Giving up fire for air

How social practices impact the transition from coal stoves to electric heaters in Ulaanbaatar, Mongolia

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Abstract

In Ulaanbaatar, Mongolia, air pollution continues to be a serious health issue despite past measures. A large part of the air pollution originates from the coal stoves frequently used in the gers (Mongolian nomadic circular tents) in which many residents live. Air pollution could be reduced by transitioning to electric heaters, but adoption rates remain low, attributed to limited grid capacity and affordability issues. However, an under-investigated aspect is the role that social heating practices play in this energy transition. Through fieldwork performed in Ulaanbaatar in April and May of 2023, it was investigated how social practices around heating need to be adjusted when transitioning to electric heating. Six social practices were identified that form reasons to keep using a coal stove, including better thermal performance, its role in the preparation of typical Mongolian dishes, and in spiritual practices around fire. Households that had adopted electric heaters find them convenient, especially important for their children's health, but frequently still kept their coal stove for other uses. Finally, recommendations to accelerate the adoption of electric heaters are provided, including to consider electric heaters as a supplement to coal stoves, rather than a complete replacement; to prioritize insulation improvements; and to make use of two social networks to spread benefits of and information regarding electric heating: family and Facebook.

Keywords: air pollution, heating transition, social practices, ger areas, Ulaanbaatar.

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Glossary

ger A circular tent made of wood and felt, originally used by Mongolian nomads.

baishin Term for a detached house in ger areas in Ulaanbaatar.

esgii Felt sheets that form the insulation for a ger.

berzent A tarpaulin cover, placed around the felt sheets of a ger, to protect them from water.

toono A circular skylight in the centre of the roof of a ger, letting light in and providing a passage for the chimney.

khoroo Administrative sub-district in Ulaanbaatar.

khashaa A fenced-off plot of land of 0.7 hectares granted to a resident, on which often multiple households live.

Tsaagan Sar Lunar new year, the most important holiday of Mongolia.

uuts A large sheep-based dish that is prepared for *Tsaagan Sar*, which is typically prepared on a coal stove due to its size.

Contents

1 Introduction

Ulaanbaatar, the capital city of Mongolia, is one of the cities with highest air pollution globally (Guttikunda et al., 2013), especially during the winter, when hundreds of thousands of households light their coal stoves to keep their homes warm. Although levels of $PM_{2.5}$, a primary air pollutant, has decreased from 2017-2019 to 2020, they still exceeded the 2021 air pollution guidelines of the World Health Organization by a factor of nearly 12 in the winter of 2020, averaging $59 \pm 29 \mu g/m^3$ in January, February, November, and December of that year (Ariunsaikhan et al., 2023; World Health Organization, 2021).

Air pollution has a significant impact on the health and daily life of Ulaanbaatar's residents. Bad air quality is associated with negative health effects, especially for children, pregnant women, and the elderly (Manisalidis et al., 2020). Every winter, thousands of Ulaanbaatar residents are diagnosed with severe respiratory diseases, including pneumonia and asthma (Koo et al., 2022; Miller, 2018). Pregnant women are especially impacted: Enkhmaa et al., 2014 found a strong correlation between ambient air pollution and spontaneous abortion. In a 2017 survey, residents indicated that air pollution affected them most in the following ways: having more difficulty in breathing; worrying about the living environment for children; irritation of the eyes, nose, and throat; and poor visibility (Koo et al., 2022).

While some part of the air pollution in Ulaanbaatar comes from its aged vehicle fleet, and some from the coal-based combined heat- and power-plants located in the city, the majority – at least in a large part of the city – is caused by the prevalence of individual coal stoves, which are primarily used by residents to heat their homes (Soyol-Erdene et al., 2021).

A report from 2018 estimated that 55% of total heated residential space in Ulaanbaatar consisted of detached houses called *baishins* (35%) and circular tents called *gers* (20%), which are traditional Mongolian nomadic dwellings (Stryi-Hipp et al., 2018). A 2017 household survey found that 92% of households in parts of the city called ger areas used coal stoves for heating (Cardascia et al., 2022). This means that about half of Ulaanbaatar's residential space is heated by coal stoves.

In order to reduce air pollution caused by current heating solutions, individual coal-based heaters need to be phased out. While the city is planning to construct new apartment buildings connected to the central heating system, it is inevitable that in the foreseeable future, a significant portion of the residential building stock will still consist of detached houses and gers that will not be connected to the central heating system (Stryi-Hipp et al., 2018).

Therefore, in order to improve air quality, it will be necessary to individually heat these dwellings using a heating solution that causes less air pollution. There are several alternatives. Gas-powered heaters are cleaner than coal-powered heaters, but Mongolia does not have easy access to gas (Cardascia et al., 2022), leaving electrically powered heating as a potential alternative. While some studies have shown that electric heaters are effective at heating gers, and access to electricity is high in ger areas, few households have adopted electric heaters (Braham et al., 2022; Pillarisetti et al., 2019; U. U. Purev & Hagishima, 2022).

Why is it challenging for households to switch from a coal stove to an electric heater as their main source of heat? According to previous studies on this transition, there are two major barriers: a high investment and operational cost of electric heaters (compared to coal stoves), and insufficient electricity supply on the current grid (Cardascia et al., 2022). It appears that progress is being made in electric grid development, as the Asian Development Bank has granted a $100 million USD loan to the Government of Mongolia for the construction of a

large-scale new battery storage system (Bank, 2022; Cardascia et al., 2022). In addition, the government implemented an electricity subsidy in 2017, providing free electricity at night in the winter months (TOG, 2017).

However, technological and economical aspects are not the only aspects that should be considered in an issue regarding energy use. In energy-related studies, physical–technical–economic models of consumption are commonly used, but these fall short of reality in two aspects (Kowsari & Zerriffi, 2011). Technical models, which focus on theoretical energy flows through the system, do not fully recognize that humans are active users of energy technology, and thus do not account for the impact of humans' interactions with the technology. Economic models, which consider energy users as rational agents who make choices based on economic factors, fail to address the large body of empirical evidence that humans do not make purely rational decisions when considering the economic and technical aspects of energy technology. A heavy focus on economic theories detracts attention from the social and psychological factors that are part of decisions in energy consumption (Stern, 1986).

The concept of social practices aptly encapsulates these social and psychological factors that are overlooked in physical–technical–economic models. Social practices provide a comprehensive framework that accounts for daily routines, behaviour, and socio-cultural norms and meanings, while technology and economics are considered in terms of how they influence these behaviours and meanings. The lens of social practice theory offers a more realistic and nuanced view of how energy consumption is integrated into people's lives, and how energy choices are influenced by wider social interactions. Rather than viewing energy consumption and energy choices related to heating as occurring independently, focusing at social practices around heating allows us to consider them as decisions that are interconnected with day-to-day activities and habits. Hence, examining social practices can be a valuable approach to gaining insightful understanding into energy consumption and transitions.

Unfortunately, there is a limited amount of internationally published research that deeply examines heating in the ger areas of Ulaanbaatar, Mongolia, with a focus on social practices, rather than technological (Pillarisetti et al., 2019) or economical (Cardascia et al., 2022; Jun, 2021) issues. This thesis aims to add on to the existing research by investigating current social heating practices common among coal-stove households, and how certain households are adjusting their social practices during their adoption of heating innovations. In doing so, this research aims to make meaningful recommendations, specific to the context of ger areas in Ulaanbaatar, that could potentially accelerate the transition from coal stoves to electric heaters by fully considering the social practices around heating in this context.

To guide this research, the following main research question has been formulated: *How are ger households in Ulaanbaatar's ger areas adapting their social heating practices in the transition from coal stoves to innovative heating solutions?*

This question delineates the research in several ways. First, innovative heating solutions refer to two innovations: electric heating and improved insulation. Second, while *baishins* in ger areas are frequently powered by coal stoves as well, the scope of this research is limited to gers. Third, technical and economical limitations are only considered to the degree in which they form part of social heating practices, on which lies the primary focus.

To answer this research question, the following sub-questions are considered:

1. What are the common social heating practices among coal-stove households in Ulaanbaatar's ger areas?

2. What heating innovations are being adopted by ger area households, as influenced by governmental and non-governmental actors in the socio-political landscape?

3. How are households changing their social practices to accommodate these adopted heating innovations?

By focusing on these questions, this thesis seeks to create a comprehensive understanding of the intersections between social practices, energy consumption, and technological innovation, contributing to a broader and deeper understanding of the energy transition from coal-based heating to electric heating in Mongolia's urban ger areas.
The issue of air pollution from coal stoves in Ulaanbaatar presents a unique case study of the metropolitan challenge of urban energy, which is faced by many cities globally. The effects of Ulaanbaatar's current energy system, heavily reliant on coal, are not only harmful to the climate due to CO_2 emissions, but also have a serious effect on residents' health locally. Furthermore, the nomadic history of Mongolian society in an extremely cold climate climate has given rise to a unique context in which coal stoves are being used, leading to novel challenges when transitioning to alternative heating sources. Nevertheless, as over 2.8 billion people rely primarily on coal and traditional biomass for cooking and heating (Amegah & Jaakkola, 2016), insights gained from the issue at hand could inform strategies of reducing harmful effects of coal worldwide.
This thesis is structured as follows. Section 2 provides an overview of heating systems in gers, together with various air pollution measures that have impacted these heating systems, and previous research related to residential heating in Mongolia is discussed. In Section 3, relevant theoretical frameworks of social practices and energy transition models are described. The methodologies used, namely ger visits, interviews, and a focus group discussion, are outlined in Section 4. Section 5 contains the results, describing the current social heating practices and heating innovations. Finally, in Sections 6 and 7, recommendations are formulated based on these results, and the research is concluded with an outlook on the future.

2 An overview of ger heating and heating-related air pollution measures in Ulaanbaatar

In this Section, an overview is provided of the heating systems that are common in gers in Ulaanbaatar. While ger heating is a traditional practice that has evolved over a large period of time, in the course of the past decade, as concerns regarding air pollution grew, several anti-air pollution measures have been implemented that have impacted the heating setup in gers. Specifically, improved coal stoves were distributed at subsidized rates, and raw coal was banned, with the government subsidizing refined coal briquettes as a cleaner alternative. In personal communications held during this research, it was mentioned that open-hearth braziers have historically been used in Mongolia, and that cattle and horse dung are still a common fuel source in the countryside. In gers in Ulaanbaatar, however, you will most likely encounter a coal stove fueled by refined coal briquettes. Two types of coal stove designs are common: the traditional Mongolian coal stove, and an improved coal stove that was introduced from 2011 onward (Cardascia et al., 2022).

Figure 1: A traditional coal stove standing next to an electric heater, in the ger of a household participating in an electrification project of the startup URECA. To the left of the stove, there is a metal container with the wood used to light the coal stove, and gloves to handle the coal and wood. (April 2023)

Figure 2: An improved coal stove for sale at the *Narantuul* market in Ulaanbaatar. (April 2023)

The traditional coal stove is essentially a metal black box on four legs (Figure 1). It is low and wide, and has a flat top surface with several metal rings that can be removed to create space for a cooking pot to be placed. It is typically placed in the centre of the ger, in order to ensure that the ger is evenly heated, and has a chimney which leads up and out the *toono*, a circular skylight in the centre of the roof. In the front, there is a small door with three small holes, which is opened in order to insert and manage the coal and wood. To light the stove, some wood is first placed and lit in the chamber, on top of which, coal is poured. If needed, coal can be added continuously (Social Impact, 2014).

In an attempt to address the issue of air pollution, the Government of Mongolia, with assistance from multiple international donor organizations, has implemented various initiatives to combat air pollution since 2010. These initiatives include electricity subsidization for heating, a ban on raw coal, as well as the implementation of programmes promoting improved, cleaner stoves (Jun, 2021). These improved coal stoves were primarily distributed in two similar programmes, in 2011 and 2013, in collaboration with different international organizations.

In 2011, the government, in collaboration with the Millenium Challenge Corporation (MCC), distributed over 100,000 improved coal stoves to households living in ger areas in Ulaanbaatar (Cardascia et al., 2022; Jun, 2021). The improved stoves were imported from Turkey, and sold at a price of ₮25,400 MNT ($7.31 USD[1], representing a subsidy of 93% Jargalsaikhan, 2018. And in 2013, 40,000 additional improved stoves were distributed to households in Ulaanbaatar as part of the World Bank Clean Air Project Cardascia et al., 2022; Jun, 2021. The total used funding for these projects was $40.4 million USD and 7.4 million XDR (Special Drawing Rights, equivalent to nearly $10 million USD), respectively UNDP, 2019.

[1]All conversions from Mongolian togrog (MNT) to US Dollars (USD) in these thesis will use the conversion rate of 2023.

In laboratory tests, the improved stove was found to be capable of reducing $PM_{2.5}$ emissions by 70-89% and reducing coal consumption by 11-26% if used correctly (Social Impact, 2014). However, despite the fact that 144,000 of these improved stoves were distributed, the impact of these two projects was seriously limited. An evaluation of the MCC improved stove distribution programme found that the programme did not significantly reduce coal consumption, in large part because residents did not use the improved coal stoves properly (Cardascia et al., 2022; Social Impact, 2014). As opposed to the traditional stove, where kindling is first lit and coal is then poured in the stove as necessary, these improved stoves burn most efficiently when the stove is fully loaded with coal, and the kindling is lit on top. Also, the improved stove should be left to completely extinguish before starting another burn, as opposed to the traditional stove, which can be refueled while it is still lit. This method of burning prevents all coal from burning at the same time, which means the burning session lasts longer while reducing fewer pollutants.

Furthermore, a 2017 evaluation of the MCC project found that "15% of households had previously used improved stoves but returned to traditional stoves, because the improved stoves were considered broken or not working properly." (Cardascia et al., 2022) And some recipient households made use of the opportunity to resell their improved stove at a much higher price to buyers outside of the city, after which they went back to using their conventional stove. One report found, after interviewing various stakeholders, that up to 40% of the distributed coal stoves might have been resold (United Nations Environment Programme (UNEP) [Frankfurt School of Finance and Management – UNEP Collaborating Centre], 2018). So while 144,000 stoves were distributed, it is uncertain how many of these stoves were still being used in Ulaanbaatar after some years.

What can the failure of these twin projects be attributed to? It could be argued that the coal stoves should have been distributed in greater quantity, and to a wider area than Ulaanbaatar, in order to prevent reselling, despite the fact that air pollution is the most pressing in the capital city. Certainly, corruption also played a role (Jun, 2021).

But the shortcomings highlighted above all had to do with social practices of the residents who received the improved stoves. They were accustomed to using the traditional coal stove, and had to adapt their heating habits in order to make proper use of the new stoves. For those who sold their stoves, the extra income was more important than the benefits of transitioning to an improved coal stove. This is not a criticism of the residents – instead, it is an observation that the materials, competences, and meanings held by residents should not be neglected. Perhaps, if the projects would have accounted better for the financial situation and heating habits of the beneficiary residents, the rumoured reselling and improper usage of the improved coal stoves could have been prevented.

