchitectural qualities arise from the influence that each material component has on the creation of a certain kind of atmosphere…the properties of architecture, the materials

> employed in architecture and the orchestration…have the capacity to create strong emotive effects on people's engagement with spatial settings…atmosphere thereby emphasizes the quality of materials not simply as a source and a static trait in architecture, but rather as the effects the materials produce through their radiance or affective influence on people. This implies that atmosphere is object-oriented or object-dependent, or spatial in character, but at the same time creative of the mood of the perceiver of the atmosphere, which works as a 'force field' (Stewart 2011, p.452)…These affective properties are synonymous with atmosphere being a multiplicity of forms and forces with the intersection of body and environment as a nexus…It is this intermingling of sensory experience and material form that can be further pursued, modelling a potential for exploring atmosphere with a strategically decentred human subjectivity"
>
> (Sørensen 2014, p.2)

Whilst this chapter has outlined the atmospheric and affective capacities of the geothermosphere, it has stopped short of understanding and unravelling the particulars of embodied geothermal urban dwelling. There is a necessity, then, to explore being-in and of geothermal heat: "…in the design, planning, and inhabitation of buildings, certain kinds of affects are specifically and locally stabilized in an effort to engender more particular forms of inhabitation" (Kraftl & Adey 2008, p.228). It is the elementally infused affective capacity of the geothermal urban, the atmospheric intensities of geothermal heat, and the particulars of embodied experiences of 'cosiness' and 'warmth' that are next addressed; tracking the processual geosociotechnical and the atmospheric geothermosphere.

- vignette v -



The body into geothermal water: immersion.



6| Bodies

"Somewhere, in all these rocks and stones, is my home"[39]
- Pétur Gunnarsson, *Landsýn*, 1973

"So where does the cyborg dwell? …What 'takes place'?"
- Shields 2006, p.211

"When the steam rises from the ground,
Levitating without a sound.
There's a peacefulness to be found,
In a breath that is skywards bound."
- Ásgeir Trausti, *Soothe This Pain*, 2013

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This chapter focuses on the human body within a geothermal urban assemblage, concerned with distinct forms of embodied dwelling characterized by and characteristic of geothermal urbanism. It turns to the human body at points of geothermal dissipation, understood as the end-point of geothermal provision and as the apex of the geothermal urban assemblage: the moments before assemblage turns to dis/reassembly. The human body is the focus of geothermal provision and is moved by and moves the geothermal. It is heated by and traverses a geothermal environment, but also exists as the conscious instrument with which switches and levers direct and control heat. The first section introduces geothermal dwelling through the urban planning of Hafnarfjörður, a part of the Reykajvík Capital Area known for its lava dominated urban landscape and geothermal heat provision. The critical role of human bodies inhabiting (and thus gathering and assembling) the geothermal urban is outlined via comparing two neighbouring areas of the city: one with homes, people, and geothermal heat – the other without.

The chapter then turns to human bodies immersed in geothermal heat within water and air, and traversing rock and fire via cooled lava fields. Revealed, is greater detail on the affective capacities of the geothermal urban, highlighting its elemental qualities and the role of human bodies in their articulation. This chapter's final section turns to understanding the affective capacities of geothermal

[39] A widely available translation of the Icelandic: 'Einhversstaðar í öllu þessu grjóti á ég heima'.

urbanism, previously highlighted as formative of geothermal urban atmospheres. Affect, permits a tracking of the processual and the atmospheric, and elementally embroiled it intersects the geologic, social, and technical. Elementality is viewed as affective, embodied by the seeking out, and in the production of, warmth and cosiness. Further, the geologic is understood as embodied in the activity of human's tactile engagements with lava fields, articulating affective afterlives of past geothermal heat. Within the geothermal urban assemblage, it is argued, bodies become geothermally elemental in their articulation of geothermal elementality; conceptualised as elemental hybrids and geo-cyborgian.

6.1| Dwelling

The town in the lava

Hafnarfjörður is a distinct municipality within the Reykjavík Capital Area. Referred to as 'the town in the lava', it sits within and on striking lava[40] fields. These fields are so prominent because they are so young – between approximately 1,000 and 10,000 years old (see Jóhannesson & Sæmundsson 1998; Mawejje 2007; Thordarson & Larsen 2007, pp.135–139) - so they have not been as eroded over time and maintain a rugged, chaotic and lively character. In this sense, the landscape is perceived as more overtly and immediately volcanic, reflective of the geophysical processes that shaped the landscape and geothermal qualities which continue to exist under (and above) ground. Meeting with employees from the local council sheds light on 'the town in the lava'. Bjarki Jóhannesson (Director of Planning), Berglind Guðmundsdóttir (Landscape Architect) and Dagur Jónssons (CEO of Hafnarfjörður Water Works) are based in offices in Hellnahraun, an area within the south-west of Hafnarfjörður which is named after the type of lava that dominates the surrounding landscape: 'helluhraun' or 'Pāhoehoe' (characterised as having a smooth and rope-like surface - see Oppenheimer 2004, p.612). Bjarki is very quick to point out that "[h]ere we have much a very geothermal area" [P14-01.00] and Dagur notes "[t]hese areas are of course world famous for rifting and seismic activity and geothermal

[40] For geologists, molten rock within the ground is called 'magma', and then 'lava' once it has surfaced.

activity is considerable" [P16-05.00]. This sets the tone for a conversation which focuses on Vellir ('the plains'), a neighbourhood of Hafnarfjörður which lies just next to Hellnahraun and is as equally dominated by a lava rich landscape (Fig. 6.1).



Fig. 6.1. Hafnarfjörður's neighbourhoods: in aerial view western Vellir (with houses) can be easily differentiated from eastern Vellir (without houses), whilst lava can be seen to dominate the landscape specifically through Vellir and Hellnahraun (Hafnarfjarðarbær 2014, p.106, adapted).

Planning for Vellir began in 2001 as an extension to the nearby Ásland ('small ridge land') neighbourhood which itself had been built in the 1980's and 1990's. Shortly after planning Vellir, work begun to turn the lava field into an expanded urban area. However, as a result of the 2008 global financial crisis, investment was withdrawn and only about two-thirds of Vellir was fully completed. As a result, the western end has infrastructures, buildings, and people - it is inhabited (Fig. 6.2). The eastern end has roads, lights, and geothermal plumbing, but no homes and no people – uninhabited (Fig. 6.3). Geothermal heat is also shut-off in this part of Vellir, whilst it flows in the west. It is an odd experience in the east: the echoes of past geothermal process are present within the lava landscape yet geothermal heat does now flow in the present. A few meters away, past geothermal

processes continue to echo but the lava is complicated in and hidden by homes. At the same time, geothermal heat continues to flow and is animated by human bodies performing everyday activities. The two locations are denotable based on the lack or presence of homes and people, whilst both spaces highlight the geothermal in different ways - through the active use (or not) of geothermal heat, and through the complicating (or not) of lava within the urban.



Fig. 6.2. *The western part of Vellir where homes have been built amongst the lava. The residents' daily routines are tied up with both geothermal water and a lava landscape.*



Fig. 6.3. *The eastern part of Vellir in Hafnarfjörður is a lava field with roads, street lights and pipes, but unlike its westerly counterpart, no homes, people, or geothermal water.*

"It's a political decision" says Bjarki, "the choice was to continue building here – from [the existing] end… it was…easier land to develop, flat land…This area is residential…it's mixed use…"" [P14-20.00-21.00]. This observation is then qualified with the figure of 6000 residents now inhabiting the Vellir neighbourhood. The viability of the new area, as occupied, was underlined by Dagur reiterating the role geothermal water plays in making the neighbourhood liveable:

> "[The district heating system] is of course integrated into the street, and every house is connected to it, and the water is metered…to give you an idea of the use we have, er, consumption every day per inhabitant of about 60 litres of 80 degrees [celsius] hot water. Additionally we require yearly 1.5 cubic litres of 80 degrees celsius hot water per cubic meter of housing within the area. So, on a scale which is maybe useful to you, on a cold day… Hafnarfjörður is using something like 400 litres per second of 80 degree celsius hot water" [P16-03.00-04.00].



Fig. 6.4. 'Schematic Plan' for Vellir and Ásland; the area is depicted as fully developed, note that lava here is presented as green space (Hafnarfjarðarbær 2014, p.33).

Protecting the lava

Berglind, as a landscape architect, summarises the ways in which lava has been embraced through the town plan (Fig. 6.4): "…you see the green areas, it's the lava, we protect [it], so people can get out to…nature… we tried to put the nature into the neighbourhood, it's a very important part" [P15-2100]. Clearly, making sure lava is a part of the urban landscape is wrapped up in ideas of exercise, getting fresh air and of maintaining a connection with the geo(thermal): "people want to go out, and have some nature, and can walk in the landscape" [P15-22.00]. Valuing lava is relatively new in terms of having formal planning guidance that states it should be protected: "[I]f you look at the old [town area of] Hafnarfjörður, you can see the houses are built in the landscape, but today it's not that way, because first we have the houses and then the nature, so, things have changed in all these years, in 100 years" [P15-35.00]. Bjarki adds to the analysis and draws out how relationships with the lava have altered over the past 50 years of planning and development: "we can look at [the northern] part of town, it's quite a sad story, when they just had bulldozers flatten out the land [in the 1970's]…[eventually] they realised lava was an asset and they had to protect it, like the old part of

town" [P14-36.00]. Berglind adds, "you have to try to, you know…you have to [be able to] take one step and just look at the nature, at the landscape, everything… you have to do some landscape analysis before you build this area" [P15-37.00]. For town planners and urban designers, maintinaing lava is a critical part of successful placemaking (or place-maintaining). "[W]e want to use this speciality [lava landscape] of this area, to make it different from other parts of the…metropolitan area…we want to use our asset, the lava, the town in the lava" [P14-38.00] concludes Bjarki. "There's no lava in Rekjavík…[it's] in Hafnarfjörður and Garðabær… we have to protect it" [P15-39.00] Berglind ends, a little after reflecting that with some lava included within the houses and streets "…it's so easy to have the children go out to play" [P15-37.00].

Inhabiting the geothermal

The lava landscape is certainly a visual dimension of the sense of place experienced within Hafnarfjörður, but perhaps critical is that this sense of place is also felt through bodies sensing the (after-)effects of the geothermal and echoes of the geophysical. What perhaps is most striking in comparing the west and eastern parts of Vellir is how the geothermal is articulated through human bodies - in taking showers, swimming in pools, heating rooms, and playing on lava. In the eastern part – without homes and people – the geothermal feels latent. In the western part – where geothermal heat flows into buildings and bodies – the geothermal is enlivened. This difference clearly underlines the role of human bodies within a geothermal urban assemblage, bodies tied up within the practices of geothermal dwelling. Moreover, these bodies and the practices of dwelling enact the final element of geothermal provision, having had extraction and circulation, we reach dissipation. Geothermal dwelling and the dissipation of geothermal energies are entwined. In essence the geothermal is articulated through the process of inhabiting, the practice of dwelling.