2.1 The 2019 raw coal ban

In 2019, faced with pressing air pollution challenges, the Government of Mongolia banned the use of raw coal in six major districts of Ulaanbaatar, offering refined coal briquettes as an alternative, which were subsidized to a price close to that of raw coal. These briquettes are produced by Tavan Tolgoi Fuel LLC, a state-owned company which has been created for this purpose (Jun, 2021). In the first year since its implementation, visible improvements in air quality were observed, suggesting that this ban did successfully achieve a reduction in air pollution (Ganbat et al., 2020). However, the implementation of these refined coal briquettes

also came with a negative consequences, as initial adoption of the new fuel source came hand in hand with an increase in carbon monoxide (CO) poisonings.
There have been numerous reports of an increase in CO poisonings after the raw coal ban, which have been attributed to incorrect use of the refined coal briquettes (Lundstrom, 2020; "Mongolia's new 'cleaner' fuel linked to deaths, illness", 2019; Sambuu et al., 2023). In the six districts in which the ban went into effect, there were 91 fatal and 1633 non-fatal CO poisonings from May 2019 to April 2022, and it was estimated that the annual incidence of CO poisoning, measured as the occurrence of fatal and non-fatal poisonings per 100,000 person-years in a 12-month period, increased from 7.2 and 6.4 in the two periods before the ban, to 38.9, 42.0 and 40.1 in the three periods after the ban, signalling an increase of nearly six times (Sambuu et al., 2023).
The proper burning technique for refined coal briquettes is different than for raw coal. According to a physicist at the Mongolian Science Academy, since the briquettes are more compact, they require up to twice as much oxygen to burn; and CO poisoning can take place when there is insufficient oxygen supply ("Mongolia's new 'cleaner' fuel linked to deaths, illness", 2019).
The government started providing guidelines and instructions only after initial reports of CO poisoning (Jun, 2021). One researcher at the Mongolian University of Science and Technology mentioned that the government should have provided instructions and information through all available networks, and that this did not happen enough (interview with Uelun-Ujin Purev).
During this time, it was also reputed that the quality of the briquettes was low, which Tavan Tolgoi Fuel LLC denied (Bayarsaikhan, 2019). Regardless of the actual briquette quality, the events around the raw coal ban are another instance of a well-intended policy which fell short because of insufficient consideration of existing social heating practices, which further stresses the importance of addressing the research gap of social heating practices in Ulaanbaatar in the efforts to reduce air pollution.

2.2 The governmental CO monitoring system

As a reaction to the increase in CO poisonings that occurred after coal briquettes had been introduced, the Government of Mongolia distributed CO monitors among ger households. However, a part of the residents kept the monitors off, decreasing the efficacy of this measure. In order to improve this monitoring system, the government commissioned two companies to develop new CO sensors that could stream real-time measurements to a centralized platform. If a sensor measures elevated levels of CO, the resident of that ger is contacted by phone. As of June 2023, about CO monitors for 65,000 households had been installed in Ulaanbaatar. (interview with Lkhagvasuren Gankhuyag, founder of Binary Systems, an IT company that developed the software platform for these CO sensors)

2.3 Related research

Due to the severity of the issue, air pollution in Ulaanbaatar has garnered scientific attention. Some efforts have assessed the degree of air pollution, its sources, and its negative health effects, while other efforts have been made to explore alternative heating solutions.

The most harmful component of polluted air is particular matter with a diameter of 2.5 microns or less ($PM_{2.5}$) (Cousins, 2019). Since people spend most of their time in indoor environments, several efforts have specifically focused on indoor $PM_{2.5}$ concentrations. Lim et al., 2018 measured indoor $PM_{2.5}$ of 60 ger households using both improved and traditional coal stoves in the winter of 2016, and found an average concentration of \$236.1 $\pm$ 112.1 μ g / m^3%, with no significant differences between improved and traditional coal stoves. Indoor $PM_{2.5}$ can originate from indoor activities such as cooking, or from air infiltration of the outside air. Hill et al., 2017, through a combination of measurements and simulations, found that 80% of total $PM_{2.5}$ exposure for ger residents came from indoor sources other than secondhand tobacco smoke, and that indoor $PM_{2.5}$ was mostly caused by air infiltration.

Recognizing the need to make changes to the heating situation in Ulaanbaatar's ger areas, several research initiatives have explored electric heating options for gers in Ulaanbaatar, focusing primarily on their heating performance and cost effectiveness. The most common form of electric heating is resistance-based heating, where an electric current passing through a material encounters resistance, causing the material to generate heat. An alternative form is used by heat pumps, which exchange heat between the inside air and outside air (or ground). In this research, the term electric heater is generally used to refer to resistance-based heaters. Pillarisetti et al., 2019 described a small-scale pilot of advanced air-to-air heat pumps, which are more power-efficient than electric heaters, in the winter of 2017. They found that the heat pumps were effective at heating a ger and a *baishin*, and they estimated its operational costs (i.e., the cost of the electricity) to be similar to the expenses of raw coal, and half that of resistance-based heating using electric radiators. However, while the upfront cost of the heat pumps was not mentioned by the paper, it is expected to be significantly higher than that of a coal stove. They also noted that the temperature profile produced by the heat pumps, which is uniform throughout the room, is substantially different from that of coal stoves; and that residents set their heat pumps' output to a high temperature, potentially in an attempt to recreate the temperature profile of coal stoves.

Another potential issue mentioned by Pillarisetti et al., 2019 was that the capacity of the electric grid in ger areas might be insufficient for widespread adoption of such heat pumps, despite their increased efficiency, a concern that is shared by other analyses of electric heating in Ulaanbaatar (Cardascia et al., 2022). One way to mitigate this could be to generate electricity locally from solar or wind power. As an additional benefit, these are renewable sources, rather than the coal-based power plants that generate most of Ulaanbaatar's electricity (Stryi-Hipp et al., 2018). Two studies showed that gers can be heated to a satisfactory level using PV-panels, but concluded that high costs made this approach infeasible for many ger residents (Bayandelger et al., 2020; Sovacool et al., 2011).

3 Theoretical framework

In order to research social heating practices, a theoretical framework has been developed which clarifies how social practices can be defined and understood, drawing primarily on the work of Elizabeth Shove in social practice theory (Shove, 2010; Shove & Pantzar, 2005; Shove et al., 2012). Furthermore, the Zooming In and Out approach, proposed by Nicolini, 2009, is used as a method to study social practices by considering both the household level as well as the landscape in which these social practices take place. Below, both social practice theory as the Zooming In and Out approach are discussed.
The replacement of coal stoves with electric heaters and similar heating innovations in Ulaanbaatar constitutes an energy transition. In this Section, several models on energy transitions and their shortcomings are discussed, after which the three-dimensional profile, proposed by Kowsari and Zerriffi, 2011, is introduced, and aligned with social practice theory and the Zooming In and Out approach in order to form a complete theoretical framework of social practices in the context of an energy transition.

3.1 Social practices

In the history of social practice theory, which consists of a collection of sociological works written from the late 20th century onward, social practices have been defined in various ways. Several of these definitions consider practices as habits or competences which are routinely reproduced. For instance, the scholar Andreas Reckwitz uses the term "routinized behaviour", existing as a "block or pattern which can be filled out by a multitude of single and often unique actions" (Reckwitz, 2002). Another scholar, Andreas Schatzki, talks about practice as a "temporally and spatially dispersed nexus of doings and sayings", which likewise emphasizes human behaviours (T. R. Schatzki, 1996).
However, Shove et al., 2012 stress that beyond behavioural patterns, materials and meanings are two important additional elements that, together with certain competences, make up social practices. In their definition, social practices *"involve the active integration of elements (materials, meanings, competences)."* (Shove et al., 2012, p. 119-120) Practices are social, because their elements are shared between a group of people. They are the links that are formed between materials, forms of competences (that make use of these materials), and meanings (of both materials and competences).
In the case of heating systems in ger areas in Ulaanbaatar, social practices are the links between materials such as coal, coal stoves, and the gers themselves; the competences would be behaviours around these objects directly, as well as other behaviours that influence certain heating patterns; and the meaning would be how ger residents perceive concepts like heat, fire, the coal stove, and heating their gers. Note that coal stoves are used for more than heating – for instance, they can also be used for cooking – making the social practices around those other uses also relevant.
One methodological approach to studying social practices is proposed by Nicolini, 2009. This approach, called Zooming In and Out, is based on two main principles. First, zooming in involves looking at social practices on a micro-level, examining the granular aspects of practices themselves – which, following Shove et al., 2012, we take to consist of materials, competences, and meaning. By zooming in, the granular aspects of the practice can be explored, and a deeper understanding can be gained of how the practice is performed, what it

means to the participants, and which materials are involved. As a subsequent step, zooming out involves looking at the broader patterns, structures, and contexts within which the social practice occurs, rather than the contents of the practice itself. This enables an exploration of how practice is influenced by and connected to larger social, cultural, and historical forces, as well as other practices. This can reveal how the practice is shaped by broader processes and help identify patterns that might not be visible at the micro-level.
In this research, Nicolini's Zooming In and Out approach will be applied in order to explore both the micro- and macro-level of social practices around heating. Since we are considering the transition between two forms of heating, the approach will be performed twice, in order to examine the current situation (where coal stoves predominate) as well as the innovations that are taking place, which, as we will see, chiefly consist of installing electric heaters and supporting infrastructure. For the current situation, the zoomed-out perspective has already been covered by the overview of recent measures provided in Section 2, while zooming in on individual practices is part of the results in Section 5. As for the heating innovations, most social practices were observed amongst participants of pilot projects and initiatives of actors in the broader context, and because these social practices were formed as a result of these efforts, the zoomed-out perspective is described prior to zooming in to the practices themselves.

3.2 Models on energy transitions

The use of certain energy sources is a key factor in the fulfilment of basic needs. The development of technologies, the economy, and the needs of a society can cause a new energy source to gradually replace another energy source as the dominant source of energy for a given service. Such energy transitions can have a variety of benefits, such as reducing energy poverty, increasing access to modern energy sources, mitigating emissions of greenhouse gases. In the case of Ulaanbaatar, a key benefit of transitioning from coal-based to electric heating would be improved air quality.
While some of the air pollution in Ulaanbaatar is caused by the combined heat-power plants and traffic, this research focuses on a transition in the domestic heating systems of ger areas. As such, it is important to understand what these heating systems consist of and why this is the case, which includes understanding how households make energy-related choices. Researchers have extensively studied how households choose which energy sources to use, with the aim of designing or implementing strategies that help accelerate the adoption of new energy sources. Two early models, the energy ladder and energy stacking, will be discussed, before arriving at the three-dimensional energy profile, which accounts for several pitfalls identified in these two models.

3.2.1 Energy ladder and energy stacking

The concept of the "energy ladder" has been widely used as a model to explain the choice between energy sources of households in developing countries (Elias & Victor, 2005). It defines a list of energy sources that a household progresses through linearly as the income of a household increases: for instance, you might have wood and animal dung at the low-income end, electricity at the high-income end, and coal somewhere in between. While the energy ladder puts a justified focus on the correlation between income and fuel choice, it

also makes the assumptions that all sources are available, that everyone has the same order of preferred sources, that households use a single fuel source for all of their energy needs, and that households will automatically substitute their energy source as soon as their income changes (Kowsari & Zerriffi, 2011).
Contrary to the energy ladder hypothesis, a number of studies have shown that households do not (always) fully switch energy sources once a 'higher' source becomes available to that household; instead, 'lower' energy sources continue being used (Kowsari & Zerriffi, 2011). Masera and Navia, 1997 have shown that, as Mexican households started using novel energy sources due to an increase in income, they kept using existing energy sources as well, a process the authors have termed "fuel stacking" or energy stacking. The novel energy sources are often used for novel processes, while previously existing needs remain addressed by the use of the same energy sources. According to their observations, energy sources are accumulated and used concurrently, rather than being switched between entirely.

3.2.2 The three-dimensional energy profile

Kowsari and Zerriffi, 2011 recognize that physical–technical–economic models, based on theoretical energy flows or economic models, are insufficient to accurately analyze the decision-making process of energy consumers, and consequently, energy consumption as a whole. They claim that the field of energy analysis has suffered from methodological issues; an overemphasis on income and an underestimation of behavioural and socio-cultural factors; and an incomplete specification of energy systems. According to them, a proper analysis of a household energy system needs to consider three dimensions it consists of: the energy carriers, energy conversion technologies (called devices), and energy service demands (called services). They propose the three-dimensional energy profile as a framework for energy use analysis. This model places the three dimensions (and their interactions) at the centre, and considers that a household's choices in these dimensions are influenced by a range of factors which goes beyond income and availability, and includes the attitudes, habits, and experiences of a household, as well as shared, contextual factors.
In the context of heating systems in Ulaanbaatar, Mongolia, the three dimensions of an energy system can be considered as follows. Energy carriers are the actual fuel sources, and include coal (both raw and refined), electricity, as well as traditional bio-fuels such as wood and livestock dung. In some cases, even trash and tires have been burned by residents to save costs, instead of coal (Jun, 2021). Energy conversion technologies consist of the devices that convert between different forms of energy: at the household level, these include coal stoves, electrical heaters in the form of radiators or heat-pumps, and heat-only boilers (powered by coal or by electricity); electric stoves, electric pans, electric kettles, and ovens are also related (Jun, 2021; Pillarisetti et al., 2019; U.-U. Purev & Hagishima, 2020). Finally, the term energy services refers to specific benefits that people gain by consuming energy. They are the reasons why people use energy in the first place (Pachauri & Spreng, 2003). The demanded energy services in this context are not just heating and cooking, but also include perceived comfort and the performance of rituals related to spiritual beliefs about fire and stove.
The three-dimensional energy model defines four categories of factors that influence the energy choices a household makes, and places these categories in two domains: personal and contextual. These factors influence choices in each of the three dimensions: the energy services that households choose to fulfil, and the energy devices, and carriers, which are used

to do so. In the personal domain, the two categories are *attitudes* and *habits and experiences*. In the contextual domain, the two categories are *personal capabilities* – referring to income, age, technical skills, resources, and other factors which determine whether an actor is capable of a certain action – and *external conditions* – including broad, contextual factors such as market actors, technologies, regulations, and institutions.
All in all, the three-dimensional energy profile goes beyond basic models on energy transitions by assuming that households accumulate energy carriers and energy devices as they fulfil more energy services. These three dimensions constitute energy systems, in which households make choices that are influenced by four categories of factors. Energy transitions, then, can be seen as a movement through this three-dimensional space: as more energy services become feasible to fulfil, the energy carriers and devices used also change – or are added alongside previous carriers and devices.

3.2.3 Social practices, policy, and individual energy choices

The three-dimensional energy profile is a "new conceptual framework to guide analyses of household energy choices" (Kowsari & Zerriffi, 2011, p. 7506), and thus places individual choices and behaviours at the core of its model on an energy transition. In doing so, it follows a common view on policy, which is that policy can only contribute to a transition by influencing the energy choices made by individuals, the latter being what ultimately effectuates change or transition (Shove, 2010). Indeed, in the three-dimensional energy profile, policies never have a direct impact on energy systems, but instead are listed as one of the exogenous factors that influences a household's energy choices (Kowsari & Zerriffi, 2011, p. 7511).
In this view, the only conclusion would be that energy transitions are ultimately effectuated by the energy choices that individuals and households make, and that governmental and non-governmental actors can only make an impact by devising policies to influence individuals, who carry all the responsibility in making the right or wrong choices.
However, Shove, 2010 argues that, if policy is only seen as a tool to influence individual choices, it is not employed to its full potential: it is "necessarily incapable of conceptualising transformation in the fabric of daily life on the scale and at the rate required [in climate-change policy]." (Shove, 2010, p. 1283) By fixating on individual choices, policymakers fail to consider the broader socio-technical systems and practices in which these choices are embedded and from which they arise.
In order to move beyond this limited perspective on policy, Shove states, it is important to shift the focus away from individual choice, and to realize the extent to which the government, together with non-governmental actors, directly shape daily life – including domestic heating systems. In practice, examples that support this notion are not hard to find. For instance, individuals don't make the choices about grid capacity – and saying that (limited) grid capacity is merely an "exogenous factor" that influences household choices to forego electric heaters just does not seem like an accurate representation of the issue. Likewise, a policy that bans the use of raw coal does not influence a household's choice in energy carrier as much as forces it.
If energy systems are composed of various components (carriers, devices, and services), these components also form the materials, competences, and meanings that social practices consist of; in fact, an energy system, which really consists of the links between these components, can be considered as a collection of social practices. And while ger residents (and

their 'energy choices') are certainly involved in this framework as carriers of these practices, so are other residents, politicians and policymakers, businessmen, volunteers, researchers, and any other person, as they together form a vast social network that reinforces some social practices by performing them over and over, while other social practices lose popularity and are forgotten. Through the reinforcement of certain social practices and the neglect of others, energy systems change, and over time, an energy transition takes place.
aim of fulfilling an energy service. Energy systems are not separate from the landscape of social practices, but rather, fully embedded within it. A social practice (a link between elements) is reinforced through its repeated performance by the social network formed by ger residents, policymakers, researchers, other residents, and so on.

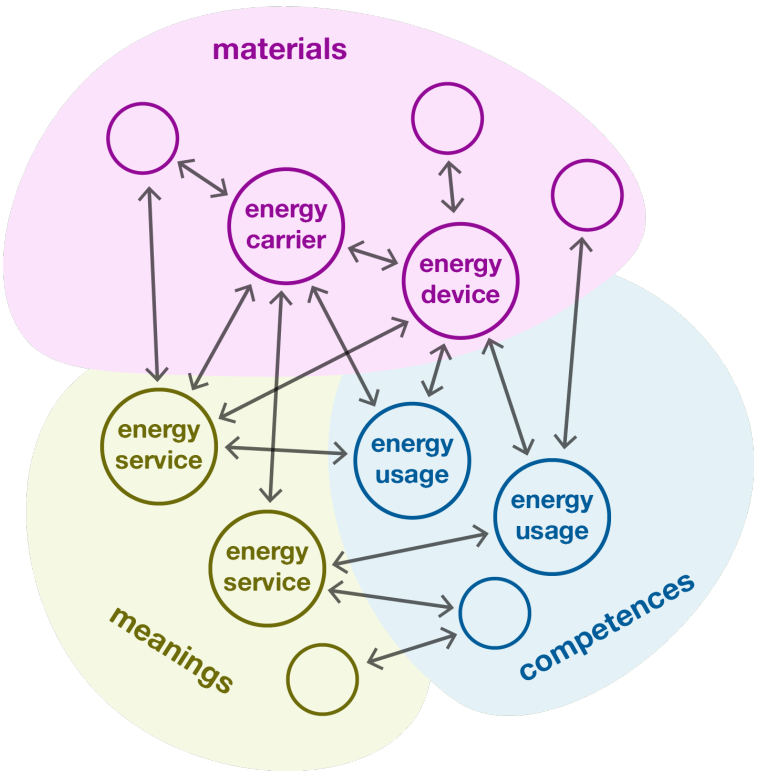

Figure 3: A representation of social practices consisting of links (arrows) between materials, competences, and meanings (circles). Energy systems can be seen as a collection of certain social practices that link together relevant energy carriers, devices, services, and a proposed fourth dimension, energy usages, which are defined as the usage of a carrier and/or device with the aim of fulfilling an energy service. Energy systems are not separate from the landscape of social practices, but rather, fully embedded within it. A social practice (a link between elements) is reinforced through its repeated performance by the social network formed by ger residents, policymakers, researchers, other residents, and so on.

This non-hierarchical view of an energy system as a collection of social practices, embedded within the wide landscape of social practices that make up a society, is illustrated in Figure 3. The three dimensions of the energy system are loosely aligned with the three elements of social practices (materials, meanings, and competences). Energy carriers and energy de-

vices are primarily present as material elements, while the fulfilment of energy services most closely aligns with meanings. In order to represent competences in energy systems, a fourth dimension is introduced called "energy usage", which is understood as the usage of a carrier and/or device with the aim of fulfilling an energy service. Note that the illustration suggests a stricter categorization of energy system dimensions into social practice elements than really is the case: for instance, carriers and devices have meanings associated to them; and an energy service can be considered as a mixture of meanings and competences.

Note that there is no clear separation of the energy system from surrounding social practices: rather, while the energy system is centrally located as the main focus point, its social practices are interconnected with other social practices that form a natural extension of the energy system, and any strict separation would therefore be arbitrary. While some social practices might be less relevant to energy consumption than others, relevance should be considered as a gradient, not as a binary distinction.

In conclusion, the theoretical framework defined above will help instruct this research on social heating practices in an energy transition in the following ways. Following Shove et al., 2012, social practices are considered as the interaction between materials, competences, and meanings. In order to identify differences between social practices of the current coal-based heating and social practices of heating innovations, both of these collections of social practices will be investigated using the Zooming In and Out approach proposed by Nicolini, 2009.

Furthermore, the three-dimensional profile, which models an energy system as consisting of three dimensions that households make choices in, influenced by personal and contextual factors, has been altered in two ways. First, energy choices are not considered as individual and exogenous, but rather, fully integrated into a landscape of social practices that all individuals, governments, and organisations shape by reinforcing certain social practices. In doing so, responsibility is shifted from individual energy users to all participants of a society, including policy and policymakers. Second, in order to represent competences in an energy system, a fourth dimension was introduced called energy usages, which are defined as competences that make use of energy carriers and/or devices with the aim of fulfilling an energy service.

Through this theoretical framework, social heating practices related to both coal stoves and heating innovations can be investigated. To this end, data was collected through interviews, observations, street conversations, and a focus group discussion, as discussed in the next Section.

4 Methods

In order to observe the social heating practices performed by ger residents, both gers using coal stoves and electric heaters were visited, and impromptu conversations were held on the street with other ger residents. At the same time, following the Zooming In and Out approach, an understanding of the broader landscape in which these social heating practices take place was formed through interviews with various actors whose efforts directly or indirectly influence the energy choices of residents, including researchers, NGO's, companies, and a local government office.
Once a basic understanding of the social heating practices and the landscape they are performed in was established, a focus group discussion was held in order to discuss potential solutions and recommendations together with ger residents.

4.1 Ger visits and resident conversations

Five gers were visited during the period of fieldwork in Ulaanbaatar. Two of these gers used coal stoves, while electric heaters were used in three gers. It should be noted that this distribution is not representative of ger areas in general: households with electric heaters were more readily available because I collaborated with organisations that focused mainly on innovations. In addition, two *baishins* were visited: a smaller *baishin* using a coal stove, and a two-story *baishin* using an electric boiler and radiators. While the primary focus of this research is on gers, some insights on heating practices were gained from these two *baishin* visits.
During the ger visits, to help ensure that none of the diverse range of topics relevant to social heating practices was forgotten during the visit, an observation frame was used. Rather than offering a rigid structure or set of questions, it served as a reminder of the topics to focus on in the course of a ger visit. This means that not every point was strictly considered during every visit. Instead, the observations made, and questions asked, were adapted dynamically based on the visit itself, with the observation frame used as a guideline.
The observation frame was partially drafted prior to the period of fieldwork in Ulaanbaatar, as part of the thesis proposal, and later expanded on, based on research and interviews. The main topics are: general household characteristics, other gers on the *khashaa*, air pollution cause and effect, electrification, the organisation of the ger's interior, materials (insulation and lifespan), cooking, clothing, and thermal comfort. The full observation frame is included in Appendix A.
Apart from ger visits, brief impromptu conversations were conducted with residents of gers and *baishins* on the street, in shops, and in taxi's. These conversations lasted between three and ten minutes, and, rather than providing a long window to observe social practices directly, proved their value mainly in expanding the perspectives that could be incorporated into this research. These conversations were informal and did not follow a particular structure: they often focused on a reduced subset of topics, or even a single topic. Notes were written down on the author's smartphone, either during or after the conversation. In total, notes were collected for ten conversations with various residents, of which nine were women and one was a man (as assumed by the author).
In all ger visits and resident conversations, the author was accompanied and assisted by a research assistant, Narangerel Mendsanaa, who translated between Mongolian and English.

4.2 Interviewing actors in the heating landscape

In order to zoom out to the broader landscape in which social heating practices take place, it was the aim to interview several actors, both governmental and non-governmental, in order to investigate their influence on social heating practices. In total, eight interviews were held: three with researchers working at the Mongolian University of Science and Technology (MUST); one with the director of the Mongolian office of the international NGO People in Need; three interviews with employees of various for-profit companies, namely URECA, Binary Systems, and Alfa Capital Group; and one interview was held with several employees of the office of a *khoroo*, which is an administrative sub-district in one of the ger areas.
For each interview, contextual information was collected beforehand, and a loose interview structure was drafted with several topics and questions. No preparation took place for the interview with the employees of the *khoroo* office, as it was an unscheduled interview. The interviews lasted between thirty minutes and one hour. All interviews were held in English, except for the interview at the *khoroo* office, which was held in Mongolian, with questions and answers translated by my research assistant Narangerel.
Several interviews were recorded and these recordings were later transcribed. For other interviews, notes were taken live by the author. These transcripts and notes are available in the supplementary materials of this thesis.
Apart from formal interviews, I have had many more conversations with people working or volunteering at NGO's, companies, students, and ger residents or their family members, which was instrumental to gaining a complete understanding of the issue. While no data has been recorded from these conversations, they have helped to shape my thinking around this issue and expanded the range of opinions I have been exposed to.

4.3 Focus group discussion

The ger visits and ger resident conversations served as a method of discovering and observing social heating practices in both traditional and innovative settings. Subsequently, once a basic understanding of the situation had been established, and the research process moved to consolidating data and shaping recommendations for solutions to the problem, it was the aim to consult ger residents again, as their inputs were considered very important to the value of the final recommendations and proposed solutions. To this end, a focus group discussion was planned and held in collaboration with Breathe Mongolia's *Let's Take Action!* project (see Section 5.2.3), of which the goals were to collect feedback for Breathe Mongolia, and to be able to shape heating innovation recommendations, based on ger residents' knowledge and experience with heating innovations.
A focus group discussion was selected for various reasons. First, it facilitates the exchange of ideas and opinions between participants, allowing them to build on each other's ideas and experiences, and agreements or disagreements about a particular topic can provide a more nuanced understanding of how it is viewed by a more diverse range of people. Second, it was a way to gain a wider understanding about the selected topics, capturing the opinion of a large group of people at once. Third, this method was suggested by the project organisers from Breathe Mongolia, and was deemed a suitable method for the project's participants, and, on a practical level, feasible to organise on a short notice.
The participants of the focus group discussion were 19 ger residents who were part of house-

holds participating in the *Let's Take Action!* project, meaning that most had gained experience with the CHIP package (a package providing electric heating, insulation, and air ventilation; see Section 5.2.2) during the winter prior to the focus group discussion.

The focus group discussion was organized following the recommendations set forth by O. Nyumba et al., 2018. A focus was placed on facilitator skills, and to this end, a guideline was developed for the two facilitators to use, which is described below, and included in Appendix B.1. The facilitators were seated at the same hierarchical level as the participants, in a circle of chairs. The location selected had previously been used for gatherings in this project, and was thus known to be accessible and familiar to the participants. Similar to previous gatherings, the discussion was held on a Sunday at noon, with snacks and tea provided for, and attending residents were compensated by Breathe Mongolia with a voucher for a grocery store.

The focus group discussion was divided into four topics, with each topic following a similar structure: first, an open discussion of around 15 minutes was held, loosely based on the questions and subtopics that had been prepared; and then, participants were asked to write answers to a specific prompt on post-it notes during ten minutes. This guideline, including the four topics, corresponding lists of subtopics, and post-it prompts, was prepared in the days prior to the discussion.

Owing to the size of the group, two circles of nine and ten people were formed that both followed the overall structure independently. The discussion was held in Mongolian. One circle was facilitated by my research assistant Narangerel, while Amarjargal Dagvadorj from Breathe Mongolia facilitated the other circle. For each circle, a volunteer from Breathe Mongolia took notes of the discussion. Afterwards, the discussion notes and post-its were translated into English by my research assistant, and they are included in Appendix B.2.

5 Results

From the conducted ger visits, resident conversations, interviews, and the focus group discussion, various social heating practices were identified, related to coal stoves, electric heaters, insulation, and the efforts and effects of actors in the heating landscape. In order to identify how social practices are changing as part of the energy transition from coal-based heating to more innovative heating systems, the Zooming In and Out approach was applied twice.
In Section 2, a zoomed-out overview of the current situation has already been provided, and that perspective will first be extended by zooming in on the current situation, discussing several social practices related to coal-based heating.
After considering these current social practices, the efforts and attitudes of actors in the zoomed-out landscape around heating innovations will be discussed, before zooming in on the actual social practices that were observed among households with innovative heating systems. The order of Zooming In and Out is reversed, because these social practices were observed among households participating in pilot projects and initiatives of these actors. By first zooming out and discussing the initiatives, a context is provided within which we can subsequently explore how households are adapting as part of these initiatives.

5.1 Zooming in on current social heating practices around coal stoves

Table 1: Overview of energy devices used for heating in ger areas, as well as usage distributions from various surveys.

Energy device	**Device type**	**% ger areas, 2017 (Cardascia et al., 2022)**	**% gers, 2020 (U.-U. Purev & Hagishima, 2020)**
Coal stove	Conventional	92%	32%
	Improved		59%
Wood stove		-	2%
Heat-only boiler		7%	-
Electric heater	On its own	0.9%	-
	Next to coal stove		4%

Currently, the vast majority of ger residents uses a coal stove to heat their gers (see Table 1). The majority of coal stoves used are improved coal stoves, but traditional or conventional coal stoves are still common.
While the predominant use of coal stoves in Mongolia can be attributed to historical and contextual factors, as described in Section 2, several social heating practices were observed that form additional reasons for households to keep using coal stoves, and that have to do with more than just heating.
Heating is, without a doubt, the primary energy service that coal stoves are used for. Social practices related to heating consist of direct heating behaviours and materials, but also to thermal comfort and the meaning of temperature, and to the insulation that the ger's envelope provides. Social practices related to these topics will be discussed below, presented together with findings from existing research in order to provide a complete picture.

Beyond heating, however, coal stoves also fulfil several other energy services. First, alongside other energy devices such as electric stoves and kettles, coal stoves are commonly used for cooking. In addition, coal stoves are traditionally used in the spiritual domain, where they fulfil an important role in several shamanistic rituals and beliefs. While it is not certain how common or widespread these spiritual practices are nowadays, they cannot be omitted when investigating why ger households keep using coal stoves.
Besides social practices that directly relate to the usage of coal stoves, there are other reasons why people prefer to keep using coal stoves over cleaner electric heating solutions. First, as mentioned before, coal stoves are considered to be more affordable than electric heaters. Second, some residents said they were averse to using electric appliances because they thought there was a larger fire risk.
So, in order to obtain an overview of reasons why coal stoves are used in ger areas from a social practices perspective, let us zoom in on the heating, insulation, cooking, and spiritual practices on the individual household level; and, subsequently, discuss the affordability and fire risk of coal stoves and electric heaters.