The term dwelling, here, is encountered through the philosophy of Heidegger, notably through Being and Time (1927), and may be conceptually drawn into the geothermal urban assemblage through Ingold (2011, p.10): "dwelling is not merely the occupation of structures already built: it does not stand to building as consumption to production[…]It rather signifies that immersion of beings in the currents of the lifeworld without which such activities as designing, building and occupation could not

take place at all". By this, dwelling within Reykjavík´s geothermal urban assemblage - geothermal dwelling - is not merely about human bodies and lives inhabiting and mobilising throughout a world infused with geothermal heat and lava landscapes. Dwelling means more than this, is world-making, and as such it is human bodies interacting with the geothermal and geophysical and the co-creation of a distinct and unique lifeworld. There are many attempts at interpreting and translating Heidegger's Being and Time (see: Dreyfus 1991; Kisiel 1993; King 2001; Mulhall 2005; Polt et al. 2005; Lattner 2006; Critchley 2008), from which this understanding of dwelling comes from:

> "What Heidegger is getting at is a mode of being-in we might call 'inhabiting'. When we inhabit something, it is no longer an object for us but becomes part of us and pervades our relation to other objects in the world. Both Heidegger and Michael Polanyi call this way of being-in 'dwelling'. Polanyi points out that we dwell in our language; we feel at home in it and relate to objects and other people through it. Heidegger says the same for the world…the relation between me and what I inhabit cannot be understood on the model of the relation between subject and object"
>
> (Dreyfus 1991, p.45)

What can be seen across the Reykjavík Capital Area, and so explicitly within Hafnarfjörður, is this inhabiting, dwelling, being-in-the-world, in which human bodies, objects and geophysical forces coalesce as a part of a geothermal urban assemblage. An assemblage which emerges, surfaces, transforms and animates not as a subject-object combining but as a co-productive coming into being. As Dreyfus surmises, "we must…overcome the traditional interpretation that theory is prior to practice" (1991, pp.46–47), indeed the geothermal urban assemblage is not independently thought and produced, it is imagined as it comes into being. To draw on Ingold once more:

> "[T]he forms people build, whether in the imagination or on the ground, arise within the current of their involved activity, in the specific relational contexts of their practical engagement with their surroundings…people do not import their ideas, plans or mental

> representations into the world, since that very world, to borrow a phrase from Merleau-Ponty (1962, p.24) is the homeland of their thoughts"
>
> (Ingold 2000b, p.186)

This is not to suggest, however, that dwelling should be the absolute conceptualisation or predominant understanding of geothermal urbanism, but that it does provide one interpretation and cannot be ignored as a critical component of the world of roads, pipes, limbs and geothermal heat. In drawing upon Obrador-Pons (2003), McFarlane notes that "…dwelling functions as a metaphor that draws attention to the contingent, practical, and sociomaterial nature of…activity" (2011, p.651). As such, of course, metaphors have limitations. McFarlane continues to suggest that dwelling lacks a "processual and mobile conception of…spatiality" and that "rather than dismiss the notion of dwelling, another route is to consider how we might rethink dwelling *through* mobility" (2011, p.663). He connects back with Ingold, noting that "Indeed, Ingold has come to regret his emphasis on dwelling, preffering now to speak of *inhabiting*" (Ibid.). Thus, there is room for confusion as 'dwelling', 'inhabiting' and 'being-in-the-world' merge into tautology. It is perhaps that the precise word used is related to the aspect which is intended to be underlined. With Reykjavík´s unique lifeworlds all three descriptors might be applied: fixed dewlling in hot tubs, the mobile inhabiting of walking through lava fields , the perhaps broader being-in-the-world of a geothermal urban nexus, with, "most directly and simply…an attempt to think of space neither as a Kantian a priori nor as an outcome or an attribute" (Harrison 2007, p.627). This, with a caveat that "…despite what is certainly an attractive means of reimagining landscape practices, there is a sense in which Ingold risks a rather 'earthly' romanticism by emphasising the territorial qualities of 'dwelling'…becoming ahistorical and ageographical" (Hinchliffe 2003, p.220). In thinking geothermal urbanism through dwelling, inhabiting, and being-in-the-world, it is important not to think these practices as dominated by a geocentrism:

> "Whereas in humanist inclined writing the emphasis in the use of the concept of dwelling tends to fall upon an 'ontological vision' of 'togetherness, belonging and wholeness'…[post-humanist] engagements tend to promote a radical relationality, finding in the concept of

> dwelling less a naturalism than an incipient antihumanism, posthumanism, or transhumanism and a performative account of existence" .
>
> (Harrison 2007, p.626)

This requires a consideration of geothermal urban dwelling (inhabiting, being-in-the-world) to acknowledge explicitly the embodied geopower within its constitutive geothermospheres. In the case of Reykjavík, attempts to understand the geosociotechnical requires a deeper attentiveness to the elementality of the geothermal urban assemblage articulated through human activity. To achieve this, this chapter turns to human bodies within Reykjavík´s geothermal urban assemblage, with a concern for the affective elemental capacities they engage, and which animate the lifeworld and form its atmospheres. By encountering human engagements with geothermal heat within the city, the distinctive types of embodied dwelling characterized by geothermal urbanism can be outlined, highlighting its elementally infused affective capacities.

6.2| Water and air

As geothermal heat courses the network of infrastructures that mobilise it across the Reykjavik Capital Area, the materials used to make and insulate the pipes, pumps and storage tanks ensure the temperature of the hot water drops by only a few degrees. Nonetheless, eventually the process of heat transfer causes the energy to dissipate. Ultimately, this is the aim of the system, to contain and mobilise heat so that at a given end-point it can then be utilised. Be it via convection, conduction, radiation or (most likely) a mixture of these processes, in contrast to the efforts put into the ensuring geothermal energy is contained, the end result is dissipation. The critical purpose of the Reykjavík district heating system, is that geothermal heat dissipates through human bodies. A typical (albeit simplified) example drawn from the encounters outlined in previous chapters might be as follows: 1) geothermal heat rises from the Earth's core to its mantle via convection within molten rock, transferring into cooler solid rock via conduction, and in-turn transferring into ground-water via further conduction; 2) Geothermal energy surfaces, convecting in geothermal fluid, drawn up through boreholes, pipes, and pumps; 3) Geothermal energy then transfers via conduction, through pipes, into cooler fresh water within a heat exchanger (for example at Hellisheiði); 4) Convecting within

geothermally heated water the heat is carried in well-insulated pipes, under pressure, to a main storage tank (like those at Perlan), continuing to convect within the liquid as it is then pumped to a building (for example a home, like Arcadia); 5) At the end-point geothermally heated water is divided, it may be drawn from a tap into a bath or shower from which it transfers into a bathing body via conduction, or it might be diverted into heating elements such a radiators from which it transfers into warming bodies via radiation (or conduction in the case of direct contact with the radiator, or indeed convection as the heat transfers into the air and from the air into a cooler body); 6) From there, heat fully dissipates, conducting away from human bodies into the air, and the wider environment.

Vesturbæjarlaug



Fig. 6.5. *An aerial view of Vesturbæjarlaug with geothermal hot water pipes overlaid in red (Borgarvefsjá, 2015).*

As, has been noted, geothermally heated swimming pools are incredibly popular in Iceland, and in the context of the Reykjavik geothermal district heating system, represent a central end-point at which humans directly engage with geothermal heat before it dissipates beyond pipes, storage tanks and bodies. Vesturbæjarlaug (Fig. 6.5) in west Reykjavik is another typical local pool, situated in a

suburban area with plenty of local users, it opened in 1961. Initially the pool just had a basic bathing area, or main pool, today it consists of a main pool split into swimming lanes and a smaller less formal area popular with children, four "hot pots" (hot tubs) at varying temperatures, a sauna and a new "large hot pot" which is more like an additional shallow heated pool than a hot tub (Fig. 6.6). In additional to this is has changing rooms, a reception area and offices, not to mention a vast basement which houses all the machinery required to facilitate the geothermal heating of all the facilities. "By regulation [In Iceland] we have two types of pool, 'A' and 'B', Hafliði Halldórsson, the pool manager explains as we meet on a February morning. Hafliði continues: ´…the A types are the new pools where you have complete circulation of water [a closed loop], and they have warm [heat] exchangers, so you use hot water to heat up cold water, and that's in…the newer pools. This is a B pool, so this is like a big hot tub. We just have cold water running in and we mix it up and we circulate it, but we make it overflow to a certain percentage, about twenty per cent per day… it just goes out to the ocean. That's a B-pool, we don't have a complete circle, a closed circle" [P1-00.00].



Fig. 6.6. *Vesturbæjarlaug.*

It is in the basement that various pieces of equipment monitor water temperature and quality, "We have a regulation where you have to circulate the hot tubs, all the water in the hot tubs though a sand filter, every 20 minutes. And for the pools, this is every 4 hours" [P1-03.00]. In addition to the

sand filters, chlorine is added and monitored and an overflow of filtered water is held in reserve to re-fill the pools and hot-pots as required:

> "There's a pumping station somewhere, in the area, that the water suppliers manage, and they just serve us with water, coming in. I think it's about 5 [Bar of pressure]... And, this is water pressure that comes in here, and then we just have equipment, pipes and so on, we don't have really any pumps for the hot water…. It just flows in. Water flows in. Then we have a filtering unit that circulates the water in the pool, and cleans it, and then we have just a little more water coming into the pool than we need, so it goes to the overflow and then runs out to the sea…The hot tub there, what you see is about 30 tonnes of water, in the large one, the new one… and we have about 10 tonnes in the basement ready to be used. And water is circulated and kept at a steady temperature. And, er, we maintain the chlorine level and the PH level. PH is a problem here, because we're using [geo]thermal water. We want to have a PH between 7 and 7.4, but the water that is coming in here is up to 9.8. So it's really, [alkaline]. We put acid in the water to lower the PH."
>
> [P1-02.00]



Fig. 6.7. *Underground and around at Vesturbæjarlaug, geothermal hot water pipes surround the main pool out of sight.*

Once processed, the geothermal water enters the pools (Fig. 6.7), and besides being processed through filters and retuned to the pool, it eventually flows out due to the pools being slightly over-filled. Geothermal heat leaves the water in the pools by conducting into people's bodies, warming them up, it is carried away within them as they leave. Heat also escapes by conducting into the surrounding ground and evaporates into the air: as getting warmed up is a felt dimension of using a geothermally heated swimming pool, seeing steam rise from the pool is a visual one. "Heat's the same, but…the feeling on the skin is different between the pure water and the geothermal water. There a definite difference there… also the smell of course" [P1-11.00] Hafliði comments. Geothermal water contains a high level of sulphur, which can be smelt where it is used directly (as opposed to indirectly via heat exchangers).

Ásvallalaug

Heat dissipates all over the Reykjavik Capital Area in a mirroring of the way in which it is also transferred and is present across it, a geothermal ubiquity haunts the city. Across to the south of Reykjavik, in Hafnarfjörður, is Ásvallalaug. Ásvallalaug is a municipal leisure centre that opened in 2008 and has 300,000 visitors a year, 200,000 for swimming in its new pool and hot-pots alone. Aðalsteinn Hrafnkelsson is the manager of swimming pools in Hafnarfjörður and Birgir Ingason is the technician responsible for maintenance (also acting as assistant manager). Whilst the experience of heat once in the centre is immediate and overt, the infrastructures behind its facilitation remain hidden under floors, behind walls, within ceiling ducts and in out houses: "Very few, people think it's just water, and er…. People have no idea about that…you don't know these things until you start working with it, it's more complicated…many frequent guests have no idea how complicated these things are" notes Aðalsteinn [P4/5-21.00]. Even temperature, for example, is monitored closely through both a system of automatic sensors and manual checking - "It's always measured in the mornings and the evenings, just by putting a sensor in the water, checking. They [staff] do it in the mornings just before opening at 6 o'clock, again at two o'clock, and then I can see it on the computer if I want to check better. That's about it. And I see it when I am in the pump room, up on the screen there." [P4/5-09.00].



Fig. 6.8. *The main pumping room, underground at Ásvallalaug.*

Water comes into building at 78°c, and is used to heat up cold fresh water that fills the pools and hot tubs, explains Birgir (see the main pumping room, Fig. 6.8). Ásvallalaug is a 'Type A ' pool, and the waste water leaves the pool at around 26°c, being used to melt ice and snow from the pavement outside the leisure complex before heading to the sea through waste pipes – Aðalsteinn comments, "Some of this [waste] hot water is used also to heat up the pavement around the house… taking the snow off the street, the walking paths…it helps older people to come here". Here, the geothermal heat is not only viewed as central to the pool itself, but also to access. As well as heating pavements, "The left over [water from] the heating of the pools is put up for the heating of the air" [P4/5-04.00]. Birgir explains, "The swimming pool, the swimming pool area, that's very hot because it needs to be hotter than the temperature of the pool – one or two degree's hotter than the pool…Because of, you know, fog, or something to do with… windows crying [condensation], all the air would be wet [humid]" [P4/5-09.00]. Usually, steam doesn't form indoors, this is because the air temperature is kept higher than the pool temperature. "It's a few times happened, that the air conditioning go[es] off [accidentally] overnight and when we come here in the morning, it's like, steam… in the pool area. [It] [t]akes one or two hours just to clear the windows" [P4/5-22.00] Birgir recounts. Swimming at Ásvallalaug (Fig. 6.9) is to be fully immersed into the midst of dissipating geothermal energy; a person

in a pool or hot-pot is surrounded by heat convecting within both water and air, conducting into and from their body, lost via conduction into other objects and carried away by the air.



Fig. 6.9. *The main competition pool at Ásvallalaug; geothermal heat flows in and through the heated water, air, building, objects and pool users.*

What is being highlighted here, in returning to Reykjavíks swimming pools, is the importance of human bodies in arcticulting the geothermal within a geothermal urban assemblage. Much like the area of Vellir in Hafnarfjörður which was divided by its presence and lack of people (and related presence and lack of geothermally heater water flow into homes), Reykjavíks swimming pools become a coinduit for the taking place of geothermal urbanism through human inhabation. Images of Vesturbæjarlaug and Ásvallalaug without people (Fig. 6.6 & Fig. 6.9), fail to express the enlivened embodiment essential to the process of the elementality and affective capacity of the geothermal forming geothermal atmospheres. The geothermal circulates, resonates and radiates through, and dissipates from the human everyday life world. It is caught up in bodies and their movements, objects and activities. This resonance and dissipation can be examined through the everyday dwelling of Reykjavík Capital Area residents. Five of them, Olga, Auður, Fjóla, Hákon and Bjarki live in different areas: Vellir (Hafnarfjörður), Old Town (Hafnarfjörður), Garðabær, Kópavogur and Miðborg

(Reykjavík) respectively. Whilst in comparing the eastern and western parts of Vellir the differences between areas of geothermal dwelling and un-dwelled geothermal-urban are highlighted, looking at the Reykjavík Capital area in broader terms reveals a place of variance in geothermal engagement and resonance. Geothermal water courses through pipes and buildings across all five neighbourhoods, however in Garðabær and Hafnarfjörður the landscape is distinct for its young lava.

Riding the Number 1 bus route from Vellir to downtown Reykjavík highlights this changing landscape as it travels through Hafnarfjörður, Garðabær and Kópavogur. When boarding the bus at Vellir the young lava dominates the urban landscape. Large expanses of it can be seen just beyond the edge of Vellir with significant 'intrusion'[41] into the urban space. Lava dominates gardens, parks and public 'greening'. As you travel through Hafnarfjörður the dominance of lava fluctuates. In some parts it has been deliberately removed, however, in the old town it remains, abundant and permeating gardens and public spaces. This continues in Garðabær, with a mixture of areas: those with lava removed, those of undeveloped lava, and many in between – again, young volcanic rock ever-present throughout urban architectures and infrastructures – a subtle but considerable part of the everyday. As the bus travels into Kópavogur the lava begins to take a back-seat. Unlike Hafnarfjörður and Garðabær, Kópavogur and Reykjavík sit on much older lava fields. As a result, the lava is less immediate. It has been weathered and removed on a much greater scale. In Kópavogur lava is mostly decorative: it is in gardens and is gathered in some public spaces (in particular, piled around the local church), but its above-ground presence is in decline.

Within Reykjavík the same exists, lava decorates gardens and notably the public space outside the largest church in Iceland, Hallgrímskirkja; basalt columns sit in Ingólfstorg (a square downtown) and outside the National Theatre. Lava becomes less dominant and the urban is intensified. Conversely, however, here the geothermal becomes a little more explicit. This is through infrastructural architectures such as Perlan (iconic on the skyline), and the presence of more melt from greater under-street heating, to the existence of geothermal boreholes (steam visibly escaping into the air

[41] Of course, it may well be argued that it is the urban which 'intrudes' on the lava field. The term is used here is it might be in urban design and landscape architecture, to describe the way is which undeveloped lava sits within roads, paths and houses.

around Laugardalur), and with public art not just invoking the volcanic through placed lava and basalt columns, but steam expelled from some of this public art (specifically an instillation at Ingólfstorg). However, no matter the extent to which lava or the geothermal tangibly exists within these areas it is the way in which it resonates through human bodies which gives it presence and conscious immediacy. This is not to claim that there is no inherent immediate 'vitalism' within the geothermal, but it is to highlight how human bodies in particular articulate the geothermal (the human body being procedurally and consciously involved). "The *feel*ing of nature extends beyond my five senses" notes Allen (2011, p.275) – and the *feel*ing of the geothermal is a critical embodied aspect of the geothermal in these places.

Miðborg

Bjarki reflects this connection between his body and feeling heat in relation to everyday practice: "I would say, in the places that I've lived or travelled these experiences [of heat] are very different, because of the origins of the energy, or because of the utility itself" [R10/ 62.00]. Our point of departure for a more detailed consideration of this begins with geothermal heat within his home:

> "I usually just go by, what I, what my body, like if, if I feel that it's not stuffy, I really can't stand stuffy air. Um, and I don't want to feel heat in the air, like, Icelandic homes are consistently over-heated, just because it's so inexpensive. My energy bill is less than 4000 (ISK) per month, like, er, you know lighting, heating and water. And, um, yes, so I basically just go with what, what it feels like in the space. The bathroom is always very hot, because we have a, a, problem with the shower that it over-floods, er, so we need to like really, the window's open and the heating is on the max"
>
> [R10/09.00]

Bjarki, clearly communicates the connections between his bodily sensing of heat, his resulting engagement with various interfaces (radiators, windows) and exerting a bodily control over the geothermal through embodied acts (turning nobs, opening windows). He expresses this connection

further in talking about his bathroom and the practice of washing, during which his hand moves to imitate the process of turning handles:

> "Just a regular shower. It's a bathtub and a shower, so you can either take a bath or a shower…Um, there are two knobs. One which turns the steam into filling the tub, and one that turns on the showerhead. And then it's just like a celsius scale that reaches I think 35 [degrees] max, and then you have to push a little button to move it higher… it tends to be on max, after the safety button… this house has a low pumping pressure of water so the cold water is annoying warm and the hot water is annoying cold…this is a new house"
>
> [R10/10.00-11.00]



Fig. 6.10. The otherwise unspectacular radiator which heats Bjarki's bedroom with geothermal heat.

In using geothermal heat, his body is engaging with the affective elementality of the geothermal, and he enacts and forms the geothermal urban through the activity of geothermal urbanism. This activity is embodied dwelling characterized by geothermal urbanism; it is taking showers, washing hands, and warming rooms (Fig. 6.10). Of course for Bjarki, at anyone else, it is not just within the home that the

body encounters the geothermal. It is within the geothermal pools the relationship between Bjarki's body and the geothermal is most conscious:

> "You play with your body, like you know, you float a little bit and go massage a little bit, you sit back and you're across from each other, like, move around. You play with the water bubbles somehow. There are things that also, you now like, not like you tossing a water bubble back and forth but just kind of like letting it float while you're talking. Just doing these things that the water enables you to do."
>
> [R10/29.00]

> "You're [in] like a similar, not experience, but you're going to a similar circumstances. It's like walking with someone in a storm or the sunshine. You, you are getting the same kind of conditions…You're like, [the] experience of your own body in the water…I realise it now that you can't generalise on it. But, for example… like…my experience...for me, it's always…it's somehow[…]intimate, it's somehow an intimate thing because you're[…]somehow doing something that feels good for your body[…]somehow you feel like you are strengthening it or repairing it…stretching…getting my shoulder blades more flexible"
>
> [R10/33.00-34.00]

> "The most stark moment is when you're at the thermal beach at Nauthólsvík (in Reykjavík), and if you've been swimming in the sea…[and] go into the very shallow hot-tub that's there…your skin 'burns', you're tingling, you have maybe knuckles and [in] your joints you have pain, particularly when you're, yeah, in your toes and fingers"
>
> [R10/80.00]

Through Bjarki the geothermal is enlivened and enables and is enabled by an embodied process of geothermal absorption and dissipation. This process is, in his own words, performative:

> "… in certain pools very short walking distance [to the hot pot], but, and it's always a kind of performance moment I think, because you know that there are [other] people…you know people are watching… there are social dynamics...it's a performative moment…there is a social performative moment"
>
> [R10/78.00-80.00]

Further, for Bjarki, the geothermal is sensed and embodied not just through his sense of touch, but through smell and taste: "I don't smell, I've lost the, my friends from aboard come here, they talk about the sulphur smell" [R10/17.00] he recounts, referring to the sulphuric aromas which can accompany the geothermal water:

> "I think you, it's like it's [a sulphuric smell] something, erm, that's quite integrated into your experience of the [geothermal] water. So, for sure, you realise sometimes that it has a particular smell, but you can't contextualise it as a bad smell, or at least I never did that. But it wasn't until maybe, friends of mine from abroad, or family from abroad, would comment on the [smell of the] water"
>
> [R10/19.00]

In addition to this, Bjarki also comments on how the geothermal affects his walking. When out and about and given the choice between a melted area of pavement or a non-melted area of pavement he chooses "[t]he melted side, for sure" [R10/55.00], favouring additional friction and assured steps over slipping and sliding. In choosing to walk on melted areas of pavement, Bjarki is articulating the geothermal through his body, the practice of walking. His steps and more confident, his rhythm is more precise – the geothermal is present in his bodily certainty. This is in stark contrast to the cautious steps and erratic slippage the body undertakes and experiences – feels – in areas without geothermal melt.

Kópavogur

Hákon relays a similar embodied experience of the geothermal to Bjarki. Having lived in Kópavogur since the 1960's an interesting element of his experience of the geothermal is wrapped up in the process of building his own home. As a result, his consciousness of geothermal heat and lava within the landscape is that more fronted in his mind – he was there when pipes were connected, when geothermal water first flowed into his home and pieces of lava were picked up and stacked to form garden walls. Indeed, as Hákon recalls, one of the ways in which the feeling of the geothermal is articulated is through heating his home – and it is underlined as a distinct experience in contrast with other heating methods, for example, when he used to use oil: "There [was] always an oil smell in the house, and er, the smoke goes up and you can feel it in the air…it's just like being…in the city with many cars…you can't compare how much easier our lives are, much nicer with [geothermal] heating" [R9/12.00]. Using oil required a different set of actions and routines to the geothermal – the ease and affordability of the latter leading to a ubiquity of heat which was previously unthinkable. "During the night we put off the [oil based] heating, but there is no difference between day and night now" [R9/13.00]. Further, Hákon illustrates the differences with washing - "Before, if you wanted to fill the bath tub, erm, there, the [oil based] central heating, it, could hardly produce enough [hot] water, and it's no problem now [with geothermal water]" [R9/14.00]. So there is a difference in the rhythms of the everyday lifeworld, the practice of dwelling and the bodily movements required between oil and the geothermal. As Hákon later comments, "the hot water, it adds so much to the quality of life…in Spain and Italy they have the sun, we have hot water" [R9/38.00]. Hákon's body is warmed differently and moves differently with the geothermal – and the way in which heat is an embodied act has changed. The embodied practice or performance of lighting oil has given way to the occasional turning of knobs on radiators: "The heat in here now is 20 degrees (celsius)…just last month, we bought a new apparatus…it is in the basement…there is a tap [control] on every radiator, and you have to fix [alter] that, but you needn't do that now…it fixes automatically" [R9/19.00-20.00].

Of course, for Hákon too, the geothermal has become a regular part of his life through Kópavogur's swimming pools. "I go for the gym, for training, it's in the basement of the pool, and afterwards I go to the swimming pool" [R9/24.00] he tells me, as we sit in his home, warm and dry (in contrast to the

wet cold weather outside). As with many other pool users, he notes the value of warming his body. "It's 42 degrees [celsius], and I like that…because you, it's important for your muscles, it's no use sitting in a cold pot…it's useless to sit on a cold pot" [R9/28.00]. Again, in going to the swimming pool and engaging with geothermal water, the geothermal is overtly embodied. This embodiment is both a subconscious and conscious process commanded by the human mind - to seek out warmth, and also an incidental outcome of proximity to geothermal heat – buildings happen to be warmed already. In each case the body is party to processes of geothermal heat transfer and dissipation. Embodied practices articulate the geothermal, but the geothermal also articulates the body: "you have to stay in until you are warmed through, but erm, if you stay too long you get a bit dizzy" [R9/30.00]. There is a ritual and a temporal exactness to Hákon (and others') bodily engagement with the geothermal: "You only take 5 minutes in the pot, it would be too much to stay in…it's very relaxing, if you have[…]sore muscles you get rid of [the pain]…if you stay too long…you don't feel well…there is a limit" [R9/29.00].