5.1.1 The thermal performance of coal stoves

As mentioned above, the primary function of the coal stove is heating. The heating season in Ulaanbaatar lasts about seven months, from mid-September until the end of April. There are two aspects of using the coal stove which are associated with social practices. First, the coal needs to be collected and stored. Subsequently, social practices that directly interact with the coal stove will be discussed.
People can purchase bags of refined coal briquettes at several distribution points throughout the city. There is a weekly limit of seven bags, which means that most households need to make this purchase on a weekly basis (Jun, 2021).
Lighting the coal stove is done by placing coal briquettes on top of some pieces of wood in the stove's main burning chamber, and lighting these pieces of wood. The lighting process takes several minutes. This starts a burning session which lasts for several hours, depending on the amount of coal placed[2]. According to one resident, a traditional coal stove is lit up to four times per day, and an improved coal stove around two times per day. The longer burning duration of an improved coal stove is due to its optimized design.
The first part of this burning session generates the most heat, as the burning coals are generating a visible flame. This makes the coal stove most suitable to cook on during the first part. Subsequently, the heat output gradually starts to decrease, as the coals smoulder and are eventually used up. In order for the ger to stay warm throughout the night, it is common to start a burning session before bedtime. If the coal stove is used for cooking, some households make use of the early part of this burn to cook their dinner, which means dinner time is close to bedtime. This burning session lasts for a part of the night, but the ger has typically cooled down by morning.
It was mentioned by several interviewed residents that, because the ger is cold in the morning, one of the members in the household wakes up about an hour before the household gets up in order to light the coal stove, so that the ger is at a comfortable temperature when the rest of the household wakes up. As far as it was understood, this household member will typi-

[2]Note that, for the stove to burn properly, a minimum amount of coal is required.

cally go back to sleep after lighting the stove. However, it is uncertain whether this behaviour occurs in households regardless of the stove type, or only in households with traditional coal stoves (that have a shorter burning profile).
In the summer or early autumn, when it is somewhat cold or rainy, households occasionally light their coal stove with wood alone, which generates a smaller amount of heat. One resident living in a *baishin* with both an electric boiler and a coal heat-only boiler mentioned that she burnt wood in her coal heat-only boiler a few times when it was raining past summer. When asked why, she answered it was just her preference. At various other moments, she indicated that using the electric boiler was much more convenient than using the coal heat-only boiler, which suggests that there were some non-tangible benefits to the wood-burning worth the additional effort to her.
In the traditional Mongolian nomadic lifestyle, responsibilities are generally divided based on gender roles, with the men tending to tasks outside the home like herding livestock and the women managing the household. Heating is primarily the responsibility of the man, including fuel collection, and lighting the stove. However, when talking to residents, in one case it was mentioned that whoever arrives home first lights the stove; in a second case, while discussing stove cooking, it was said that women light the stove if they want to use it to cook; and in another case, it was said that with several adults living in the ger, there was always someone present to manage the stove. This suggests that lighting and managing the stove has become a shared responsibility, at least in the urban context of Ulaanbaatar.
Finally, it is worth noting that handling coal leaves dust and dirt on clothes as well as on the floor of the ger (focus group discussion). One resident also mentioned they had designated dirty clothes that they wore when handling coal.
In conclusion, there are various behaviours related to heating, the primary energy service that coal stoves are used for. While these findings give an idea of the direct behaviours of ger residents with regards to heating their home, it is equally important to analyze what the meaning of a warm home is for residents. In order to consider clean heating alternatives, it is important to know why households heat their homes to specific temperatures in specific ways. Next, we discuss the notion of thermal comfort, and how both the material context and behaviours of ger residents impact what it means for a ger to be comfortably warm.

5.1.2 Thermal comfort of ger residents

In this section, we will analyze certain factors in the lifestyle and norms of ger residents that influence their notion of a comfortable temperature, also known as thermal comfort. Thermal comfort refers to the perception a certain temperature as comfortable, i.e., not too hot and not too cold. While there are building standards and regulations, such as ASHRAE's Standard 55, that suggest the existence of objectively optimal thermal situations, Shove, 2003 argues that these are both a result and a cause of a global convergence of thermal comfort, from a wide variety of context- and climate-dependent preferences, to a narrow range of accepted temperatures and heating styles.
Thermal comfort is subjective, and influences an individual's energy choices as an aspect in the *attitudes* category. It is not just a personal norm, but rather, determined by the social context we are habituated to. Relating to our definition of social practices, this perception could be seen as a shared meaning of a physical context (and its temperature) which influences heating behaviours.

For several generations, the habit has been to heat the ger to a maximum, and then regulate the temperature by opening the door or *toono* (interview with Mungunkhishig Batbaatar from People in Need, an international NGO; see Section 5.2.2). This practice of regulating temperature was also mentioned by several residents during the focus group discussion.

Why does this habit occur? While coal is heavily subsidized, it's not free. Widespread poverty in the ger areas means that for many households, coal is a significant part of their expenditure (Jun, 2021). According to Mungunkhishig Batbaatar, there is at least some financial incentive for coal users to save coal by being energy efficient, but it conflicts with thermal comfort habits, and with billing schedules: since most people buy their coal on a weekly basis, costs are split up into small expenses, which obfuscates the potential savings from more frugal use of coal.

It is easy to explain this habit of heating to a maximum by assuming that ger residents are "simply used to a pattern, and not aware of its suboptimalities." However, rather than negligence, this habit might have to do with the burning profile of a coal stove. As described above, a burning session lasts for several hours, with the most heat generated during the first part of the burn, and heat output gradually decreasing over time. Due to this uneven heat output over time, the coal stove will either generate too little heat towards the end, or too much heat towards the start. It would not be strange to assume that, in the cold winter months of Mongolia, ger residents prefer to generate too much heat at the start so that the temperature remains comfortable towards the end; after all, it is easy to decrease the temperature by opening the door or *toono*. And, while traditional coal stoves can be refueled during a burning session, people might not have the opportunity, or the habit, to do so regularly.

Beyond the burning profile of the stove, there are other social practices that could contribute to the habit of heating to a maximum, one of which is the need amongst ger residents to frequently go outside for brief moments, also in winter. Ger residents often have to go outside, to visit the toilet (typically a latrine on the khashaa), or to retrieve more coal (U.-U. Purev & Hagishima, 2020). These activities can be associated with thermal comfort in two ways. First, the indoor temperature is affected, as opening the door to go outside or inside causes cold air to infiltrate the ger. Second, going outside frequently when it is cold outside might cause people to prefer higher indoor temperatures, so that their bodies can warm up before and after moments spent in the cold. This also depends on the clothes that people wear when going outside.

The type of clothes that people wear, both indoors and during brief outdoor visits, is another factor that correlates with thermal comfort. During the ger visits as part of this research, it was observed that several residents wore nothing more than T-shirts, while other residents were wearing sweaters[3].

For a more quantitative analysis of the thermal insulation of winter clothing worn by ger residents, we can consider their clo values. Clo is a metric which can be used to express the thermal insulation of clothing, with a three-piece western business suit having a clo value of 1 (Shove, 2003). U.-U. Purev and Hagishima, 2020 measured clo values of ger residents' winter clothes, and found that the median clo value was 0.64 for males ($n = 23$) and 0.55 for females ($n = 47$). These values are similar to the median clo values of clothing worn in office buildings located in California and Michigan in the US, Canada, and Australia during winter (Schiavon & Lee, 2013). However, note that the suggested clo value of winter attire in inter-

[3]Keep in mind, however, that the ger visits did not occur during the coldest months of the year.

national standards is 1. Although the importance of homogenizing international thermal comfort standards is questionable (Shove, 2003; Van Hoof, 2008), these clo value measurements give an indication that ger residents do not dress particularly warmly. This could be both a cause and an effect of the high indoor temperatures in gers.
As a final reason, it appears that extra high temperatures are preferred, or considered important, for children and by elderly people. In various cases, it was implied that an electric heater could not provide a temperature high enough specifically because the household included either children or elderly people.
For instance, one participant of an electrification project by URECA (see Section 5.2.1) received her electric heater last winter, but continued using her coal stove in the coldest months, and said she did so to heat reach a sufficiently high temperature for her young children. In an independent conversation, her father, living in a ger on the same plot, said that he was a fan of the electric heater, and he would get one *if* they did not have his grandchildren stay in their ger frequently.
Another ger resident, the owner of a small grocery store, told us that she has an electric heater in her ger that she bought during the COVID-19 pandemic, because electricity was provided for free during that time. From December to February, she uses the coal stove concurrently. While her ger was relatively well-insulated, she said that one of the members of her household is an elderly person of 80 years who prefers a much warmer temperature than the rest of the household.
In conclusion, ger residents using a coal stove are accustomed to relatively high temperatures for various circumstances, such as the burning profile of a coal stove, the accommodation of frequently having to go outside, and the perceived importance of high temperatures for elderly people and children. The relatively low thermal insulation of typical clothing, and the opening of the door and *toono* to regulate the temperature, are two consequences of these circumstances that reinforce the habit of heating the ger to a maximum.
It is important to consider these findings in the broader context of air pollution, including in relation to heating innovations such as electric heaters. Electric heaters have a lower heating potential than coal stoves and are likely unable to reach the temperatures that ger residents are accustomed to, and this could be a potential reason for ger residents to stick with the coal stove. Indeed, the desired heat output of electric heaters is also relevant for other limitations to electric heater adoption cited in the literature, namely grid capacity and affordability. However, even in the context of coal stoves, examining the reasons why ger residents consider their living environment comfortable at a certain temperature might provide novel ideas for reducing coal consumption without having to change the heating device of every household.
In a similar vein, reducing the heat load of gers by improving insulation is both important for heating electrification as well as reduction of coal consumption. Let us take a look at the status quo of the insulation of gers in Ulaanbaatar's ger areas.

5.1.3 The challenge of proper ger insulation

Insulation is an influential factor in determining the heat load of a ger (U. U. Purev & Hagishima, 2022). The better the insulation, the less energy is needed to heat the ger to a certain temperature. In personal communication with Mr. Gankhuyag, the CEO of Alfa Capital Group, a Mongolian company producing electric heaters, he mentioned that, rather than the

heat source, insulation is really the first step in reducing air pollution, because good insulation reduces the amount of coal required to heat homes. While the government has focused on reducing the emissions from coal stoves and coal by subsidizing improved versions of both, insulation remains a weak point of gers, owing to its nomadic heritage.
The insulation of a ger is primarily determined by its envelope, i.e., its walls and roof. The envelope of a ger consists of several layers that are placed around the wooden skeletal frame of the ger. A standard of appropriate materials and layer order has been specified by the Mongolian Agency for Standardization and Metrology (MASM), but there are variations between gers, depending on the preferences, habits, and financial limitations of households (U.-U. Purev, 2022). From outside to inside, the following layers are typically used. U.-U. Purev, 2022 surveyed the percentages of households that use each layer, and these have been included here:

1. A thin, white cotton layer called *gadne tsaagaan burees* used for aesthetic purposes. The white appearance of a *ger* has a symbolic and traditional meaning. Used by 100%.

2. A tarpaulin layer called *berzent* which protects the insulation and interior from external water infiltration (melting snow or rain). Used by 65%.

3. Optionally, a thin polyethylene sheet, also for water protection, used in lieu of the *berzent*. Used by 20%.

4. One to three layers of felt sheeting called *esgii*, used as the main insulation material. Each layer consists of several overlapping pieces. The number of pieces (within each layer) depends on the size of the ger. Used by 96%.

5. An inner layer of thin, white cotton called *dotor tsavag* or *tuurga*, used to prevent flakes of the *esgii* to fall inside the ger. Used by 94%.

The nomadic heritage of the ger has been a determining factor in the insulation practices of ger residents: thick and stiff envelopes that improve insulation typically found in buildings in Northern Europe would limit the mobility of the ger, and have thus never been adopted, with Mongolians preferring powerful heating devices instead (U.-U. Purev, 2022).
Because gers are traditionally nomadic dwellings, they are reassembled several times a year. In a nomadic setting, gers are relocated three to four times a year. Even though gers in Ulaanbaatar's ger areas are used as permanent, non-nomadic dwellings, they are still reassembled once or twice a year. According to one survey of 49 households, 67% of gers was reassembled twice a year, and 24% once a year, mainly in order to dry the *esgii* and other insulation layers in the ger's envelope (U.-U. Purev & Hagishima, 2020).
There are indeed several reasons for ger reassembly in the context of ger areas. During one ger visit, the owner indicated that he reassembled the ger twice a year, for several reasons: he relocates the ger several metres in the summer season, to a place with a different type of flooring (earth instead of wooden planks); he dries and inspects the condition of *esgii*; and he changes the number of *esgii* layers from three in winter to two in summer.
Insulation can be improved in various ways, and residents as well as official actors can hold varying opinions as to what is best, and what can be expected. The women who worked as social managers at the office of one *khoroo* agreed that good insulation is important to reduce the heating load of a ger or *baishin*, but stated that there were not many families who could

afford good insulation, and that it was not really possible to improve insulation without spending money. According to them, ger residents really know how to insulate their ger correctly, using *esgii* and stacking snow against the walls.
However, at the same time, the *khoroo* office employees also complained that more residents should use a *berzent*, and that residents were too lazy to clear the snow from the roof of their gers, but that they definitely should be doing this. These are two important measures to prevent the *esgii* from becoming wet, which greatly reduces its effectiveness as an insulating material (Braham et al., 2021). As noted by Uelun-Ujin Purev during our interview, if snow is not cleared off the ger's roof, it can melt and seep into the *esgii* on the roof, especially on the "back" side (not facing the sun), as the lack of direct sunlight makes it more likely for the *esgii* to stay wet. This characteristic is also the reason why it is important to reassemble the ger and dry the *esgii* prior to winter, as they might get wet from rain in the autumn (interview with Uelun-Ujin Purev).
Finally, despite the fact that *esgii* are used by nearly all ger households, these insulation layers might not always be properly installed. During the evaluation of an electrification project by the startup URECA (see Section 5.2.1), which installed low-cost insulation and electric heaters powered by solar panels, substantial gaps were found around the lower circumference of the ger of one participating household (internal report, GerHub & URECA). This occurrence suggests that not every household properly protects their ger against the infiltration of cold air. It should be noted that the *esgii* were badly deteriorated, which could have caused the gaps, so it is possible that the gaps are a result of financial constraints, rather than bad insulation practices or a lack of awareness.

5.1.4 Cooking on coal stoves

Besides heating, coal stoves are used to cook meals and prepare hot beverages. The designs of both traditional and improved coal stove facilitate cooking. In the top surface of traditional coal stoves, rings are cut out that can be removed to make space for a pan or pot (see Figure 1), while the improved coal stove likewise features rings in the lid at the top of the stove (see Figure 2). Note that the entire top surface, and therefore also the removable rings, of the improved coal stove is smaller than that of the traditional coal stove, limiting users to smaller pans and pots.
While electric cooking devices are available, such as electric stoves, pots, and kettles, coal stoves are still commonly used for cooking. According to one survey, 31% of households said they used their coal stoves for cooking throughout the year (U.-U. Purev & Hagishima, 2020). Another study found that 45% of surveyed households used the coal stove for cooking, while 64% used an induction range or an electric pot (So et al., 2018).
It should be noted that neither of these studies included any indication of the frequency or exclusivity of the use of these cooking devices. Even if electric devices are used as the primary cooking devices, this does not preclude occasional use of the coal stove. Instead, the coal stove can be used as a secondary cooking device. For instance, it is typical to drink something hot during a meal – such as milk tea, a traditional Mongolian hot beverage – and the coal stove can be used to heat this beverage while the meal is being cooked on a separate device (interview with Uelun-Ujin Purev). In addition, it was mentioned during private conversations that people might cook on a coal stove if it is already lit, to take advantage of the heat; even if they also own electric cooking devices.