Whilst Bjarki is based in Miðborg where lava is much less a part of the visible landscape, in Kópavogur it starts to appear more obviously. It is interesting to note that the discussion with Bjarki does not really engage lava, but with Hákon it begins to enter the conversation. Most notable, in building his own home, Hákon was aware of pieces of lava within the landscape which had to be moved to enable construction:

> "It was here, there's a wall here…those stones were already in the garden…there is a huge stone there…this is thousands of years old…I don't exactly know how this lava is under Reykjavík…gradually we made these surroundings here, it took some years…It was mostly me who did it, I finished [it] about 1972 or so…I wanted the surroundings to be nice, I just wanted to have a fine garden…the rocks were there and the thing was to put them in the right place"
>
> [R9/48.00-29.00]

Crucially, this clearing of lava is another way in which the geothermal is tied up with embodied practices. Although not one of heating, or warming, there is an echo of past geothermal energies in

the rock and a connection between human consciousness and the geophysical. "I didn't have money to go on holidays and I was not married, so it was just, just a way to use the, the time" [R9/50.00], notes Hákon, reflecting on making garden walls out of bits of lava (Fig. 6.11). Just like taking a walk in the woods or going for a swim in the sea – a way in which nature is complicated with human dwelling. "I think it is very inspiring to live in a country like Iceland, you can use, or get close, to nature and you have…the whole country is alive…of course you have earthquakes all over the place, but it's not everywhere you have volcanoes" [R9/52.00]. For Hákon, the geothermal is very much a part of his daily practices and rhythms of living. Through his body he directly connects with the geothermal, making his lifeworld: "I think it's nicer, because it's more natural…maybe because I did it myself" [R9/58.00] he offers in a concluding comment about walls made from lava.



Fig. 6.11. The wall made out of smaller lava rocks outside Hákon's home, the driveway is clear of snow and ice due to under-pavement geothermal heating.

Towards the end of our conversation, Hákon, also like Bjarki, reflects upon how the geothermal is felt through more than just touch. The geothermal does not only make itself consciously present through warmed skin and the grappling of rocks. The geothermal is also present for Hákon through a sulphuric smell and taste, but although he knows it's there, he has gotten used to it – it has become

subtle through familiarity: "…I do not notice the [sulphur] smell anymore, I know it is there but I never notice it… it's different from place to place" [R9/63.00]. It is still highly noticeable to him if tasted though, "The only thing is coffee…I never make coffee with [geothermal] water from the taps here, [I] always heat fresh water…[with] coffee and tea… a [sulphuric] taste [spoils it]" [R9/64.00].

6.3| Rock & fire

Garðabær

Not only are resident's experiences of the geothermal embodied, they are affective. Geothermal water and a lava infused landscape resonate distinct elemental atmospheres. They resonate in the process of surfacing and transforming surfaces, though and with objects and bodies. The geothermal has an affective capacity which is experienced and amplified through geothermal urban dwelling. Fjóla has lived in her home in Garðabær for 11 years. As with Bjarki and Hákon, her everyday routines are embedded into the geothermal:

> "I always start with [a] hot shower. Er, [a] normal day, usually, usually I get my younger girl to school, go to work, from, I work from 0815-1600, sometimes longer…I go to [the] gym, and, er, especially when the, the, day starts to get longer, then I try to use my neighbourhood. I go hiking, er, cycling, running or something. There are a lot of places I can, you know, just a few steps and I'm in the nature. I use that a lot from spring to fall…it's, er, clear's your mind, to go 'out' of the city. So, I, I do that a lot".
>
> [R20/02.00-03.00]

What is notable about Fjóla's routine is that she makes a specific note of being "in the nature". Here, she is referring to the lava landscape that extends beyond her garden and across and through her neighbourhood (Fig. 6.12). This landscape is something which is held in high regard by Fjóla: "You know, after getting this place to live, it's er, I think it's fantastic to have this [lava landscape], I think I'm very lucky" [R20/48.00]. What is rather special for Fjóla is that the lava extends from her garden,

so for her, everyday life really is an overt and immersive geothermal experience. Geothermal water flows through her home keeping her warm, whilst outside her window past geothermal energies dominate the landscape and reverberate in the present; sensed not through heat but visually and in walking the landscape. "This [lava] is what keeps me here" Fjóla comments, "I think it's important for me…It's very important to have this [lava], I often spend time just looking at the nature…from the inside, and in summer I sit outside…just sit here and watch it, watch the weather and the landscape" [R20/53.00-54.00].



Fig. 6.12. Fjóla's living room. The lava field can be seen through the window in the garden and extending beyond, accessed through a door to the left. Under the window, a radiator keeps the room warm thanks to geothermally heated water.

Fjóla explains how the lava landscape is a part of her lifeworld through specific seasonal activities:

> "I often go here [out into the garden] in summer time and my, er, daughter and her friends play, like to play there, and also, with this little water, they also like to play there…there is no path here, but a lot of people walk here, along, and also with the lava… there is a new path that opened last summer that goes into the lava, it's very beautiful… you can walk around" [R20/51.00].

For Fjóla, navigating the lava landscape is also tied into memories of growing up in the area:

> "I have a very good view here, I see the mountains on, on Reykjanes peninsular, I can see that, and I can see Helgafell…these old volcanoes, and er, I have a very good view of a, of a landscape view, which I like a lot, it's like staying, you know, it's not like staying in a city I think, and er, I er…I grew up in this town, and I have lot of memories, from here, there were no buildings here…we went hiking one day through this lava, it took the whole day, when I was younger, but er, today, there are a lot of new houses, but still, they keep this [lava], this is like a, er, this area here they will not build in this part, and er, there are a lot of people that use this place for hiking or you know, walking…there's a path going through the lava here, it's nice to take a walk after working inside all day"
>
> [R20/44.00]



Fig. 6.13. A path moments away from Fjóla's home meanders through an undeveloped part of the lava field.

Indeed, for Fjóla – and many other residents, there is a curious difference between navigating the lava and navigating a pavement (Fig. 6.13). Lava juts, is uneven and undulates. It has a degree of

unpredictability and a visual form that mirrors the frenetic energy present in its formation. A path, however, is smooth, even and easily navigable: "You can just walk all over…I, I just hike wherever… you know, you have to look where you step down [on lava] so you don't fall or something like that, but otherwise it's, here, it's not a problem, but you can find lava where it's very difficult to walk, you know, further [out] in[to] the country[side]" [R20/53.00]. For Fjóla the lava is a critical, integral and valuable part of her experience of living in Garðabær. "I think it would be completely different [without the lava landscape]" she notes, "because when I go to other houses even though they are nice, the houses, you know, I feel er, I feel you know, like [I'm in] a box or something…because it's so open [here] it's totally different…I usually don't pay attention to the traffic of the street, things like that" [R20/65.00-66.00]. As her body traverses the lava landscape, it enacts a performance with past geothermal energy. This is an embodied performance with geothermal echoes; the lava still possess a geopower, an affective elementality, that continues to be a part of the geothermal urban assemblage articulated through bodies moving across a lava field's surface.

Hafnarfjörður

Auður's home in the old town area of Hafnarfjörður is similar to Fjóla's in that lava is a highly visible and felt aspect of the neighbourhood and this everyday life. "I never gave it a thought, the lava, the surroundings or anything, it was a practical thing to do" [R21/02.00] Auður comments on her initial reasons for moving into her home with her family. However, it was not long before Auður and her family came to really appreciate the lava and the distinct and unique landscape within which they live. Without lava, Auður reflects, "our garden would lose it's charm" [R21/41.00] (Fig. 6.14 & Fig. 6.15).



Fig. 6.14. Lava frames and dominates Auður's home in the old town area of Hafnarfjörður.

For Auður, the lava has a value not just in its visual and haptic qualities, but for practical and pragmatic reasons. Whilst it adds a special and natural distinctiveness to the landscape in which her home and garden sits, it has also been utilised to provide shelter and shade:

> "I didn't think it was that, you know, particularly great or bad or good or anything, but you know, when you start living here you just, yeah, you start to see it, it's a bit special…When you see it in the garden, in the summer time here, it, it's always never very windy, because of the big lava…gives us shelter from the wind" R21 3500



Fig. 6.15. The lava is utilised as a part of the garden.

This may seen like a novel idea, to use the lava as a shield from the wind, but all around Hafnarfjörður's old town there are examples of architectures meeting with lava and making use of the rock. This might be in a beam resting against lava to provide support to a structure, or in lava being used in the centre of a roundabout – a visual block which reduces speed. Further, the lava is often made useful by human addition – in Auður's garden this is the case with a set of steps built into the lava, providing access to it's peak. This opened up a small a more secluded part of the garden, otherwise not readily accessible, "[t]he lava part is mostly wild…I can show you, there is a special part where I used to grow vegetables" [R21/36.00]

For Auður, as with Fjóla, the lava is also tied to broader memories of the landscape: "you hear stories, I use to play here as a child, this is where my mum and her friends would sunbathe" she tells me. "The children from [the] school would be playing over there [on the lava]…a lot of people have memories [tied within the lava]" [R21/43.00]. The knot of memories, embodied experiences of lava landscapes and the affective atmospheres of geothermal place are present in her accounts – as have been with others. "You always need to be awake and alert" Auður tells me about walking or climbing through the lava – again highlighting the unique bodily processes and movements related to and

which articulate a lava landscape. "[Y]ou don't want to…you know you are stepping where it's safe to step, but again, you don't want to destroy moss, you want to be careful with the plants, all the things growing there" [R21/ 5.100] she continues, with an awareness of how precious the landscape is:

> "The town in the lava…it started out like that because the lava was here and people wanted to build houses and they didn't have equipment to, to move the lava away, so they had to build between you know, and make houses adjust to the landscape, which is nice we think now…but if they had the equipment and the techniques… probably they would have destroyed more parts [of the lava], because it's practical, very practical as well, you always have to go, you know, around things"
>
> [R21/44.00]

The lava within Hafnarfjörður undeniably resonates with an affective quality that is missing in areas without it. As bodies articulate the geothermal by traversing lava fields, the innate elementality tied to former geothermal heat impacts the body via its affective capacities; the elemental resonates and is subconsciously and consciously registered. The difference in the experience of walking through non-lava or non-geothermal landscapes (the part of Hafnarfjörður where the lava fields were dug-up, or the area of Vellir without people, homes, and geothermal heat) underlines this difference. In places where the geothermal is engaged with by humans bodies, the geologic agency within a geothermal urban assemblage is foregrounded. Auður's reflections of how parts of her neighbourhood differ based on the presence – or not – of lava underlines this, and highlights lava's distinct role within a geothermal urban landscape.

> "And of course, there are larger areas where [there is] more lava…if you look at an [and aerial] map, you can see you know, bits of areas, you know, you wouldn't know if you just drive this street, this street and this street, but it, in the centre, there is a whole part with lava. I think that's nice, you know, and you have it past, you know, going through…you wouldn't want to have it all filled with houses, I think it's nice… The geothermal, you know,

> we don't think about that, how we use the hot water…but er, the lava, of course, I mean, we do think about it, you know…it's unique and nice""
>
> [R21/52.00-54.00]

Vellir

In coming back to Vellir, the role of lava within the geothermal everyday lifeworld is further highlighted through Olga's routines. She had lived in the area for three years, and the neighbourhood is connected by pathways that snake through a lava field (Fig. 6.16). Bodies walk, run, and cycle through and sometimes they pause, play, and climb over the lava. The lava is a striking and a dominant feature. When it is not sensed and engaged tactically through the skin, it is observed with the eyes, a distinct natural backdrop for the urban everyday. For Olga living amongst the lava, this visual engagement is an everyday occurrence – more than that is it almost constant, as soon as you walk outside, or look outside the window, it is there. "There's not always houses and pavements – [it's] house, pavement, lava…it makes it more, you know, different" [R13/44.00] Olga tells me as we talk in her apartment in Vellir, "It [lava] does so much for the place, it's not just pavements and roads, it's also lava…it makes it more fun to live in" [R13/44.00]. For Olga, lava really is everywhere:

> "When I walk to the swimming pool there's lava on both sides, and, just when I walk around this area here, Vellir, there's lava all around…it's all kinds, you know, up's and down's, everywhere, so when I walk around and I get out of the places with the houses and pavements…then I'm constantly walking up, down, up, down"
>
> [R13/39.00]

Not only is lava everywhere, but it fixes in her mind - "the lava [can be] so high, you know…sometimes when I walk around this neighbourhood I feel like I'm in [a] video Bjork made, 'Jóga'…and I think of that" [R13/38.00]. The Jóga music video is notable for its use of images of lava fields and graphics

depicting geothermal and geophysical activity[42]: "I don't walk through and don't think of it [the lava] at all, I always look around and think it's beautiful" [R13/48.00].



Fig. 6.16. Pathways through the lava connect Vellir.