In these scenarios, the coal stove is used as a convenience or out of habit, and it seems like it could be replaced with (additional) electric appliances without much difficulty. However, two additional cooking practices were identified in which the coal stove seems to play a more essential role. First, two residents who had switched to electric heating mentioned that they would still use their coal stove to prepare dishes outside during summer, as a sort of barbecue.
Second, traditional coal stoves are used to prepare a traditional dish called *uuts* during the Mongolian lunar new year (*Tsaagan Sar*). *Tsaagan Sar* is the most important holiday in Mongolia, and many families come together to celebrate. One important component of these celebrations is a traditional dish called *uuts*, which is prepared using the bottom of a sheep. Various residents have mentioned that this dish is so large that it is necessary to prepare on the traditional coal stove, as neither electric stoves nor the improved coal stove can fit this dish.
Of course, many Mongolians do not have a traditional coal stove because they own an improved coal stove, or because they live in apartments. In these cases, I learned that people tend to ask someone else, often a friend, family member, or neighbour, to prepare it for them on their (traditional) coal stove.
One resident with an electric heater kept his coal stove mainly for this reason; he said he no longer had uses for the stove, other than preparing the *uuts*. He commonly prepares the *uuts* for his family, including for his mother. When asked what he would do if his coal stove were to break, he said he would ask a neighbour, or purchase a new coal stove. The willingness to purchase a new coal stove exclusively for this purpose indicates the importance of preparing *uuts*, at least to some residents. Since *Tsaagan Sar* is a day with traditional food, clothing, and customs, it might perhaps also be a sentiment of tradition which adds to the desire to prepare *uuts* on a coal stove.
Uuts can also be prepared on various other occasions, such as weddings, moving into a new home, when someone receives an award, or a child's first haircut ceremony.
In short, while electric cooking devices are commonly used by ger residents, coal stoves still perform a substantial role during cooking: at least a third of households indicate they primarily use the coal stove for cooking, and even if not, coal stoves are still occasionally used, as a secondary cooking device or for summer barbecues; and, at least once a year, for the important traditional dish *uuts*.

5.1.5 Coal stoves and spiritual practices

One participant of the electrification project of URECA (see Section 5.2.1), Davaajargal, has used an electric heater this winter. However, she kept occasionally using her coal stove alongside the heater in the coldest months. This coal stove actually was her father's stove (their parents live in another ger on the same plot). She told how about a year ago, she was experiencing some issues in her personal and professional life. She and her parents thought it might have to do with the fire spirit not being present in her home, because the coal stove was not hers. They performed a ritual of handing over the coal stove from her father to her. Since then, she has gotten a new job and her life has improved overall.
Baris et al., 2006 describe how the stove, at the centre of the ger, symbolizes the family's ties with ancestors. Dwelling inside the stove is the *golomt*, the fire spirit, which brings peace and good luck to the home's residents. The stove, together with the fire spirit, is passed from

parent to child, and when a new stove is installed, "... a lama or priest takes ash from the old one to place in the new one and prays that the *golomt* will reside in the new stove and bring blessings on the family as before."
In a conversation with women who worked as social managers at a *khoroo* office it was also mentioned that the stoves are, in a way, the centre of the household, and that they are passed down over generations. However, it was said, it would not be a problem if coal stoves were replaced as the main heating source, because people would keep and value their coal stoves even if they would not be using them on a regular basis.

5.1.6 Affordability of coal stoves and electric heaters

The main concern of adopting electric heating mentioned by interviewed ger residents is that they will not be able to "afford the bills". One taxi driver who lived in a *baishin* told us that she would like to have an electric heater if possible, but that the electricity bill would increase too much. She guessed her bill would go from ₮20-30k MNT ($6-9 USD) to ₮200-300k MNT ($60-90 USD) a month. A young woman getting water also said she thought her family could not afford an electric heater.
Likewise, another shop owner told us she thought that switching from her current coal boiler to an electric heater for her shop would cause total costs of electricity and coal to rise from ₮500k MNT ($144 USD) to around ₮1M MNT ($290 USD) per month. She indicated that the electricity subsidies do not apply to small businesses like hers. Additionally, her shop has a large area to heat compared to a ger or *baishin*, and she keeps the door open for air ventilation, to reduce the chance of diseases.
The opinions of these residents – that adoption of electric heaters is limited by financial constraints – is reflected in international research and by local stakeholders (Braham et al., 2022; Cardascia et al., 2022; Pillarisetti et al., 2019, interviews with various stakeholders).
In general, there are two types of costs associated with electric heating: first, the one-time investment cost when purchasing the electric heater and any auxiliary materials, such as insulation or air ventilation, and second, the operational costs of the electricity required to power the heater.
In fact, it is far from certain that electric heaters are "unaffordable". Electric heaters that cost anywhere from ₮200k to ₮1.5M MNT ($60 to $431 USD) are advertised on Facebook[4], although they might not all be adequate to properly heat a ger. As for operational costs, several studies concluded that it was possible to electrically heat a ger at comparable operational costs as when using a coal stove (Braham et al., 2022; Pillarisetti et al., 2019).
However, it is not the goal of this research to estimate the actual investment and operational costs of electric heaters, compared to that of coal stoves. Rather, I want to discuss various contextual factors that might influence residents' perception of the increased costs of electric heating.
Related to investment costs, a ger can be purchased for a fraction of the price of an apartment, and U.-U. Purev and Hagishima, 2020 found that many residents owned things whose prices exceeded the cost of their ger, like a car, a premium smartphone, or a large television. The author hypothesized that, perhaps, residents are not used to spend a lot on their ger

[4]Posts advertising such prices were found by searching "цахилгаан халаагуур" (electric heater in Mongolian) on Facebook, on 2023-05-26.

(and heating system), even if they can afford it, due to the comparatively low price of a ger (interview with Uelun-Ujin Purev).
However, as illustrated above, most of the affordability concerns had to do with the monthly electricity bills. Already, the fact that operational costs are recurring might make them more intimidating than the one-time investment of purchasing an electric heater. Another factor is the inherent uncertainty of estimating the electricity consumption of an electric heater, which is highly variable, depending on the ger's insulation, size, and the composition and daily schedule of a household.
The weekly limit on coal purchasing means that most households buy coal on a weekly basis, whereas electricity is billed per month. According to Mungunkhishig Batbaatar from People in Need (see Section 5.2.2), this difference in billing frequency might also contribute to people's perception of high electricity bills – even if overall costs would be the same, electricity bills would display an amount that is four times higher than weekly coal expenses. In fact, the aforementioned shop owner in one of the ger areas also said it was more tricky for residents to pay one larger, monthly bill, rather than equivalent weekly bills (conversation with shop owner in ger area). It should be noted, however, that the weekly coal limit was implemented in 2019, prior to which Mongolians typically saved money and purchased the (raw) coal in bulk for the entire season, which suggests that longer-term financial planning was common among residents (Jun, 2021).
The importance of paying the electricity bill is high: if residents cannot pay the electricity bill, their household is cut off (conversation with shop owner in ger area).
Starting in the winter of 2017-2018, a subsidy on electricity during night-time was introduced. From November 1st to April 1st, residents are able to use electricity for free between 22:00 to 06:00 for domestic use, and up to 700kWh/month – excess electricity is 50% of the cost (TOG, 2017). This subsidy has since then been applied every winter (TOG, 2022, conversations with ger residents). While this subsidy can help reduce electricity costs, not every household is in a position to receive this subsidy, depending on whether they have individual electricity meters.
U.-U. Purev and Hagishima, 2020 found that five residents (out of 49) said they did not have individual meters. Indeed, Plueckhahn and Bayartsetseg, 2018 describe how it is common for households to act as a middleman in electricity distribution, distributing their electricity to neighbouring households that do not have a registered electricity connection, often for a small profit. In order to have a registered electricity connection, a household needs to have possession rights of their *khashaa*. The legal process of acquiring these rights can take years, and not everybody is eligible.
Without an individual meter, a household does not receive electricity subsidies (private communication with Uelun-Ujin Purev). Even if the household that resells their electricity would agree to incorporate the night-time subsidy into the pricing, the subsidy's limit of 700kWh/month would still apply to the multiple households using that connection, limiting how effective the subsidy is for those households.
In conclusion, one of the main concerns is the affordability of electric heating, which can be broken down into one-time investment costs and recurring operational costs. While electric heaters are more expensive than coal stoves, people's homes and coal-based heating is relatively cheap, which might make electric heaters seem disproportionately priced. As for operational costs, even if electric heating has a similar cost to coal-based heating on paper,

electricity subsidies do not apply to every household, and there are additional factors that might cause residents to perceive electric heating as being more expensive than it really is.

5.1.7 Fire risk of electric appliances

Apart from financial challenges, a perceived risk of fire or injuries from electric devices seemed to deter some residents from considering adopting electric heating. Two ger residents indicated an aversion to electric heaters, because of a fear of accidents due to electric appliances.

One woman whom we talked to on the street was critical of electric heaters. According to her, they would not help with air pollution – to solve that problem, everyone would have to move into an apartment. Initially, her criticism of electric heaters was mainly the increased cost, and she indicated she might get an electric heater if she could afford it. But as we got a little more into the conversation, she started speaking very negatively of the heater's risk of fire, and said she would never get an electric heater. She hadn't experienced it herself, but she'd seen many Facebook posts about people saying their ger had burnt down because the electric heater had caught on fire. She indicated she did not like electric appliances and (being close to) electric cables because of the fire risk.

Another woman whom we talked to on the street lives in a ger with a coal stove, and is planning to move to a *baishin* where their family will use a coal-based heat-only boiler. She said that she did not like the idea of electric heating in her ger or her *baishin*, because she is afraid of the electricity, after she had an accident once with an iron that "sort of blew up" as she was using it (she did not sustain any significant injuries from it). Also, the cables swinging in the wind in spring time scared her.

The necessity of improving the poor quality of cables was also mentioned during the focus group discussion. Participants indicated that the CHIP package (a package providing electric heating, insulation, and air ventilation; see Section 5.2.2) should have included longer cables with better covering, that professionals should have come to install the electrical components and cables, and recommended that new CHIP users should check their cables and "fix them" if necessary. One participant mentioned that "some people are afraid of adjusting to an electric heater because the cables are not safe enough." The informal, non-professional redistribution of electricity, as mentioned in the previous section, might well contribute to the unsafe state of electrical components in ger areas.

The National Emergency Management Agency reported that in the first 10 months of 2018, there were 3,040 fires in facilities throughout the country, in which 1,380 homes burned down and 58 people died (National Emergency Management Agency, 2018). These were the three most common sources:

- 27.6% from open fires and spilled ashes;
- 20.0% from stoves, ovens, chimneys;
- 19.1% from electricity.

It should be noted that adoption of electric heaters was very low in 2018, and that these statistics can therefore not be used as an argument that electric heaters are at least as safe as coal stove. However, it is noteworthy that coal stoves are a significant source of fires in Mongolia. With proper management and maintenance of cables and other electrical components,

electric heaters might become safer than coal stoves, and this could become an additional argument in favour of electric heaters.

5.2 Zooming out: the landscape around heating innovations

During the past fifteen years, as Ulaanbaatar built up a reputation of the city with the worst air pollution in the world, the issue of air pollution from coal stoves has received national and international attention. As described in Section 2, the Government of Mongolia has, in collaboration with international organisations, attempted to improve air quality by distributing improved stoves and banning the use of raw coal, providing coal briquettes as a cleaner alternative.

While air pollution has decreased somewhat in recent years, much more profound changes in the heating systems used in ger areas are needed in order to improve air quality to healthy levels[5]. Reducing coal consumption is a key factor in improving air quality. In this research, ger heating innovations are understood as any change to ger heating systems that contribute to this reduction.

The clearest example of a heating innovation is the electric heater. According to a brief from the Asian Development Bank, the Government of Mongolia is working on a strategy to electrify ger area heating, taking into account that this will require an additional 1.6GW of electricity generation and increased grid capacity (Cardascia et al., 2022). The brief includes a timeline, stating that after a preparation and piloting phase in 2021-2022, a roll-out of electric heat pumps and heaters is to take place in 2023-2026, alongside a large-scale energy efficiency programme to reduce household consumption and bills.

However, outside of this brief, no other reference to these plans was found during this research, nor mentioned in any of the interviews conducted. Instead, in August 2023, the Minister of Energy announced that 132,000 tons of semi-coked coal from China would be imported for ₮177.5 billion MNT ($51M USD), with the aim of testing how much air pollution could be reduced with coal briquettes made using this semi-coked coal (Gogo, 2023a). The minister stated that if all households were to use semi-coked coal briquettes, air pollution might be reduced by 50% – and, that there is no other way to reduce air pollution in Ulaanbaatar (Gogo, 2023b; iSee, 2023). Even if air pollution could be reduced by switching to semi-coked coal, the plan suggests that the government continues to look for solutions within the world of coal itself, much like the measures that it has already taken in the past decade.

Apart from the government, several electric heating initiatives and pilot projects have been organized by several actors based in Mongolia. Among these actors are URECA, a startup building a marketplace for carbon credits on which ger electrification will be one of several projects; GerHub and Asia Foundation, two NGO's that participated in a ger electrification pilot project together with URECA; People in Need, an international NGO that developed an electric heating package that can be installed in gers; and Breathe Mongolia, a Mongolian NGO whose aim it is to provide people with the tools to combat air pollution. Their efforts are discussed below. In addition, the research of Uelun-Ujin Purev on novel affordable ger insulation, and the attitude on electric heating of employees at a local *khoroo* office,

[5] Although, in order to fully achieve good air quality, changes in transportation and the heat and electricity sources for the entire city, including the central districts, are also necessary.

are discussed.

5.2.1 URECA: addressing affordability through carbon credits

Electric heating is partially limited by the capacity of the electricity grid. However, pressure on the grid could be alleviated by generating electricity locally, from renewable sources. As mentioned in Section 2.3, two studies previously concluded that heating gers through electricity generated by PV-panels was possible, but too expensive for most residents (Bayandelger et al., 2020; Sovacool et al., 2011).
In order to make solar-powered heating feasible despite its high costs, the startup URECA wants to utilize carbon credits to finance these heating systems for ger households. The main mission of this startup, founded by Mongolians, revolves around carbon credit trading for different projects around the world. URECA itself wants to launch several carbon credit projects in Mongolia, one of which is providing solar-powered heating systems in ger households. In the winter of 2022-2023, they piloted this heating system for three ger households, in collaboration with GerHub and the Asia Foundation. In each of the households, a heating system was installed which consists of additional insulation, an electric heater, an array of PV-panels next to the ger which can supply a part of the heater's electricity, batteries, and measuring equipment used to verify the carbon credits that are generated.
The additional insulation has been developed as part of GerHub's Dulaanger project, and is adapted from recommendations described by Braham et al., 2021. It includes materials that cover the edges between the door and the walls, and the lower edge where the walls meet the floor. After a thermal performance assessment, gravel was additionally supplied to place around the external circumference of the ger (internal report, URECA and GerHub, March 2023).
During the pilot project, several workshops were organized in order to familiarize the participants with the equipment. Despite this, in the first two months after installation, participants called several times, asking questions about how to operate the thermostat. Since multiple households live on a single *khashaa*, URECA also instructed neighbours on taking care of the PV-panels, and told children to not throw balls or rocks near the panels. Despite the fact that URECA had mentioned that snow needed to be cleared off the PV-panels, participants needed to be reminded the first time it snowed. URECA also made a Facebook group with the participating households, in which residents actively interacted, posting updates and helping each other out. (interview with Bujinlkham Bandikhuu from URECA)
Ultimately, the goal of this initiative is to leverage carbon credits to finance expensive heating systems for gers at scale, in order to reduce CO_2 emissions and improve local air quality. The initial pilot project, with only three households, serves as a way to improve the package, assess whether its cost can be reduced, and evaluate URECA's carbon credit verification methodology (interview with Bujinlkham Bandikhuu from URECA). While the main focus is the novel approach to financing the investment costs, and solving technical challenges related to solar-powered heating, URECA is aware that successful implementation depends on how well residents accommodate their behaviour to the new heating system, exemplified by the requirement that the solar panels are not blocked by snow or other dirt. Nevertheless, it appears that URECA does consider financial constraints as the primary barrier to wider adoption of electric heaters.

5.2.2 People in Need and the CHIP package

Similar to the heating system designed by URECA, which covers several components related to heating, including insulation, the Cooking, Heating, and Insulation Products (CHIP) package was developed in 2018-2021 as part of UNICEF's Ger of the 21st Century project, in order to provide a clean and safe alternative to coal stoves (UNICEF, 2020). A team of international and local researchers experimented with various insulation protocols, and performed a case study which showed that a properly insulated ger could be heated electrically in an affordable way, but that indoor air pollution did not decrease in gers that were electrified, as it was mainly dependent on outdoor air pollution (Braham et al., 2022). This is consistent with the findings of Hill et al., 2017, who found that indoor $PM_{2.5}$ was mainly attributable from outdoor sources and the high air infiltration of gers.

In its current iteration, the CHIP package consists of several elements. First, a wooden table mimics the form of the coal stove: three electrical radiators are mounted on its sides, and its surface is intended for a electric stove to sit on. The elevated position of the electric stove was designed after researchers noticed that many residents placed this stove on the ground while cooking with it, causing burn incidents among children (interview with Munkhbayar Buyan, who contributed to the design of the CHIP package). A centrally placed thermostat controls the output of the electric heaters. In addition, the table includes a power outlet for the electric stove with a timer, in order to prevent people from forgetting to turn off the stove. The CHIP package also includes additional insulation for the *toono*, door, and floor of the ger. Finally, fans are installed to improve air ventilation in the ger: one is installed through a hole that is cut in the door, and a white shaft rises up through the *toono*, forming a stark visual contrast with the dark, metallic chimney of a coal stove.

The distribution and financing of the CHIP package project is being led by People in Need, an international NGO. According to Mungunkhishig Batbaatar, the Country Director for People in Need Mongolia, the goal of this project is twofold. The first goal is to increase awareness and push behavioural change on the household level.

The second goal of the CHIP package to push the energy sector towards electrification more rapidly, by increasing electricity demand. This is also the reason that People in Need has not promoted their improved insulation as a separate package. While offering only insulation would enable residents to reduce their coal consumption by decreasing the thermal load of their ger with a lower investment than what the full CHIP package requires, the increased electricity demand of electric heaters is intended to accelerate grid capacity upgrades, which will enable heating electrification on a wider scale (interview with Mungunkhishig Batbaatar, People in Need).

The main limitation of the CHIP package is its price, according to Batbaatar. The market of ger heating is too small for foreign companies to operate in, which limits how much cheaper these materials can get. While People in Need has experienced interest from residents, there is little actual demand. People in Need typically cooperates with donors that finance part of the CHIP package. For instance, the organisation Breathe Mongolia received a grant with which they could partially finance the installation of the CHIP packages for 25 households.

5.2.3 Breathe Mongolia's *Let's Take Action!* project: raising awareness and electrifying gers

Breathe Mongolia is an NGO whose mission it is to provide professionals and residents with information and tools which enables them to combat air pollution in Mongolia. They focus on educating the public, creating a community for researchers and professionals, and acting as a watchdog of public policies and decisions. One of their major contributions has been the development of *Agaar Neg*, a platform that serves to facilitate collaboration on initiatives against air pollution (private communication with Azjargal Tsogtsaikhan, Breathe Mongolia).

From September 2022 to May 2023, Breathe Mongolia implemented a project titled *Let's Take Action!*, with the goal of increasing community awareness, piloting a community-based air quality monitoring network, and evaluating the implementation of the CHIP package, with a special emphasis on the impact of air pollution on children. 28 ger households with children received indoor air quality monitoring devices; furthermore, 25 of these households received the CHIP package, partially financed by Breathe Mongolia. The participating households were selected based on a prior understanding of the negative effects of air pollution, as well as an interest in the CHIP package. (Dagvadorj & Ilie, 2022; Dagvadorj et al., 2023)

In addition to the installation of the air monitoring devices and CHIP packages, educational workshops and events were organized, some for the participating households, and others for a wider public. Since the project focused on children's health, four out of nine workshops included topics related to children's health and development, covering both scientific knowledge as well as practical steps to take. The remaining workshops covered a variety of topics, including practical topics related to the CHIP package, the sources and accountability of air pollution, and preliminary results of the air monitoring network. One of the workshops was the focus group discussion that was part of this research (see Section 4.3). In order to incentivize attendance and active participation, a gift voucher was provided to each attending household during every workshop. (internal project report, Breathe Mongolia, 2023)

Throughout the project, surveys were conducted among participating households to collect feedback and monitor the participants' perception of air pollution, the installation and operation of the CHIP package, and its impact on their living environment, children's health, and daily routines. In addition, during the focus group discussion near the end of the project, participating households had the opportunity to provide additional feedback.

The most common complaint during the project was that about half of the households reported "unpleasant air/fogginess" (internal project report, Breathe Mongolia, 2023). Unfortunately, the surveys did not provide additional information about what specifically was experienced. Note that this was provided as a multiple-choice option in the survey. Complaints about indoor air quality do reinforce the importance of proper air ventilation when coal stoves are replaced by electric heaters.

Another common point of feedback concerned the installation timing of the CHIP package. For many households, the CHIP package was delivered too late in the year, when households had already reassembled their gers for the winter season. Installing the insulation of the CHIP package requires the ger to be partially disassembled, which becomes infeasible at some point in the winter. Households said that the CHIP package should be delivered in September or early October. (focus group discussion)

Other feedback related to the CHIP package included complaints about difficulty commu-

nicating with the providers of the package's parts; and about the lack of quality of the floor insulation, the electric cables, and the air ventilation. It was mentioned that professional electricians should have come to install the electric components. Furthermore, part of the air ventilation system is installed by cutting a hole through the wooden front door, in order to place a wide plastic tube. One resident did not install the air ventilation because she thought it was bad luck to cut a hole in the door, while another resident broke it with her shoulder due to the placement of the tube. (focus group discussion)

Beyond practical complaints, participants appeared to be happy and content with both the CHIP package, considering it as an upgrade to their living environment, and with the *Let's Take Action!* project as a whole. In January, 38% of households were "very satisfied" with the CHIP package with one household indicated being dissatisfied, while in April, all households indicated that they were satisfied or very satisfied with the CHIP package (internal project report, Breathe Mongolia, 2023).

While households expressed their satisfaction regarding the convenience of electric heating, most households had not discarded their coal stove by January, and were still using it on a daily basis to heat their gers. In the January survey, 60% of households (n=20) used both coal and electricity, 35% only electricity, and 5% only coal, to heat their gers (internal project report, Breathe Mongolia, 2023). Note that three households did not yet have the CHIP package installed in January, but it is not sure whether these households participated in the survey. Regardless, it is noteworthy that around half of households still were using their coal stove on a regular basis alongside their electric heater during their first winter with the CHIP package installed.

5.2.4 Affordable ger insulation: the PhD research of Uelun-Ujin Purev

One collection of publications with a strong focus on the social heating practices of ger residents, including thermal comfort, is the PhD research of Uelun-Ujin Purev, on the development of an affordable insulation product for gers. U.-U. Purev and Hagishima, 2020 describes the results of a field survey conducted in the summer of 2018, which analyzed several characteristics of insulation and heating solutions in gers, as well as residents' behaviours with regard to these materials. Subsequently, field measurements were taken in two gers during winter to analyze spatio-temporal variations in temperature when using a coal stove and when using an electric heater, and it was concluded that insulation improvements are an important step in the process of heating electrification (U.-U. Purev, 2022).

From the field survey, several relevant social practices were learned, and in the final PhD manuscript, a novel insulation product was prototyped that accommodates these social practices (U.-U. Purev, 2022). This insulation product is also presented in U. U. Purev and Hagishima, 2022. First and foremost, the social practice of annual or bi-annual reassembly of gers, even when used in a sedentary context, suggested that novel ger insulation also needs to be easy to reassemble. In addition, since adjustments to the ger envelope are difficult in the winter, the insulation was designed to be installed from the inside, making installation during winter feasible. Finally, the prototype was designed using local materials, which is also the case for existing ger insulation, and a fire-resistant material was used for the ceiling insulation because it could fall down on the coal stove.

5.2.5 The attitude towards electric heating at a *khoroo* office

The *khoroo* office is the local office of a *khoroo*, an administrative sub-district in Ulaanbaatar. The *khoroo* office employs unit leaders (*hesgiin ahlagch*), who work as the liaisons between *khoroo* employees and the *khoroo*'s residents. These unit leaders form the main channel for the *khoroo* office to distribute information to the residents, such as updates to social and economic policies and regulations, and local events. According to Plueckhahn and Bayartsetseg, 2018, they "play a crucial role in distributing information to residents in their area, as well as promoting civic participation in community campaigns such as organizing collective cleaning days and collecting household data for the city's welfare programme."
This means that the *khoroo* office and the unit leaders play a role in shaping the social heating practices of its residents. For instance, an elderly mother-in-law said she would go to the *khoroo* office for information regarding the CHIP package. Therefore, it is important to understand the attitude of the *khoroo* office with regards to heating innovations, the information it provides.
I visited the office of the 31st *khoroo* in the *Songinokhairkhan* (Сонгинохайрхан) district on a Friday afternoon, and spoke to a group of four or five women who worked as social managers at the *khoroo* office. These women organize events and activities from the office, and seem to have a connection to residents through these events.
Some *khoroo* offices maintain closer relationship with the *khoroo*'s residents than others. In this *khoroo* there live some six- to seven-thousand residents, and the women from the office said that about 80% of those residents have a constant connection to the *khoroo* officials. If this is indeed the case, it highlights that the *khoroo* office might be an important avenue to reach residents.
In this office, there were pamphlets with written information available for various topics, including one on divorce. It was stated that these pamphlets were quite well-read by residents, and that it was mainly valuable for older people who do not use social media. However, there was no written information available regarding electric heaters, insulation, or green loans.
The women's attitude to electric heating was ambivalent. According to them, the biggest challenges were financial: both that people were afraid that they could not afford their electricity bill, and the high investment costs. In regards to investment costs, they estimated that electric heating would cost about ₮1.5-1.8 million MNT ($435-522 USD) for a ger, ₮3-5 million MNT ($870-1450 USD) for a normal *baishin*, and ₮7-8 million MNT ($2030-2320 USD) for a large *baishin*. For a ger, this price is for a more high-end electric heater, which is large and square, has batteries that can be charged overnight, when electricity is free, and is safe for children to touch. There are heaters of ₮200k-400k MNT ($58-116 USD) advertised on Facebook, but the women were skeptical about the accuracy of the advertised heating performance and that several units would be needed to properly heat a ger, and did not rely on the positive reviews that people had commented underneath the Facebook posts.
Additionally, one of the women mentioned that she was worried that the grid capacity would not be high enough if everyone adopted electric heaters. According to her, the minister of energy had said that the power plants are close to shutting down because the city was close to max capacity, and that city-wide blackouts would occur if capacity would be exceeded. If office workers hold such attitudes might influence the information provided by the *khoroo* office.
Finally, this woman also believed that electric heaters dry the air, causing respiratory dis-

eases. She had heard people complain about this. Despite a heater advertisement on Facebook claiming otherwise, she did not believe there were electric heaters that did not dry the air, perhaps except for expensive ones.
Thus, while this *khoroo* office, together with its unit leaders, form important avenues to reach ger residents, especially older people, there is currently no written information present on electric heating or insulation, and while the issue of air pollution is recognized, electric heaters are not necessarily seen as feasible, or even desirable.
In conclusion, despite international loans and grants, in practice, government promotion of heating innovations seem to be oriented mainly in practice, as has been shown by the distribution of improved stoves, refined coal briquettes, and a recent announcement to test briquettes with semi-coked coal, imported from China. After the increase in CO poisonings following the raw coal ban, a centralized CO monitoring and warning system was implemented among some sixty-thousand ger area households. However, no large-scale initiatives regarding insulation or electric heating have been organized by the Government of Mongolia. On the other hand, there are various non-governmental initiatives to innovate on the current heating situation, where the primary focus appears to be on the material dimension. URECA, GerHub, and People in Need are developing and providing financing for electric heating systems with improved insulation and, in the case of URECA, PV-panels and batteries. Breathe Mongolia, in their *Let's Take Action!* project, partially financed the installation of 25 CHIP packages, but have also organized workshops and set up a community-based air monitoring network, in an attempt to improve people's awareness and knowledge on air pollution.

5.3 Zooming in on heating innovations at the household level

Having taken a zoomed-out perspective of the overall landscape around heating innovations, consisting of governmental and non-governmental actors and initiatives, we can now take a closer look at how those heating innovations are incorporated at the household level, and how households that participated in innovative pilot projects are adapting their social practices.
The ger visits that were conducted as part of this research included one visit to a beneficiary of the URECA pilot project; one visit to a household having received a CHIP package from Breathe Mongolia; and one visit to a household that was not affiliated with any initiative, but had independently purchased an electric heater.

5.3.1 Electric heating is considered much more convenient

Listening to, and observing, ger residents who adopted electric heaters in the past winter made it clear that using an electric heater provides significant personal benefits over using a coal stove. Using electric heater is easier, saves more time, and causes less dirt in the living environment than using a coal stove. All ger residents with an electric heater cited several of these benefits when talking about their experience, and in some cases, family members of these residents changed their minds about the use of an electric heater after having the opportunity to see electric heaters being used. While some of these advantages may seem obvious, their being mentioned by residents validates that they are indeed considered as such by ger residents.

First, using an electric heater makes heating much more convenient than when using coal stoves. Temperature can simply be regulated using the thermostat, instead of having to fire a coal stove which will burn over the course of several hours. The overall temperature was said to be more constant and comfortable, and one resident said that they do not have to change clothes as often to adjust for changing temperatures. Also, it is no longer necessary for one family member to get up early in the morning to fire up the coal stove. (Ger visits and focus group discussion)
Second, electric heating saves time, as was also mentioned during the focus group discussion. A coal stove takes several minutes to light, and people spend additional time retrieving coal from outside and switching to dirty clothes. Furthermore, the weekly visit to buy coal briquettes can take up to several hours, depending on availability at distribution points and traffic (Jun, 2021).
Finally, using electric heaters is cleaner than coal stoves, as coal leaves dust and ashes. During the focus group discussion, the effect of cleanliness that the CHIP package had on the participants' gers and clothes was mentioned several times.