The lava field can become a playground (Fig. 6.17), experienced through fun and play. Even the local school has lava within its grounds, "It's just by the pavement, you can walk by the pavement in front of the house and step on the lava…they use it in the school, [as] part of the environment in the school, the kids are playing [on] the lava" [R13/37.00]. Olga explains further that "[s]ometimes, when I'm picking up my girl [from school], she is outside playing [on the lava] and I walk up to find her" [R13/45.00]. Of course, being on lava is different to being on tarmac:

> "Walking over the lava you have to watch every step…if they have made a path between…[you can] walk safely and look around…it's a different feeling from walking on the

[42] Further, the lyrics provoke, reference, and reflect the power and energy of the geophysical: "Emotional landscapes, They puzzle me, The riddle gets solved, And you push me up to, This state of emergency, How beautiful to be! State of emergency, Is where I want to be".

lava and watching every step, it's also fun walking on the lava, you're more connected to the lava itself"

[R13/53.00]



Fig. 6.17. Lava forms a surface for the everyday in Vellir, especially public spaces, like this children's play area.

Not that this need to take more care with how you travel over the landscape worries Olga or others. "It is not dangerous for the kids" she tells me "I haven't heard of any accident's from the parents here…they probably, also, make sure there is no, where the kids are playing around the houses, there is nowhere they can get hurt" [R13/42.00]. Indeed, the lava provides a surface for different forms of every day life. The geothermal in surfacing and then cooling eventually has a direct connection with human bodies, impacting modes of inhabitation that characterise a distinct form of geothermal urbanism. For Olga, the lava is her neighbourhood, and she feels connected to nature having it so visible and accessible. This connection is undeniably volcanic, geothermal: "It's a nice neighbourhood, it's so close to the nature, it's so close to the energy" [R13/41.00]. One of her

concluding comments underlines how integral a lava landscape is to her everyday life, and how it resonates with energy even though the geothermal heat itself has long dissipated:

> "If you would take the lava away…I would feel, there was…less energy in the area, because I think the lava has energy…the nature gives me energy, when I walk around the lava, and [I'm] in the nature it gives me energy"
>
> [R13/52.00-53.00].

6.4| Geothermal affects

Cosiness

> "The feeling would be, I think, homely and cosy…to come home to a cold house would be, you know, the worst thing I think"
>
> [R21/18.00]

What is critical to the process of dwelling within Reykjavík is the existence of warmth, it being geothermal warmth that provides comfort against a predominantly cold climate. Cosiness is key and warmth is central to this cosiness. "A wide range of material things and consumption practices are part of…cosiness" notes (Bille 2014, p.60). A cosiness which is "a feeling of contentment…a state of physical and mental well-being" (Chappells & Shove 2004, p.3). When Reykjavík´s residents talk about the geothermal they don´t talk about forces and structures, they don't even talk about heat unless prompted. They do however, talk about comfort, about warmth and cosiness; and most critically as warmth as cosiness and cosiness as warmth. Further, the key implication is that within geothermal urbanism, this warmth is beneficial. If we are to draw here upon Bille, who focused on the Danish word "hygge", we can see how a specific atmosphere formed from specific lighting arrangements in apartments in Copenhagen:

> "[C]omfort, coziness, cheerfulness, and friendliness. To be in a situation characterized by hygge is to be in a state of pleasant well- being and security, with a relaxed frame of mind and open enjoyment of the immediate situation in all its small pleasures."
>
> (Hansen 1976, p.54, *cited in* Bille 2014, p.60)

Reykjavík abounds with atmospheres of comfort tied up within its geothermospheres and geothermal warmth. Swimmers emerge from hot-pots, families spend evenings in warmed rooms, workers travel heated pathways, children learn in thermally infused schools. To reconnect with DeLanda (2006), the geothermal is both material and expressive: it has the physical qualities of warmth wrapped up in the forces and structures of the geothermal urban assemblage and also affective qualities, wrapped up in warmth, cosiness. The geothermal urban, then, is not just a geosociotechnical process or a hybridized commodity – it is an affective assemblage. Moreover, it is possible to map the interplay between the materialities of the geothermal urban, the world-making and world-maintaining aspects of geothermal urban dwelling, and the affective atmospheres which resonate and animate.

If resilient geothermospheres are the purpose of geothermal urbanism, cosiness is the experiential result of the successful achievement of that goal. It is the process of dwelling that enables the geothermal urban assemblage to take form and in turn creates cosiness. Indeed, cosiness becomes the desired domestic atmosphere:

> "I want to keep it warm and cosy, especially winter time, when it's dark outside and so on, you know, it's shelter, so you want to feel good inside...I think…if I didn't have the heating I would have some other kind of, er…a fireplace, something like that. But, er, yeah I think I would find something else then to keep it nice and warm, but, er, in this place… when we moved here we changed the system [placement of radiators]…I think we, er, maybe cut too many ovens [radiators] away… in winter time, er, it's hard for me to say exactly… we got new windows and everything just last spring, so er…this winter I've felt more comfortable than before"
>
> [R20/19.00-21.00]

Of course, these atmospheres of cosiness are not constant and do not appear everywhere, although they may be multiple and commonplace. Indeed they mirror and shadow geothermospheres, undoubtedly tied to geothermospheres of warmth and geothermal energy dissipating into, through, and out of various structures and objects. Further, cosiness is contingent on a sense of discomfort, these atmospheres of warmth are identified by not being atmospheres of cold:

> "It's nice to come inside when it's warm…I think so…it's always nice to come home, you know, it's just that feeling I think, nice to be inside, especially when it, and also think it's very nice to stay here when it's not[…]nice weather outside, when it's warm [inside] and you can watch the, like now, a bit of snow outside, and it's very nice to stay inside, and you, then, er, I, you know, sometimes think of how lucky I am…enjoy the heat but be able to stay inside and see the nature outside"
>
> [R20/23.00-24.00]

> "I like to be in the cold air, hot water…when the weather is not so nice, and you feel, you know it feels so good to be outside and you don't want to go walking…you go swimming, it's the perfect thing to do, you're outside but you're still cosy"
>
> [R21/27.00]

Primarily of course, these atmospheres of cosiness are felt, sensed and enacted via human bodies: negotiating switches and taps, absorbing and transferring geothermal warmth. Whilst the geothermal may be seen as steam, it is also smelt: "of course you notice it yes, but it doesn't annoy me…it's not like you know, when we would go to Geysir, you know, hot springs" [R21/10.00]; and it is sometimes tasted: "You can taste it…it has some taste, I don't think it's horrible…I could just drink [it]" [R21/33.00]. However, it is the haptic quality which is most overt: "You know, if it's cold outside and you come inside, it's, you feel, er, you feel better, you feel more, how to describe it, you feel more relaxed when you come inside, you know, somehow like that" [R20/24.00]. This haptic quality has an immediate, conscious effect which stems from the preconscious prevailing affective atmospheres of a geothermal urban assemblage: "I feel [my] muscles are, it's good for relaxing, just,

you know, feeling nice" [R21/31.00]. Moreover, these affective atmospheres result in inflecting the movement of bodies, the thoughts they make and actions they take. Geothermal dwelling, as much as it is enabled by the geothermal, further enables the geothermal to present. Changes to routines, placements, enhancements, and alternations to homes illustrate the "practical engagement with their surroundings", to connect back to (Ingold 2000b, p.186), of geothermal dwelling within a geothermal urban assemblage:

> "I don't want to be cold, and I, you know, we are often barefoot and you know, people you know, will be wrapped in towels, you know, going to [the] shower or wherever, yes, but sometimes you know, it's, yes, it's just cosy, to be able to walk on bare feet"
>
> [R21/16.00]

> "Heated floors in the parts where we, you know…the kitchen over there, and the bathroom over there, and where you entered, and all the downstairs, and you know a big part of the garden has underground [heating]…We do, actually, we have, we had these pipes installed in our back, er, part, er, entrance, but there's something wrong with it, so you know, it's been snowy and, you know very icy there this whole winter, you just don't go there, just use this door"
>
> [R21/20.00-21.00]

Geothermal urban dwelling is infused with distinct affective atmospheres of cosiness and discomfort, warmth and coldness. The immediacy of it all is enwrapped and animated by human bodies, mobile and immobile, consciously and unconsciously a part of the geothermal urban assemblage. Routines, daily life, the everyday lifeworld of the Reykjavík Capital Area, are experienced and crafted via an emergent elementality which gathers and transforms in and through bodies, or as Ong notes:

> "If we stop to consider that our daily routine is punctuated by what are essentially acts of homeostasis – adjusting the temperature of our baths or showers, making sure our food and drinks are of the right temperature, putting on or taking off pieces of clothing, and so on –

> we will begin to realize just how important it is to get the pleasure and satisfaction of these actions right in order for us to function properly. It is no accident that heat dominates the discipline of architecture"
>
> (Ong 2012, p.16)

Affective afterlives

What is perhaps so interesting about the affective atmospheres which abound the geothermal urban assemblage is their immediacy. Geothermal heat is drawn from the ground, into pipes, on to skin, and it is felt instantaneously. Indeed, it is so immediate it impacts before it is felt, "the mystery of the missing half-second" (Massumi 1995, p.89), an illustration of "[t]hat it is within the precognitive that the dynamic concept of 'affect' can be found…considered transpersonal, fluid and mobile" (Pile 2010, p.8). This thinking implies that the affective atmospheres of Reykjavik's geothermal urban assemblage are exclusively made up of present events: that is the geothermal energy of the current moment. This is not so, however. As illustrated by the distinct lava landscape and its role in the perception and experience of an immediate geothermal lifeworld, the geothermal urban assemblage is as much about past events echoing into the present and present events echoing into the future. This underlines how the geothermal urban assemblage and its related affective atmospheres are on-going, emergent (especially through human bodies), and processual.

Indeed, this highlights further the capacity and role of humans, through dwelling, in animating, articulating and resonating the affective elementality of the geothermal urban. The affective atmospheres of the geothermal urban are part of present urban life and the resonance of past geophysical phenomena: "the experience of space and place is always haunted by a noncoincident spatio-temporality in which past and future participate simultaneously and in unpredictable ways" (McCormack 2010b, p.642). The geothermal urban assemblage is made of present current geothermal engagements, but also the reverberation of past events – eruptions from hundreds and thousands of years ago, felt and experienced in the presence by a hand on a piece of cooled lava. Not only this, but these echoes possess and manifest the potentiality of the ongoing future of the geothermal urban assemblage: "the affective resonance of past events…a distributed field of affective

materials" (Ibid., p.650). The concept of an affective afterlife and of a distributed field of affective materials is all the more interesting given the prominence of dissipation within geothermal urbanism. Geothermal heat transfers away and the affective capacities of the geothermal urban assemblage disperse into futures exposing a fluctuating field of materiality. The affective afterlives of past geothermal energy are articulated through human bodies into the present geothermal urban assemblage, which in its present affective elementality has the potential to resonate beyond the current moment into futures assemblages and bodies.

Elemental bodies

In turning to the ways in which humans inhabit, and bodies navigate, a geothermal urban assemblage two valuable observations can be summarised. The first, is that bodies articulate the elemental qualities and the affective capacities of the geothermal within Reykjavík. They do this through acts such as swimming in geothernally heated water, breathing in geothernally heated air, and tactically engaging geothernal landscapes. This is a crucial and critical part of the geothermal urban assemblage which would not take shape without the embodiment of the geothermal. The geothermal, with its distinct frenetic energetic qualities, consists of and displays a distinct form of geologic agency, a *geothermal* geopower (Grosz 2008; Clark & Yusoff 2017a). This geothermal geopower comprises of a specific elementality which is non-carbon and is tied to the kinetic and radioactive energy of the Earth's formation. This geothermal elementality is both affective "in the midst of inbetween-ness: in the capacities to act and be acted upon" (Seigworth & Gregg 2009, p.1), and creates elemental atmospheres, "an environmental milieu within which different forms of life are immersed, enveloped and take shape" (McCormack 2016, p.4). Without the embodiment of this affective elementality the geothermal is not articulated through acts of geothermal urbanism and the geothermal urban assemblage fails to form. This is highlighted by the uninhabited part of Vellir, and in starker contrast, the non-urban parts of Iceland. The human body is the instrument through which infrastructures and architectures are built and the geothermal urban is enacted, the instrument through which the geosociotechnical process unfolds.