5.3.2 Benefits for households with children

There are particular benefits of electric heating for households with children. First and foremost, children's health is disproportionately affected by air pollution (Manisalidis et al., 2020). In 2018, UNICEF stated that "air pollution has become a child health crisis in Ulaanbaatar", affecting children and pregnancies, with risks including stillbirth, preterm birth, lower birth weight, pneumonia, bronchitis, asthma, death; and probably, impaired cognitive development (for Public Health & UNICEF, 2018, p. 6).
The individual switch to an electric heater will not impact the average outdoor air quality, and research suggests that it does not significantly improve indoor air quality (Braham et al., 2022). Nevertheless, in the focus group discussion, as well as surveys of the *Let's Take Action!* project, some parents indicated that they noticed an improvement in their children's health since they switched to electric heating in the past winter. This suggests that there are perceived health benefits when switching to electric heating, regardless of whether indoor air quality actually improved. It should be noted again that participating households had previously attended several educational workshops on the negative effects of (indoor and outdoor) air pollution on children's health (internal project report, Breathe Mongolia, 2023). Apart from the workshops, this perception might also have to do with visible consequences of eliminating coal use. As reported above, handling coal leads to dust and dirt inside the ger, and a visibly cleaner indoor environment could potentially contribute to a perceived increase in children's health. In addition, burning coal generates a waste stream of ashes which contain heavy metals that are toxic to human health, and due to poor waste management in combination with improper sealing of trash bags, residents, including children, are exposed to this ash (Battsengel et al., 2021). When a household adopts an electric heater, they will not have to manage the waste stream from coal burning, which has a positive impact on the level of pollution of their living environment.
Apart from health impacts due to environmental pollution, electric heaters have several other benefits for children. According to Bujinlkham from URECA, it is very common in Mongolia, especially in the ger areas, to leave the kids at home and lock the home from the outside when the parents have to go to work. This behaviour mostly takes place during summer, when the

schools and kindergartens are closed. Perhaps the neighbours are notified and keep an eye on the children, but the kids are alone at home. In this case, the electric heater is useful because the children do not have to take care of lighting a coal stove, and there is a lower risk of getting burned.
If leaving the children locked in the home alone indeed mostly takes place in the summer, a season in which it is not likely to be necessary to heat the home on most days, this particular benefit might be marginal. However, also when the parents are at home, the risk of children getting burnt by the coal stove disappears when it is replaced by an electric heater. This was also mentioned as a benefit of the CHIP package by several parents in the focus group discussion. And one woman on the street said that she was planning to get an electric heater for the upcoming winter, because she would start working during that period, and an electric heater will be safer for her two children when she is not at home.
Not only are there particular benefits for households with children, parents might also be more receptive to arguments that address their children, rather than themselves. In 2016, journalist and mother Purevkhuu Tserendorj founded an NGO called Parents Against Air Pollution, which organized protests. Their Facebook group had more than 140,000 members in 2020 (South China Morning Post, 2020). Likewise, in the focus group discussion, a husband and wife mentioned that other parents at their daughter's kindergarten were "happy and interested" after they had been talking about their recent adoption of the CHIP package.

5.3.3 Coal is considered unhealthy

The negative health effects of coal consumption have been widely discussed: in this thesis, in scientific literature regarding this topic, and by Mongolian organisations, news articles, researchers, and so on. However, ultimately, it is important to consider whether this sentiment is shared by ger residents themselves, and how much influence this factor has in choices regarding coal stove use.
One study found that ger residents are well-aware of the severity of air pollution, as well as its causes (Koo et al., 2020). This was also the experience I had when talking to people, although my exposure might have been biased, as most of the ger residents I spoke to were associated with a project related to air pollution and electric heating.
In addition to air pollution, residents are concerned that refined coal briquettes in particular are associated with an increased potential to cause CO poisoning, when compared to raw coal (see Section 2.1). Some residents even kept their coal stove unlit at the start of the first heating season after the ban, out of fear of CO poisoning (Dagvadorj et al., 2023). Because of their density, refined coal briquettes require more oxygen than raw coal, and CO levels increase with an improper setup.
Coal has been used for a long time. However, the refined coal briquettes have been introduced in residents' lives only recently, and so, the meaning of this energy carrier is less rooted in long-time experience, and more in the reports of the outbreak of CO poisonings in 2019. Even if it is the case that improved setups will fully revert the increase of CO poisonings, this precedent might lead residents to be more inclined to try out non-coal-based heating innovations than variations on coal briquettes, clean as they might be.

5.4 Distribution of information about heating innovations

Two more social practices were observed that, while unrelated to heating innovations specifically, are relevant for actors in the heating landscape whose aim it is to increase the usage of heating innovations. First, strong family ties in ger areas, with family members of different households frequently visiting each other, might help convince more households of the benefits of heating innovations, electric heating in particular. Second, Facebook has been found to be a primary source of information – specifically of electric heaters – for several residents to whom I talked.

5.4.1 How strong family ties can accelerate the adoption of heating innovations

In my conversations with ger residents, I noticed that family seems to play an important role in Mongolia. Two researchers observed, while researching inter-generational relationships in Mongolia, "the tremendously strong bonds between family members that form a single, tightly linked unit", both between family members that resided together, as well as extended family beyond that. Interviewees indicated that they maintain very close relationships with other family members, and referred to children of relatives as children of their own. They told about how, during *Tsaagan Sar*, many families travel to a single destination to celebrate it together. These findings led them to conclude that "Traditionally, Mongolian family ties are incredibly strong" (Stol & Adiya, 2010). This matches my own experience: during visits, both children and adults would walk into a family member's ger on the same *khashaa* as if it was their own.

Figure 4: Satellite image of the *khashaa* on which Davaajargal, her children, and her parents live, annotated by author. (1) The ger in which Davaajargal and her children live; (2) The ger in which her parents live; (3) Solar panels that were installed by URECA; (4) Toilet (pit latrine); (5) Entrance. The blue outline indicates the *khashaa*. Maps Data: ©2023 Google, Imagery: ©2023 Maxar Technologies, CNES / Airbus.

Family members often live in close proximity with each other, mostly sharing the same *khashaa*, and visit each other's homes frequently. A 2018 survey found that of 72 households

observed, only three households shared a *khashaa* with people to whom they were not related (So et al., 2018). Additionally, most of the 2.1 people visited a ger per day on average were said to be "relatives or family members who lived within the same [k]hashaa" (So et al., 2018). These strong family ties, with family members from different households visiting each other frequently, might help in the promotion of the benefits of electric heating.
One instance of this is the case of Davaajargal and her parents, who live on the same *khashaa* in two separate gers (see Figure 4). As part of the pilot project of URECA, Davaajargal's ger, where she lives with her three young children, would receive an electric heating system, including solar panels installed on the *khashaa*. The parents of Davaajargal had initially been very skeptical of this system, and nearly refused its installation (interview with Bujinlkham from URECA), despite the fact that the costs were fully covered by the project grant. This refusal stemmed from doubts about the electric heater's performance in the winter, and because the installation of the solar panel necessitated the relocation of trees and berry bushes they had planted. Finally, URECA convinced them by proposing that if they did not like it after one winter, URECA would remove the system.
Several months later, when I visited Davaajargal's ger, I also spoke to her father, who came to her ger to say hello. He had a positive attitude towards the electric heater. He spoke with familiarity about its benefits, such as ease of use, cleanliness, and he indicated that he would like to have an electric heater for his own ger, which he also communicated to URECA.
It is noteworthy that Davaajargal's parents frequently take care of her three young children, who spend plenty of time in either ger. Because of this strong family bond, Davaajargal's father has likely frequently experienced the electric heater in use, and might even interact with it himself on a regular basis. While this was not explicitly mentioned during the interview, it would perhaps not be a stretch to assume that this positive experience with the electric heating system played a significant role in his complete shift in attitude towards it.
A similar influence of family visits was present in a conversation with a woman who, together with her husband, was planning to purchase three electric heaters for their *baishin*, which they were currently heating with a coal stove. She and her husband had been talking about it for several years already, and they had become interested after they had seen an electric heating system in the home of her husband's sister.

5.4.2 Facebook as a widely-used source of information

While family ties might form physical channels through which experience with heating sources is distributed, it is also important to look at the sources that ger residents use to search for information about electric heaters. One such source is the internet. In 2021, 84% of the population in Mongolia had access to the internet, although it would not be strange to assume that this average is higher in the capital city (World Bank, 2023a). While the fieldwork of this research does not provide quantitative evidence as to which digital channels formed primary sources of information, it is worth mentioning that, during several conversations, residents mentioned Facebook as a primary source of information about electric heaters.
In one instance, a woman, planning to buy electric heaters for her *baishin* with her husband, said they looked for information on Facebook. In a second case, another woman who was thinking about getting an electric heater before the next winter, also said she would first look on Facebook for information. Likewise, one participant of the *Let's Take Action!* project mentioned that information about the CHIP package should be more available through media

and through Facebook, as it was thought that people had very little information about the package (focus group discussion).
Facebook was not always cited as a primary source of information. An elderly woman, whose son-in-law had received a CHIP package last winter, said she would go to the local *khoroo* office to get information about the CHIP package. Interestingly, the sister of the CHIP package recipient subsequently emphasized that Facebook was also an important tool to reach people, which suggests possible differences in the primary sources of information considered by residents of different generations.
Contrastingly, Facebook is also a potential source of skepticism towards electric heaters. As mentioned before, one woman was afraid of the fire risk posed by electric heaters, which was in part based on Facebook posts she had seen about fires caused by electric heaters. This instance illustrates the dualist nature of Facebook as an information source. Just because it provides information at the fingertips of millions of people, does not mean that this information is necessarily positive towards heating innovations.
The fact that Facebook came up in almost every case when talking about sourcing electric heater information might not be such a surprise if we consider its wide usage. In early 2023, there were an estimated 2.3 million Facebook users in Mongolia, which is about 67% of its 3.4 million population (in 2022); but, when counting only people over the age of 13, actually amounts to 94%[6] (We Are Social and Meltwater, 2023; World Bank, 2023b). While this estimated number of users is not entirely representative of the true number of individuals using Facebook, it again is a national estimate, which, if anything, is likely lower than is the case in Ulaanbaatar.
Taken together, these observations highlight that Facebook is an extremely widely used platform, and considered by at least part of ger residents as a source for information regarding electric heaters. They suggest that efforts to promote the adoption of electric heating innovations should include a presence on Facebook, but should perhaps also work with *khoroo* offices in order to reach the older generation.

5.5 Overview of results

Figure 5 presents a summarized overview of the results reported above, highlighting reasons for preferring coal stoves or electric heaters. In all, five reasons were identified to use coal stoves, while three reasons were identified to use electric heaters. Each reason corresponds to one or more related social practices, and has been deconstructed into the three elements: materials, competences, and meanings.

[6]The use of Facebook is restricted to people aged 13 and above.

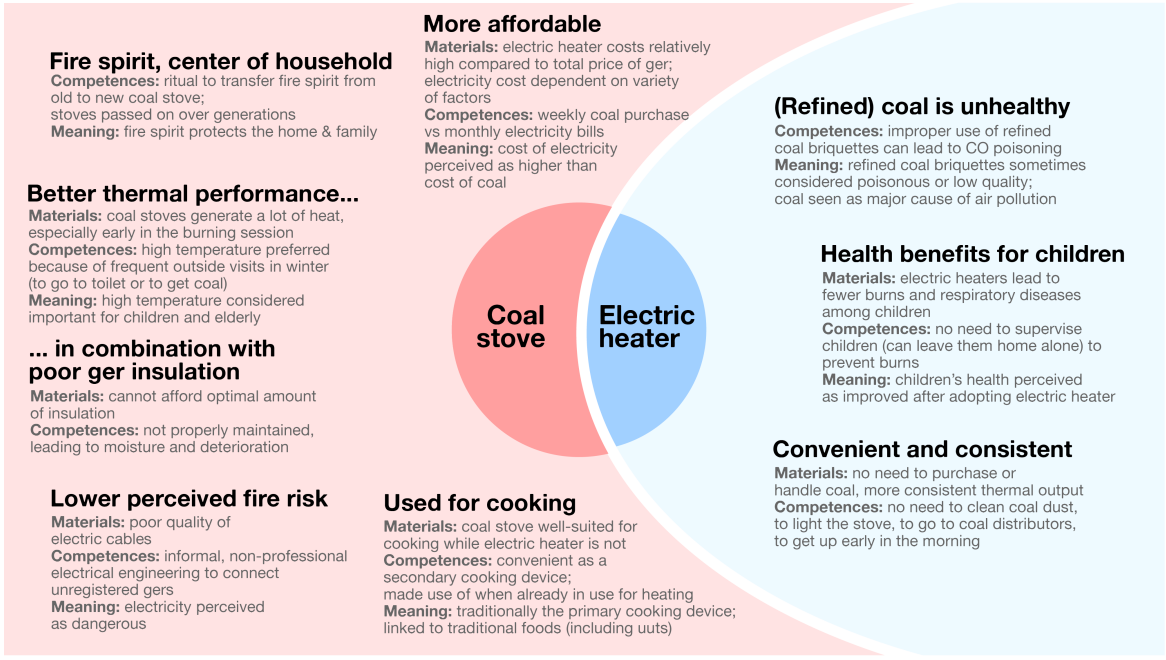

Figure 5: Reasons to choose to use coal stoves (red) versus reasons to use electric heaters (blue). Each reason is split up into the three components of social practices: materials, competences, and meanings. Reasons fall into one of the two levels at which social practices are represented in the three-dimensional energy profile: a direct level, and an indirect level.

6 Discussion

Air pollution is a well-recognized issue in Ulaanbaatar, Mongolia. Despite several air pollution reduction measures by the government, air pollution levels continue to have a negative effect on the health of Ulaanbaatar's residents.
While there are several sources of air pollution, the prevalence of coal stove usage in the ger areas of Ulaanbaatar contributes the most to the poor air quality of the city. Air pollution is especially bad in the winter months, when temperatures plummet and coal is burned by hundreds of thousands of households, living in gers (traditional Mongolian circular tents) or *baishins* (small, detached houses), in order to stay warm.
The impact that coal stoves have on air pollution can only be reduced by reducing coal consumption at the household level, which requires changes in the heating systems of gers and *baishins*: either the heat load of these dwellings needs to be lowered by improving insulation, or the fuel source needs to transition to a cleaner alternative, like electricity. Ideally, both should be done concurrently, as a lower heat load will make it easier to electrify the heating source. The feasibility of electrification has been investigated by several researchers, and pilot programmes that aim to electrify gers have received substantial international and governmental funding and effort.
There are two oft-cited limitations, namely the financial constraints of ger residents and the limited capacity of the grid. But, as the authors of the three-dimensional profile argue, it is naive to focus only on these two technical-economical problems: real change happens through the energy choices of a household, and that these choices are influenced by factors like habits and attitude, as well as contextual technical and economical factors (Kowsari & Zerriffi, 2011). This is a common perspective among policymakers: that policy can only aim for change through individual choice, which is a consequence of their attitude and behaviour. Social practice theorists like Elizabeth Shove consider this as an incomplete perspective that unnecessarily limits the power of policy: individual choice is not the only change-maker, some exogenous process that can only be influenced through the tweaking of certain contextual factors, but processes in daily life happen through social practices – links between materials, competences, and meanings – that exist in a flat ontology, and that make up both uncoordinated and coordinated actions, which all influence each other. Policy influences the world because it directly defines a set of social practices: while at the same time, policy is a consequence of social practices itself.
The Government of Mongolia has not had a great track record of implementing truly effective policy against air pollution by moving beyond coal-based heating, and relatively little progress has been made in reducing coal consumption through insulation and electrification, despite large budgets being spent on these issues. One might consider that citizens are not making the correct choices, or that the government should do a better job at protecting their citizens through policy that promotes the correct choices more effectively – a process in which corruption is definitely a disruptive factor. However, if we take the social practice theory perspective, and consider heating issues and practices in Mongolian society as embedded in of a non-hierarchical network of social practices, perhaps certain social practices can be identified that keep Mongolian citizens and policymakers alike on the track of coal stoves.
Through interviews with actors, ger visits, street conversations with residents, and a focus group discussion, an understanding was gained of the social heating practices among ger res-

idents in Ulaanbaatar, and how these social practices influence the energy transition. From this understanding, several recommendations were formulated that are aimed at actors in the heating landscape in ger areas in Ulaanbaatar. Below, the main insights and recommendations are discussed, and I comment on the potential of aligning social practice theory and the three-dimensional energy model.