Secondly, human bodies become geothermally elemental in their articulation of geothermal elementality. This isn't to suggest that bodies do not already contain *an* elementality, but that their elementality *becomes distinctly geothermally affected and inflected* by virtue of their presence within geothermospheres and a geothermal urban assemblage. Indeed, in doing so they form an elemental hybrid (Whatmore 2002), existing as elemental cyborgs (Haraway 1991). This elemental hybridity conceptualises the way in which the geothermal and the human body are not just combined, but form geothermal human hybrids constitutive of the geothermal urban assemblage. Further, this hybridity can be viewed as "a characteristic of the elements themselves" (Jones 2009, p.301). That is, a characteristic of human bodies and geothermal energy within the geothermal urban assemblage; but also of elementality. The distinct affective elementality of the geothermal is a hybridising force (as observed through its transformative and transformed capacities) and is hybridised in its embodied actualisation. This can be connected back to the "boundary breakdowns" Haraway notes in conceputlaising the cyborg, especially the idea that "there was always the spectre of the ghost in the machine" (1991, pp.193–194). In the case of the geothermal urban, the human body is not just techno-human. It is caught up within the geosociotechnical and thus is geo-techno-human; a geological, geothermal cyborg. As Grosz et al. have noted, "the human is always in excess of itself…[i]f thinking, inventing, acting, are characteristics of…material forces, then the human is composed of intensities that are themselves not human, or not only human" (Grosz et al. 2017, p.143). The 'ghost in the machine' is the affective elementality of the geothermal.

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This chapter has focused in from the infrastructures and architectures of the geothermal urban into the bodies of its inhabitants. Through this embodied gaze, the geothermal urban assemblage has been further understood as a continual production through the concept of dwelling, and as consisting of and generating distinct affective atmospheres tied to geophysical processes and geothermal heat. These affective atmospheres have been outlined through the everyday elementality of the geothermal and go towards explaining the felt distinctiveness of place perceived and experienced throughout the Reykjavík Capital Area. In addition, this chapter has not only added to the spatial perspectives of the geothermal urban, but has also unravelled its temporal dimensions. The

geothermal urban assemblage forms across distance, depth, and time. Past events infiltrate and inflect the present, current occurrences resonate with visceral immediacy, and each dissipates into a future underpinned by the geothermal. Geothermal affect should be understood as embroiled with an embodied geothermal elementality, present through surfacing and forming atmospheres.

- vignette vi -



Garðabær.
Performing on lava.
Geometrics and frenetics.
Inhabitation.



7| Conclusion

"Assemblages are throbbing collectives with uneven topographies…a turbulent field in which various and variable materialities collide, congeal, morph, and disintegrate"
- Bennett, in Kahn 2012, pp.44–45

"There they are tied together, and there they come undone."
- Derrida 1999, p.41

.

The geothermal has been traced through moments of human exploration, extraction, distribution, and utilisation; through infrastructures, architectures, and bodies. In doing so, it has been approached as contextual, contingent, and relational. This has led to new observations and understandings of what has been identified as geothermal urbanism; fundamental to and indivisible from the geothermal urban. This chapter draws together these new ideas towards a summary of the ways in which the distinct places, shaped by human processes and proximity to geothermal heat, have been better understood. Three research questions developed from gaps in existing literature directed this new thinking: How might the relation between the geothermal and the urban be understood?; How is the elementality of the geothermal articulated through infrastructures, architectures, and bodies?; What kinds of practices and places are characteristic of geothermal urbanism? These questions facilitated a detailed engagement with geothermal urban lifeworlds through which the elementality of the geothermal was made more explicit. Critically reflecting on the experience and lived realties of geothermal urban life, existing concepts have been applied and developed to better comprehended geothermal urbanism.

Firstly, through a tracing of geothermal energy as it is extracted from the ground and facilitated within Reykjavík´s city-wide heating system, the geothermal urban was approached by turning to its inherent forces and structures. These forces have been identified as pressure, heat, and flow; innate to the geothermal and complicated by human intervention. Structures are identified as the instruments through which the geothermal urban forms; both physical and social, infrastructural and organisational, Earthy and human. These essential geothermal urban components are formative of a material assemblage which comes into being through the process of surfacing. As 'surfacing',

geothermal urbanism is revealed as a *geo*sociotechnical process, underlining a geothermal geopower. Turning to surfacing has also revealed how the geothermal urban is transformative: of geothermal heat as it leaves its subterranean domain, and of surfaces which this heat transfers through and into.

Secondly, in turning to specific envelopes of geothermal heat, geothermospheres have been identified. Geothermospheres are understood to form from the gathering of geothermal warmth within architectures, to produce distinct thermal spaces that enable human dwelling. As such, geothermospheres have been understood as in flux, contingent and relational; and as forming distinct atmospheres. As 'atmospheric', the geothermal urban is experienced as gathered, elementally infused, and palpable.

Thirdly, the geothermal urban has been understood by focusing in on the human body, revealing distinct forms of embodied dwelling, characterised by and characteristic of geothermal urbanism. Embodied, the geothermal urban assemblage has been further understood as continually produced through the process and practice of dwelling. This bodily turn has also highlighted the affective capacities of the geothermal urban, which are central to the formation of its distinct palpable atmospheres. As 'affective', the geothermal urban is understood as embroiled with an embodied geothermal elementality, tracking the processual and the atmospheric.

These findings open up the geothermal urban, and have gone some way towards answering the focused research questions regarding geothermal urban relations, geothermal geopower, and geothermal urbanism. In the following sections, these questions are revisited, situating and affirming the original contributions to knowledge made through this thesis. A reflective exercise, it provides the critical space to underline how knowledge regarding the geothermal urban has been progressed, and the opportunity to map out the implications of these findings in the context of non-carbon elementality within the changing circumstances of the Anthropocene. Highlighted first is the necessary revision of the geothermal field from an exclusively chthonic entity, extended beyond the subterranean into the urban and understood as atmospheric and affective. Second, it is underlined how a discrete geothermal form of geopower is identifiable, advancing a non-carbon geologic agency,

intersecting the geological and the affective. Third, geothermal urbanism is established as requiring a geosociotechnical ontology, an elemental epistemology, and characterised by distinct practices and places of embodied dwelling. This chapter then reviews the inevitable limitations of the work undertaken so far, and closes the thesis with suggested directions for further research.

7.1| An expanded geothermal 'field'

Fields abound in geography. They may be tangible (Franzson et al. 2005; Paterson 2009), ethereal (Wylie 2005; Anderson 2009; Ingold 2010; Graham 2013), conceptual (Smith 1987), actual, virtual, real, possible (Deleuze 1988a; Deleuze 2004). They consist of forces, dynamisms and potencies. They possess and form spacetimes, materialities, and politics. They have an ability to be robust and weak, transient and enduring. Fields may focus in on phenomena or be broad containers. Fields are often porous. Fields may overlap and may be multiple. Fields have manifold definitions and interpretations. Most commonly, they are understood as the sites of specific phenomena as tied to a distinguishable spacetime: the geothermal field. Beyond this they are contested as places of encounter (fieldworking the geothermal field, inhabiting the geothermal field); and as conceptual frames (a geothermal - *is it a* - field?). Rather than the geothermal field defined by geophysics, geology and volcanology as restricted to heat within the ground, this research has revealed something more complicated, less easily defined, and dynamic. A geothermal field understood wherein the subterranean emerges and overlaps with the above-ground; embroiling heat, surfaces, and flows; and which is not merely physical but atmospheric and affective. Experienced as processual ("the dual meaning of 'formation' as process and outcome" - Clark & Yusoff 2017, p.6) there are key implications for the geothermal field: that is must be re-understood as emergent, atmospheric, affective; and that the geothermal and the geothermal field are synonymous. This requires a significant revision of the concept of the geothermal field, drawing it out of a strictly buried and bounded geophysical syntax, into being a subject of new materialist and relational discourse.

The emergent geothermal field

A key aspect of a revised geothermal field is the expanded sense of, and understanding of, its emergence. The geothermal field's origins are undeniably tied to the subterranean, however the geothermal field does not emerge solely as an underground locus of its heat. The geothermal field also surfaces, extending beyond the ground into the air, rocks, pumps, pipes, and bodies. This is geothermal "materiality in a relational, emergent sense" (Coole & Frost 2010, p.29) which is gathered and forms assemblages in excess of itself; extending the geothermal field into complex formations. The geothermal field must be viewed as gathered (Ingold 2000b; Ingold 2010; Gissen 2009) and assembled (Graham & Marvin 2001; DeLanda 2006), and gathering and assembling. By emerging within and through the city the geothermal field, geothermal urbanism, exists as part of a geosociotechnical assemblage. This processual emergence has also been observed as transformative, as it impacts upon and alters what it comes into contact with; be it infrastructures, architectures, or bodies.

In questioning the definition of the 'field' within geography and science studies, Greenhough draws upon Ingold (1995), connecting with dwelling, and the notion that a field is inhabited: "fields are paradoxical spaces neither fully defined by (as in cartography) nor definitive of (through the practice of field research) geographical knowledge…[i]nstead fields are negotiated, contingent, *situated knowledges* (Haraway 1996)" (Greenhough 2006, p.224, *emphasis in original*). With Iceland also the locus of Greenhough's research, there is a focus on how field sites are "constantly being re-defined and contested" (Ibid., p.226). This is mirrored in a revised conceptualisation of the geothermal field. By emerging into and through the urban, the geothermal field is also inhabited and in permanent flux. Through this thinking, geothermal urbanism can be viewed as the geothermal field enacted, articulated through infrastructures, buildings, and bodies. The geothermal field emerges in a process of constant production, "the 'field' may be understood as a region which is always in the process of being constructed" (Driver 2000, p.267).

The atmospheric and affective geothermal field

The geothermal field, as defined by the earth sciences, has always possessed distinct capacities and qualities: intense heat, high pressures, being of the underground. The geothermal field, understood as surfacing and surfaced, builds on and alters this. Most crucially, the geothermal field becomes understood as place forming. As it occupies infrastructures, buildings, and bodies it extends into and forms atmospheres. These atmospheres are affective, impacting the other materialities which come into contract with them: "[t]hey 'envelop' and thus press on a society 'from all sides' with a certain force" (Anderson 2009, p.78). The geothermal field as atmospheric forms in the context of a broader materiality, it is "not an inert context but a force field in which people find themselves" (Stewart 2011, p.452). The geothermal field is bounded and articulated by urban phenomena and is in part reliant upon it to form.

The geothermal field as an affective atmosphere is observed in the geothermospheres, envelopes of heat, that manifest throughout Reykjavík. Space envelopes (Lefebvre's 1974, p.329; Kaika 2005, p.4) of warmth, that are filled with the elemental affects of the geothermal and lead to sensations of cosiness (and potentially discomfort). This quality of the geothermal field also calls upon Sloterdijk's 'bubbles', 'globes' and 'foams', and underlines the human roles in articulating the geothermal field: "If coexistence engenders existence, human beings are 'creatures who inhabited and administered a sphere' (SII 47)" (Couture 2016, p.55; citing Sloterdijk 2014). The geothermal field must be extended far from the subterranean, above the surface and through buildings and bodies into broad geosociotechnical assemblages in which its affective elementality is articulated and resonates. For Isaacs et al. (1989, cited in Beer 1996, p.x) a field is "a region in which a body experiences a force as the result of the presence of some other body or bodies…thus a method of representing the way in which bodies are able to influence each other". In that sense, the geothermal field must be understood as embodied. Embodied within the Earth, embodied within objects, and embodied within organic living things formative of an affective atmospherics.

7.2| Understanding a geothermal geopower

The geothermal is a fundamental component of Reykjavík, with its affective field articulated via the city, forming distinct geothermal urban place. This affective capacity has been revealed via two conceptual pathways; geopower and the elemental. Bennett's (2004; 2010) thing-power which paves the agency of the non-human leads to Grosz's (2008) geopower, which highlights the capacities of inherent earthly forces. Elementality (following McCormack 2016) is concerned with states of matter, their properties, and as palpable milieu. Both geopower and elementality can be understood as affective - concerned with precognitive forces that 'arise[…]in the midst of inbetween-ness: in the capacities to act and be acted upon" (Seigworth & Gregg 2009, p.1). As affective, the distinctive geothermal atmospheres that shape the geothermal urban can be understood as elemental: the elemental is itself a form of geopower "the geological, inhuman and preindividuated forces that subtend and provoke organic life" (Grosz et al. 2017, p.134). Further, the geothermal has its very own elementality; and in possessing its own form of elementality, the geothermal must also be understood as having its own form of geopower. The implications of an observed *geothermal* geopower are twofold; firstly that it requires a distinct geothermal elementality, secondly that this possesses a distinct geothermal agency.

Geothermal elementality

A geothermal elementality is distinct in a number of ways. First there is its core characteristic, its thermal quality, a specific and different form of fire, better understood as heat, which is not formed of combustion but gravity, kinetics, and radioactive decay. Second, there is its interplay with the other elements. Fire is doused by direct contact with a large volume of water, and the elements cancel each other out as heat is smothered and the ability for combustion is removed. Water does not douse the geothermal, however. Geothermal heat radiates into water and rather than its source being disposed, its energy is continually transported. This is similar to the way in which fire requires air to expand and transport its heat. The geothermal makes use of this conduit too, but unlike fire, can survive without it. Fire too has a sensitive relationship with rock; its heat can conduct through it, but fire must exist *on* it. The geothermal radiates and conducts through rock, but can also exist *within and under* it – partly due to its relationship with the other elements. Third, the elementality of the

geothermal imbues it with unique qualities and capacities. These properties derive from its distinct heat, and Earthly structures and forces, to form - when surfaced and in assemblage with other materialities - especially elementally inflected places.

A separate key observation concerns geothermal elementality becoming embodied on distinctively geothermal terms. That the affective elemental force of geothermal heat warms human bodies (which in turn impact the geothermal through infrastructures, architects, and objects) is an "intimate geography" (Rodaway 1994, p.x). Geothermal elementality contains its own qualities, intensities, and capacities which affect in different ways the broader urban assemblage. The human body affected by geothermal elementality becomes in part geothermal. This is to enact, geologically and geophysically, "boundary breakdowns" (Haraway 1991, pp.193–194) from which geothermal-cyborgs emerge. For Haraway "there was always the spectre of the ghost in the machine", and in the context of the geothermal urban, in which the sociotechnical is geosociotechnical, the cyborg is underlined as geo-cyborgian. Geothermal cyborgs are "hybrids that support the construction of multiple materialities and space-times" (Graham & Marvin 2001, p.185). Elemental thinking is valuable as it permits a tracking of the geological and the affective as processual. Elementality enables a positioning of geopower as the top layer of a taxonomy of geologic agency. There are different types of, and configurations of, elementality, which shape distinct versions of geopower; one of which is a geothermal geopower.

Geothermal agency

As geopower has agency, and geopower takes different forms, an elementally distinct geothermal geopower must be understood in terms of its own geothermal geologic agency. This agency is geologic, as the geothermal is entirely of the inner Earth, molten and solid rock within or beneath the crust. What makes it particularly unique, is that a geothermal geopower is non-carbon[43], and thus a geothermal elementality extends the 'geosocial' put forward by Clark & Yusoff (2014, p.224) from the carbon-centric into the realms of the non-carbon. Clark & Yusof have undertaken what they term a

[43] The Earth's core is approximately 88-92% Iron (Fe) and Nickel (Ni), the remainder consisting of light elements, of which Carbon (C) it thought to contribute ~1% at upper concentrations (Wood et al. 2013).

"combustion-centred analysis" (2014, p.206), but as has already been noted, the geothermal possesses its own non-combustion and non-carbon form of fire: kinetic and radiative heat. A geothermal agency is as unique as the geothermal energy which possesses it and extends it into broader assemblages. In the sense that the geothermal is emergent, transformative, and transient; so is its agency.

A geothermal agency is also important to note in the context of the geothermal urban given "human agency is best conceived itself as the outcome or effect of a certain configuration of human and non-human forces" (Bennett, cited in: Kahn 2012, p.52). Within the context of the Anthropocene, a geothermal agency sheds lights on non-carbon human practices. As Yusoff notes, "The epochal identity of the Anthropos is subtended by the geologic power of fossil fuels" (2016, p.6), but this does not mean that the Anthropocene does not exist amongst other non-carbon geologic powers. Whilst the combustion of carbon has dominated the Anthropocene, it is important to note other 'pyro' practices (developing Pyne 1994; 1997a; 1997b; 2001) and human-geological assemblages which occur simultaneously. Indeed, with efforts within climate science and contemporary global politics to reduce the amount of carbon in the Earth's atmosphere with turns to alternative energies (wind, solar, tidal, nuclear, geothermal); non-carbon practices, elementality, and agency, present as a significant circumvention of dominant problematic carbon actors.

7.3| Geothermal urbanism

Through observing, engaging, and discussing human processes proximate to geothermal heat, a number of concepts and terms have been applied, enhanced, and created, forming a new vocabulary with which to understand the geothermal urban. The geothermal urban itself is a new term, which, crudely bringing together the geothermal and the urban, has been deployed as a way of denoting urban places embroiled with geothermal heat. Geothermal urbanism has been similarly utilised as a new term to mean the activity, practices, of the geothermal urban: its performance, emergence, and embodiment. In many respects. the geothermal urban and geothermal urbanism are synonyms (much like the geothermal field and the geothermal); with the former applied more frequently in the

context of a specific locus, and the latter to processual emergent phenomena. Geothermal urbanism is a particularly valuable concept, as it is the door which opens up understandings of how and why the geothermal urban comes into assemblage. As a new concept which describes a novel phenomena, geothermal urbanism has been unfolded and conceptualised in such a way, that it is important to consider its contributions to an advanced ontology, epistemology, and identification of the practices and places, of human processes proximate to geothermal heat.

Conceptualising geothermal urbanism

Conceptually, geothermal urbanism has come into focus in such a way that it requires a geosociotechnical ontology and an elemental epistemology. The former develops the 'sociotechnical processes' identified by Graham & Marvin (2001, p.10) by necessarily acknowledging and adding conceptually the geologic agency underlined by Clark & Yusoff (2014) via Bennett (2004; 2010) and Grosz (2008). By acknowledging the human component critical to geothermal urbanism, a geosociotechnical ontology also absorbs the "technonatural" (Swyngedouw 1999) but offers a conceptualisation that attends to a new materialist agenda by turning more to the material than the symbolic. This new materialist approach in outlining an ontology of geothermal urbanism is important, as it allows for a required relational understanding, assemblage thinking, which brings the geological towards the foreground. Furthermore, it draws out a geologic, geothermal, agency.

The elementality of the geothermal urban has been highlighted as an essential aspect of its assembly, and it is elementally that it is possible to know the geothermal urban. Geothermal geopower has been identified as forming of and possessing an elemental affective capacity, and the geothermal urban is known through its lived and embodied experience of the elemental: "When we inhabit something, it is no longer an object for us but becomes part of us and pervades our relation to other objects in the world" (Dreyfus 1991, p.45). To know the geothermal urban requires inhabitation, dwelling (Heidegger 1927; 1996; Ingold 2011), within it. Thus we inhabit the geothermal field to come to know it, affected by (and affecting) the pre-cognitive (Pile 2010, p.8) agency - elementality - of the geothermal. This elementality is "affect [a]s the capacity of interaction that is akin to a natural force of emergence" (Thrift 2004a, p.64).

Practices and places of geothermal urbanism

We come to sense and understand the geothermal urban through cosiness and warmth. With geothermal heat a part of homeostasis, we are reminded again that *humans are geological* (Clark 2015). Thus, geothermal urbanism is character forming, via distinct practices of embodied dwelling which resonates with and articulates geothermal geopower and elementality. These practices form geothermospheres, atmospheres where geothermal elementality becomes palpable, identifiable as geothermal urban place. This sense of place resonates with a distinct sense of geothermal intensities, capacities, and qualities: heat, pressure, transformed and transformational surfaces. In looking back to Ingólfstorg within central Reykjavík, with its basalt columns, geothermal steam, electric lights, shops, cars, and people; the square is clearly the enactment of geothermal urbanism - its character of place, *genius loci* (Norberg-Schulz 1980; Jivén & Larkham 2003), awash with the properties of geothermal elemental capacities and geosociotechnical qualities.

Geothermal urbanism can be understood through specific places and practices. This research has come to know the geothermal through the homes, offices, swimming pools, cafes, cultural spaces, public buildings, open public spaces, and infrastructures of Reykjavík. In essence, the places of the geothermal urban are urban places, but shaped by a distinct and specific relationship with an otherwise non-urban elementality. These are places of processual assemblage (Deleuze & Guattari 1987; DeLanda 2006; Farías & Bender 2010) and geologic agency. Further, these places are formed by the embodiment of geothermal heat. This research has also come to know the geothermal through daily thermal practices: washing, cleaning, swimming, melting snow and ice, and getting warm. Again, these practices are mirrored across all urban spaces, yet within Reykjavík they are specifically inflected and facilitated by the geothermal. Combined, these places and practices consist of subtle and overt differences with the non-geothermal urban. Buildings have slightly different plumbing and bodies are kept warm by ubiquitous background heat, pumping stations are spotted down town and swimming is a major social activity. This is a palpable lived distinct geography of the geothermal urban.

7.4| Broadening elemental concerns

The research has significantly opened up and expanded understandings of the distinct places shaped by human processes and proximity to geothermal heat. In doing so, it has been bounded by the practical limitations of a need to focus: in the field, conceptually, and analytically. However, these limitations are valuable as they underline how the geothermal urban might be better understood, and further advanced, through additional research. Further, this new understanding of geothermal urbanism can be applied beyond its current context, with the potential to contribute more broadly to thought on energy, the urban, and the elemental.

Advancing geothermal urbanism

Four specific pathways for further expanding understandings of the geothermal urban can be put forward. Firstly, this study has been necessarily limited to one site and context. The geothermal urban will form a number of different assemblages based on its relational context. Thus, this research may be broadened to explore the geothermal urban as experienced elsewhere, such as in New Zealand, Italy, Japan, The USA, The Philippines, Indonesia, Kenya, China, Australia or the UAE. Such further research would provide additional accounts of geothermal urbanism, and feed in from the perspectives of other geophysical and socio-economic perspectives. Further empirical engagements may reveal geothermal urbanism to be varied, especially in the face of less stable social and technological infrastructures. Within alternative contexts the key elemental aspects of geothermal urban phenomena, especially related to the affective atmospheres of geothermal heat, will remain core to understanding the geothermal urban experience. Future studies focused on alternative case studies may proceed with a similar methodology to this research, designed to attune to the geothermal through becoming geothermal, with a more-than-representational concern for exploring the elementality of such phenomena. Further geothermal chats, with other residents and professions, would be an opportunity to enrich understanding of geothermal urban lives. In addition to this, further performative and creative engagements may broaden the apprehending of the affective elementality of geothermal urban worlds. In doing so, it would be advisable to push head with a full commitment to the potential of videographic and creative field materials; following digital

elementality into research outputs that extend beyond the textual and make further use of a geothermal urban kinetics and cinematics.

Secondly, this research highlighted the vital role of human bodies within geothermal urban assemblages. There is a vast expanse of additional research on the human body that could be engaged to develop a much more detailed understanding of the elemental geothermal body. In particular, Clark & Yusoff's forthcoming work on 'queer fire' (2017b) might provide an interesting avenue from which to explore further, the thermal body. Further studies might for example, be concerned with the geothermal urban experience focused more on different bodily engagements. They might proceed from the conceptualisation of geothermal urbanism outlined within this research, and turn to explore in more detail how it is articulated through specific varied embodiments. This may enhance understandings of the geocyborg, as engagements with the geothermal urban world occur through a spectrum of human experiences. The questions posed might concern any differences between engagements with geothermal heat, and any variance in the sensing of elemental intensities with regards to sight, mobility, age and gender. Such an approach may underline universal aspects of the geothermal urban experience, whilst having further regard for the complexity and individuality of geosociotechnical assemblages tied to unique bodies.

Thirdly, the notion of a geothermal geopower might be applied to other geological formations and energy sources, and in doing so might reveal more about the geothermal. The term is open to further development, and may be better defined in a study which opens up and explores in much greater depth the potential for various forms of geopower. Fourthly, there is an opportunity to think about the ways in which the geothermal urban in new materialist, elementally affective, relational terms, may inform built environment professions and practice. Graham and Marvin suggest urban design, policy, and planning "practices must emphasise *relations and processes* rather than objects and forms" (Graham & Marvin 2001, p.414, *emphasis in original*), this is a clear call to re-approach the planning, design, and maintenance of geothermal and energy infrastructures; perhaps with a policy concern for geothermal subnatures (Gissen 2009).

Beyond geothermal urbanism

As well as expanding further knowledge of the geothermal urban and geothermal urbanism, it is possible to map some directions in which the findings of this research speak to other research trajectories, and answers to wider questions about how life on Earth is shape by elemental forces. First, elemental understandings of the geothermal can open up the elemental understandings of other forms of energy, perhaps expanding work on water (Gandy 2014; Kaika 2005) and air (Adey 2014; Engelmann 2015) by thinking through the affective elementality of the hydrological, tidal, and wind. Vannini & Taggart, for example, take note from their work on off-grid living, that understanding other energy practices can "provide us with important evidence on the many ways in which habitation skills may radiate out to the rest of the world and therefore on the large potential to 're-engineer' affect (Latham and McCormack, 2004; Thrift, 2004) and thus enact sustainable living" (2013, p.80). This connects with a second trajectory: that there is scope for an affective elemental understanding of geothermal energy to speak to work on politics and ethics (see: McCormack 2003; Thrift 2004; Popke 2009) concerned with other forms of energy, the urban more broadly, and other configurations of affective capacities. This is valuable given the "[s]ystematic engineering of affect has become central to the political life of European-American cities" (Thrift 2004a, p.57). The affective elementality of a phenomena as ubiquitous as energy, heat, or the very ground on which life occurs, might reshape how we understand the politics and ethics of practices like town planning, architecture, and urban design. These may benefit from expanding their engagements with the more-than-human and further reframe "the social organisation of thermal energy" (Shove et al. 2014, pp.120–122).

Third, this research can direct attempts to open up and understand the non-human agency of other phenomena. Much as the geothermal field has been expanded to incorporate an affective elementality and atmospheric quality, this thinking might apply to other concepts which have not yet been thought about in relational, new materialist, vitalist terms. As "[t]he intensity of affective atmospheres, and their socio-spatial capacities, moves our focus from the bounded human subject towards more porous forms of urban sentience" (Gandy 2017, p.369), this porosity might expand beyond the urban to suggest elemental, affective, and atmospheric considerations of multiple other

processes, assemblages, and hybrids. Fourth, this research has developed and built upon a number of concepts drawing from urban theory, most notably the sociotechnical, cyborg, and dwelling; enhancing each through an elemental optics that draws explicitly on the capacities and qualities of the geothermal. This research has differed from existing work by pursuing the elementality of the geologic, which broadens the more-than-human concerns of urban geographies. This regard for the geothermal can expand work such as Gandy's focus on the hydrological by underlining a thermal dimension to water's "oscillation between different cultural and material realms" (2014, p.224), supporting Squire's observation that "elementality seeps into both the fundamental life sustaining act of drinking water and the sovereign act of establishing national infrastructure" (2016, pp.553–554). Alternatively, as previously noted Gissen comments that "subnatures often operate within social and architectural frameworks, more so than technical or geological ones" (2009, p.213); a position questioned by a geosociotechnical understanding of geothermal urbanism. As such, further work may turn back to these and similar concepts and consider how they might be applied to other geo-urban phenomena, broadening their definition and application to as-yet fully explored urban realms. This in-turn reverberates to broader interests in space, nature, materiality, and everyday human lives. The existing body of urban theory stands not to be replaced by more-than-human and elemental inflections, but to facilitate ever-more detailed explorations and understandings of human-non-human phenomena that underpins geographic debate.

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This research has explored the distinct places shaped by human processes and their proximity to geothermal heat. In doing so, it has outlined geothermal urbanism as an emergent assemblage of elementally affective materialities, which form distinct atmospheres – geothermospheres – of geothermal urban place. Critical to this is the idea of surfacing, as geothermal energy leaves the ground and enters infrastructures, architectures, and bodies. Revealed and understood as processual, the concepts of the geothermal field and the sociotechnical have been advanced to both be understood as geosociotechnical assemblages. Further, the elemental capacities and qualities, inherent to geothermal energy, have been understood as a geothermal version of geopower; positioning geopower as the top layer of a taxonomy of geologic agency and open to multiple sub-

variants. Finally, this research has presented a conceptual vocabulary with which to express new and more detailed understandings of geothermal energy within the city, outlining the distinct practices and places that typify geothermal urbanism. These new understandings of the geothermal urban also speak more broadly to the task and value of attending to non-human agency and elementality across other Earthly phenomena. Be it the geothermal urban forming and emerging, the advance of the next theoretical steps, or a piece of geothermal steam dissipating from public art in the centre of Reykjavík: "It doesn't mean to come to a finish…[i]t wants to spread out into too many possible scenes with too many real links between them" (Stewart 2007, p.128).

- vignette vii -



Bodies leave buildings.



Envelopes of geothermal heat.



Warmed.



Travel the landscape.



Concrete, lava, asphalt, basalt columns.



Infused.



Dissipate.



Time-lapse.



Hallgrímskirkja.



Ingólfstorg.





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List of Interviewees[44]

Name:	Date:	Location:	Node:	ID:	Interview No:
Haflidi Halldorsson	06/02/15	Vesterbaerlaug	Swimming Pool Manager	P1	1
Bjarki Kjartansson	09/02/15	Laugardalslaug	Swimming Pool Manager	P2	2
Matthildur	09/02/15	Reynimelur	Urban Planner/Designer/Resident	P3	3
Anna	10/02/15	Mosfellsbaer	Resident	R1	4
Adalsteinn Hrafnkelsson	11/02/15	Asvallalaug	Swimming Pool Manager	P4	5
Birgir Ingason	11/02/15	Asvallalaug	Swimming Pool Manager	P5	5
Sigurdur Steinthorsson	12/02/15	OR	Geothermal Engineer	P6	6
Harald	13/02/15	MidBorg	Resident	R2	7
Gudni Axelsson	16/02/15	ISOR	Geosurveyor	P7	8
Ulfa	17/02/15	Stofan	Resident	R3	9
Vilhjalmur	18/02/15	Vesterbaerlaug	Swimming Pool Employee	P8	10
Ingunn	18/02/15	Vesterbaerlaug	Swimming Pool Employee	P9	10
Arinbjorn Vilhjalmsson	19/02/15	Gardabaer	Urban Planner/Designer	P10	11
Þorsteinn	19/02/15	Bólstaðarhlíð	Resident	R4	12
Hannah	22/02/15	Hateigsvegur	Resident	R5	13
Agusta	23/02/15	Kleppsvegur	Resident	R6	14
Birgir Grí	23/02/15	Brekkutangi	Resident	R7	15
Heiða	24/02/15	Vesterbær	Resident	R8	16
Páll Sveinsson	24/02/15	OR	Geothermal Engineer	P11	17
Hilmar Friðþorsson	24/02/15	OR	Geothermal Engineer	P12	17
Hermann Sigurður Jónsson	25/02/15	Sundhöllin	Swimming Pool Manager	P13	18
Hákon	25/02/15	Kópavogur	Resident	R9	19
Bjarki Jóhannesson	26/02/15	Hafnarfjörður	Urban Planner/Designer	P14	20
Berglind Guðmundsdóttir	26/02/15	Hafnarfjörður	Urban Planner/Designer	P15	20
Dagur Jónssons	26/02/15	Hafnarfjörður	Urban Planner/Designer	P16	20
Guðmundur Óli Gunnarsson	26/02/15	OR	Geothermal Engineer	P17	21
Bjarki	27/02/15	Holtsgata	Resident	R10	22
Halldóra Hreggviðsdóttir	02/03/15	Alta	Urban Planner/Designer	P18	23
Kristin Rafnsson	03/03/15	Hellisheði	Geothermal Engineer	P19	24
Ragna Karlsdóttir	04/03/15	ÍSOR	Geosurveyor	P20	25
Olafur	05/03/15	Mosfellsbær	Resident	R11	26
Svava	05/03/15	Mosfellsbær	Resident	R11	26
Birna A	05/03/15	Hallgrimskirkja	Resident	R12	27
Haraldur Sigurðsson	10/03/15	Reykjavík City Council	Urban Planner/Designer	P21	28
Pétur Ármannsson	12/03/15	Minjastofnun	Architect	P22	29
Olga	13/03/15	Berjavellir	Resident	R13	30
Birna B	13/03/15	Strandgata	Resident	R14	31

[44] All interview participants gave permission to be named in the thesis and any resulting publications via a signed research participation consent form ('yfirlýsing um samþykki til þátttöku í rannsókn'), approved through Oxford University's ethics process. Those contributing in a professional capacity will be fully named, whilst those contributing in a personal capacity will only be identified via their first names. One exception is the architect Olafur Sigurðsson, whom is fully named to credit him as the architect of 'Arcadia' and to fully acknowledge the copy of an original site-plan kindly provided for inclusion in the research.

Name:	Date:	Location:	Node:	ID:	Interview No:
Ingvar	16/03/15	Smáíbúðahverfi	Resident	R15	32
Eyrún	17/03/15	Grafarvogslaug	Swimmer	R17	33
Ragnar	17/03/15	Grafarvogslaug	Swimmer	R18	34
Dóra	17/03/15	Grafarvogslaug	Swimmer	R19	35
Fjóla	18/03/15	Gardabær	Resident	R20	36
Stefán	18/03/15	The Pearl	Business Owner	P23	37
Kristján Guðlaugsson	19/03/15	Landspítali	Hospital Manager	P24	38
Auður	20/03/15	Hafnarfjörður	Resident	R21	39
Sigurður	23/03/15	Kópavogskirkja	Resident	R22	40
Finnur Birgisson	24/03/15	Mosfellsbær	Urban Planner/Designer	P25	41
Tómas Gíslason	24/03/15	Mosfellsbær	Urban Planner/Designer	P26	41
Steve Christer	26/03/15	Studio Granda	Architect	P27	42
Helgi Birgisson	27/03/15	Askja	Plumber	P28	43

Geo-Urban Attunements: Reykjavík, convection, *genius loci*
[ESRC grant ref: ES/J500112/1 (DTC 2012 Geography & the Environment)]

RESEARCH PARTICIPATION CONSENT FORM

Yfirlýsing um samþykki til þátttöku í rannsókn

This form enables persons to give: i) consent for their participation in the above research project; and ii) permission for use of their contributions in the final written thesis and other forms of disseminating findings.

This Research Participation Consent Form has two parts:
• Information Sheet (to share information about the study with you)
• Certificate of Informed Consent (for signatures if you choose to participate)

You will be given a copy of the full form.

PART 1 – INFORMATION SHEET

Research Title[†]*: Geo-Urban Attunements: Reykjavík, convection, genius loci*
Institution*: University of Oxford*
ESRC grant ref*: ES/J500112/1 (DTC 2012 Geography & the Environment]*
Researcher*: Matthew Ross Shepherd (matthew.shepherd@ouce.ox.ac.uk)*

About

This research project is being undertaken as a part of the requirements of a doctoral degree (DPhil) in Geography & The Environment. It is focused on Reykjavík, Southwest Iceland and is investigating how nearby geophysical processes are embedded within everyday urban life.

This project is interested in better understanding how senses of 'place' within urban spaces are connected with the natural environment. In addition to observations and 'participation', abstract/artistic methods will be used to attempt to apprehend 'place' (or '*genius loci*'), and draw out connections between the city, everyday life and nature.

Participation

Participation in the study may be for as little as a few minutes or, if agreed, much longer. Participants may withdraw at any time. Participation may result in the (co-)creation of a variety of materials (such as dance, music, film, photography, writing, painting – and so on – there are no restrictions) and/or a recorded interview. As such, participants may be filmed, photographed or recorded (audio/written accounts). Unfortunately, participants cannot be reimbursed for taking part.

PART 2 – CERTIFICATE OF IMFORMED CONSENT

Research Title[†]*: Geo-Urban Attunements: Reykjavík, convection, genius loci*
Institution*: University of Oxford*
ESRC grant ref*: ES/J500112/1 (DTC 2012 Geography & the Environment]*

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study and give permission for the use of my contribution(s) in the final written thesis and other forms of disseminating findings.

Please choose one option:

☐ *I consent to be identified and/or named in the thesis and other materials.*

☐ *I would like to review being identified and/or named in the thesis and other materials, before publication, with the possibility of asking for anonymity (please provide email address below* – if contact cannot be made, contributions will be made anonymous).*

☐ *I would like all my contributions to be anonymous (default).*

Name:
_____

Signature:
_____

Date: _____/_____/_____
(day) (month) (year)

☐ Please tick if you would like to receive a copy of the completed thesis and provide an email address to which it can be sent below:

*Email:
_____

[†] This is the research project's working title at the time of fieldwork - the final title may alter.

Experiment/Session Ref: (leave blank - office use)