6.1 Social heating practices in the current situation

The most common aspects of energy systems – consisting of energy carriers, devices, and services – of ger households are as follows. The primary energy carrier, coal, as well as small amounts of wood, are burned in a traditional or improved coal stove (the energy device), in order to fulfil the following energy services: heating the interior of the ger; cooking or heating liquids using the top of the coal stove; and having a spiritual function. Besides coal stoves, other commonly used energy devices for cooking are electric stoves and kettles. Energy usages consist of burning coal in the coal stove, optionally employing cooking equipment on top of the coal stove (with its rings removed), performing rituals that interact with the coal stove, and employing electric stoves and kettles.

Overall, six social practices were identified for coal-stove households that form valid reasons to keep using a coal stove. First, it is defining that coal stoves can generate a lot of heat and therefore provide the right thermal comfort, with high temperatures deemed important for children and elderly, and possibly influenced by the necessity to frequently go outside the ger in winter.

Second, coal stoves are still commonly used as primary, or secondary, cooking devices. Certain typical Mongolian dishes are traditionally cooked on a coal stove: most notably, *uuts*, which can only be cooked on a coal stove due to its size, and which forms an essential part of *Tsaagan Sar*, the most important Mongolian holiday of the year.

Third, electricity is perceived as dangerous and associated with a high risk of fire. One woman perceived electric heaters as negative, after having sustained a burn injury from a different electrical energy device. In general, this perception might be bolstered by the low quality of electricity cables and informal electricity redistribution in ger areas, which could indeed make the use of electric energy devices more dangerous.

Fourth, there are affordability concerns for electric heaters, and the common perception is that using a coal stove is cheaper than using an electric heater. For operational costs, this is not necessarily the case, as two studies have claimed that heating a ger electrically is cost-effective compared to coal-based heating, at least when the ger is properly insulated (Braham et al., 2022; Pillarisetti et al., 2019). Regardless, the perception of higher operational costs might be influenced by several contextual factors, including the fact that gers are a relatively cheap form of housing; that electricity costs are billed monthly, versus the weekly purchase of coal; and that a part of ger households does not have an individual meter, but needs to indirectly purchase electricity from another household, and therefore does not receive electricity subsidies.

A fifth social practice has to do with the spiritual role bestowed upon the coal stove of a ger. Coal stoves have been passed on through several family generations, and they are considered to house a fire spirit that protects the home and the family. This is symbolized through a shamanistic ritual that is performed when changing coal stoves, where ashes are passed

from the old stove to the new stove, to ensure that the fire spirit is carried over to the new stove and can continue to protect the home.
Finally, coal stoves are powerful enough to heat poorly insulated gers, whereas electric heaters are not. Owing to their origin as a nomadic dwelling, gers are inherently difficult to insulate well. Still, many gers are not insulated as well as they can be. This is partly due to financial constraints of residents, but there are some practices that can be performed in order to ensure that the present insulation works optimally, such as removing snow from the roof in winter, and ensuring that there are no gaps between *esgii*, the typical felt layers of insulation, when reassembling the ger before wintertime.

6.2 Heating innovations and social practices around electric heaters

In recent years, anti-air pollution measures have been taken by the government that have impacted the energy systems of ger residents: improved coal stoves were introduced, raw coal was replaced by refined coal briquettes, and free night-time electricity was meant to promote the use of electric heaters as a secondary heat source, although electric heater use remained low. Apart from the electricity subsidy, the government's efforts have largely focused on coal, and technical challenges remain in electrification efforts.
Apart from governmental efforts, several initiatives and pilot projects have been organized by NGO's, companies, and researchers, exploring the feasibility of innovating ger heating systems through electrification and the improvement of ger insulation. As electric heaters remain unused by most ger households, these small-scale projects appear to be the main instances of heating innovation in ger heating in Ulaanbaatar.
Ger households that have participated in such initiatives have indicated several key changes in social practices that form reasons to use electric heaters as their main heating source. First and foremost, electric heaters are associated with ease of use, convenience, and cleanliness, reducing the time and effort that ger residents need to spend in order to keep their ger heated: there's no need to handle dirty coal, wear special clothes, go outside to get coal, wake up early in the morning to light the stove, or make a weekly trip to purchase coal (which can last an hour or more). This reason is what ger residents who have adopted electric heaters have been most enthusiastic about.
Second, the benefits to children's health, both in terms of burn risk and respiratory diseases, appear to be meaningful to parents. Participants in Breathe Mongolia's *Let's Take Action!* project perceived improvements in their children's cognition and health after using an electric heater and attending workshops on air pollution's negative effects on children's health, although these improvements were anecdotal. As for burn risk, an electric heater gets less hot than a coal stove, which means parents need to worry less about children moving close to it, and being left at home alone, a practice which is not uncommon in Mongolia.
Third, the increase in carbon monoxide poisoning after the introduction of refined coal briquettes have led some residents to consider refined coal briquettes as unsafe and/or unhealthy. Besides the general health concerns regarding air pollution, which ger residents are widely aware of (Bonjun, 2021), the refined coal briquette and its association with carbon monoxide might, ironically, provide additional reasons for residents to move on from coal-based to electric heating.
It is noteworthy that residents indicated that, while they are happy with their electric heater due the above reasons, they did not plan on getting rid of their coal stoves. Instead, they

said they would continue to make use of the coal stove occasionaly, such as when cooking a traditional dish. This decision reflects the importance of the coal stove in Mongolian society beyond a daily heating device.

6.3 Recommendations

In this research, more social practices were found that promote continued use of a coal stove than social practices that promote adoption and use of an electric heater. Though it can be hard to quantify how important these social practices actually are to ger households, it is beyond doubt that there are valid reasons for households to keep using coal stoves. Perhaps this is not surprising, considering the slow adoption of electric heaters.
While adopting electric heaters and improving insulation will remain a challenging process, several recommendations to accelerate this process were drafted based on the insights gained in this research. These recommendations are mainly aimed at the actors who are designing policies, programmes, or products that promote the reduction of coal consumption, such as the government, NGO's, and private companies. They are calls to consider aspects of the social heating practices of residents that likely impact the energy choices they make – and as such, are important to account for when designing policy, programmes, or products.

6.3.1 Consider electric heaters as a supplement to coal stoves, not a complete replacement

The term energy stacking describes a process where people accumulate fuel sources over time, using novel sources to fulfill novel energy services (Kowsari & Zerriffi, 2011; Masera & Navia, 1997). People do not simply switch from a current energy device or carrier to the next: rather, these are accumulated over time, with older devices and carriers still being used for their original purposes. In this research, this phenomenon has been observed as residents use coal for heating and cooking, gasoline for vehicles, and electricity for refrigeration and entertainment.
While air quality can only be improved by limiting the use of coal stoves, it is crucial to understand that the objective should be its reduction, not complete elimination. Limiting coal stoves to occasional use would already provide large benefits for air quality in Ulaanbaatar. Therefore, it is not necessary to promote electric heaters as a complete replacement for a coal stove.
During this research, several instances were observed in which residents kept their coal stove for occasional usage after adopting an electric heater. Around half of the participating households in the *Let's Take Action!* project still had their coal stove installed, and one participant said, "We will never get rid of our coal stove." (focus group discussion) Another household that had only used their electric heater for heating still kept their coal stove in order to prepare *uuts* during *Tsaagan Sar*. Similarly, an electrically heated *baishin* still used their coal-powered boiler to prepare *uuts* and to occasionally burn wood during rainy summer days. In another electrified ger, the coal stove was still used in the coldest months.
Accepting an accumulative adoption of electric heating, while the coal stove still fulfils a number of essential services, would simplify the path towards cleaner air by reducing the number of social practices that would need to be adjusted. Importantly, it would allow the coal stove to remain a significant symbol in Mongolian culture. Practices like preparing traditional dishes, and performing fire-related rituals, can be fully sustained while using the

coal stove only a few times per year.
As a matter of fact, the Government of Mongolia did try to promote auxiliary use of the electric heater by implementing a free night-time electricity subsidy. However, not all families have individual meters, which is required in order to receive the subsidy. Furthermore, temperatures at night might be too low to use only the electric heater, which would reduce its utility when used specifically because of the electricity subsidy. Thus, supplementary electric heater adoption might be promoted more effectively by adjusting such policies.

Use electric heaters at the start and end of the heating season
For instance, electric heaters could be used more effectively during the start and end of the heating season, when temperatures have not reached their coldest point. During these periods, electric heaters could accommodate residents' thermal comfort without having to match the thermal performance of coal stoves, and without an immediate need to invest in better insulation, trimming investment costs. The coal stove would continue to heat the ger during the coldest months, and could still be used for cooking throughout the year. If a blackout would occur due to limited grid capacity, the coal stove could be used as a backup.
At the same time, seasonal use of the electric heater would familiarize ger residents with its benefits, primarily the convenience, ease of use, and reduced burn risk. As residents get accustomed to the benefits of an electric heater, they might have more motivation to take measures that enable them to use their electric heater during a larger part of the heating season, like improving their ger insulation, for which investments could be spread over time. Based on the positive reaction of the participants of the *Let's Take Action!* project, it can be expected that these benefits will not remain unnoticed to most ger residents.

Design the electric heater so it fits well next to the coal stove
The CHIP package provides a wooden table with electric heaters on three sides, which is designed for an electric stove to be placed on top. This design imitates a coal stove in its shape and function. Such a familiar design can be beneficial for a strategy in which the coal stove is intended to be fully substituted for an electric heater, but due to the limited size of a ger, might not fit well alongside a coal stove. On the other hand, a thin and wide electric radiator does not provide a familiar form, nor a surface to cook on, but fits better alongside a coal stove in the centre of the ger like in Figure 1.

6.3.2 Prioritize the improvement and proper maintenance of ger insulation

Since electric heaters generally have a lower heat output than coal stoves, for some poorly insulated gers, it is necessary to improve insulation before electric heating can be used. In addition, better insulation reduces the heat load of gers, which can lead to reduced coal consumption and a decrease in air pollution. This is why it could be considered as a first step towards reducing air pollution, one that comes before attempts to electrify ger heating. However, in order to guarantee that improved insulation actually leads to reduced consumption, the social practice of heat regulation needs to be considered. Ger residents are used to powerful heating with sub-optimal insulation, and some react to overheating by opening the *toono* or the door. In the effort to improve insulation, it is essential to consider this practice, so that improved insulation does not lead to people opening the *toono* or door more often, while continuing to use the same amount of fuel.

While it is true that certain insulation improvements cost money, some insulation practices can be adopted without additional costs. Insulation practices cost money when they require the purchase of new materials. These practices include using three layers of *esgii*, and a *berzent*, in the winter; replacing *esgii* and *berzents* when they are degraded or damaged; using an anteroom to improve the thermal performance around the door; and installing air ventilation to reduce the probability of indoor moisture condensing in the *esgii*.
On the other hand, many insulation practices can be adopted without additional financial expenses: regularly clearing snow from the roofs of gers in the winter to reduce the chance of *esgii* becoming wet from melting snow; insulating the joint between wall and floor from the outside by packing dirt or gravel (if available), or alternatively snow, against the edges of the ger; reassembling the ger prior to the cold season to allow the *esgii* to dry; and minimizing air infiltration by making sure that there are no gaps between the *esgii*.
Ensuring good insulation is an important step to reduce air pollution from domestic coal consumption. Since financial limitations – whether real or perceived – are predominant in the energy choices of ger households, it would be a worthwhile effort to encourage the adoption of the insulation practices that do not require residents to spend money.

6.3.3 Utilize two powerful social networks in ger areas: family and Facebook

As suggested by Section 5.4, the strong family ties in Mongolian culture could act as pathways through which information and benefits regarding electric heating and best insulation practices are spread. Different households of the same family often live on the same khashaa, and family members frequently visit each other's gers. It was observed several times that people became interested in adopting electric heating after they experienced the benefits first-hand, while visiting another ger that belonged to a family member. Such experiences might especially be effective to reach groups of people who might otherwise dismiss such innovations, or who are particularly accustomed to traditional coal-based heating.
While information will naturally be distributed in this way as electric heating is adopted, actors who are vending or distributing electric heating or insulation could take advantage of this network. For instance, a small discount could be offered if family members are referred. Or, if professionals go to a ger to install some component, they could be instructed to invite family members from different households on that khashaa during the installation process.
Similarly, Facebook is used by a very large percentage of the Mongolian population, and the social media platform has been named as a primary source of information by several ger area residents. For these reasons, it is essential to have an established presence on Facebook, as it is a primary way to disseminate information to a large part of the population.
Thus, understanding that family networks in ger areas will provide family members of households that adopt heating innovations with first-hand experience, and that Facebook is a widely-used primary source of information, can assist in the design of a strategy to distribute information (and experience) regarding the advantages of electric heating and proper insulation.

6.3.4 Adjust electric heater design to become more aligned with Mongolian culture

As has become clear in my many conversations with residents, Mongolian people value their culture and cultural heritage highly. Their nomadic way of life is ancient and has been com-

mon practice up to three decades ago, so most families are not more than a single generation removed from this lifestyle. This is not to say that Mongolians do not adopt new technologies: televisions and refrigerators are common in gers, at least in Ulaanbaatar (U.-U. Purev & Hagishima, 2020).
However, the energy transition implies a phasing out of a traditional technology, the coal stove, which both literally and figuratively is located at the centre of the home, is commonly handed over through generations in families, and plays a role in spiritual practices. This is why my principal recommendation is to account for a transition strategy in which the coal stove will retain some of its uses, like for cooking (special) meals, fulfilling spiritual practices related to the fire spirit, and, at least during a transitional period, providing heat on the coldest days. Still, some additional considerations in the design of the electric heater could ease the introduction of the electric heater as a new icon in Mongolian culture.

Figure 6: A miniature version of a traditional coal stove encountered at a stand selling shamanistic items on the *Narantuul* market in Ulaanbaatar, with functional lid, ash drawer, and door. (May 2023)

According to religious beliefs, a fire spirit resides in the coal stove, providing good fortune and protecting the household. When one coal stove is replaced by a new stove, ashes are transferred between the two. While there is no fire chamber in an electric heater, a small chamber could be incorporated into the design, or clipped onto the heater, that can carry ashes from the coal stove that the heater is replacing (or supplementing). Alternatively, a miniature version of the coal stove, like one that was encountered on a market (see Figure 6), could become a symbolic representation of the coal stove that ashes could be placed in.
Another possible adjustment to electric heater design is to incorporate symbols that are commonly seen in Mongolian culture, including in ger areas. Gers themselves can be richly decorated, especially the wooden skeleton. One symbol that is ubiquitous in ger areas is the Buddhist eternal knot, which can be found on wooden skeletons, on the fences around a

khashaa, on the improved coal stoves that were distributed (see Figure 2), among others. Adapting the electric heater design to include traditional Mongolian symbology might help to align it better with the design of gers.
It would need to be investigated further whether such symbology would indeed have a significant positive effect, and what form or shape these adjustments should take. However, small design adjustments that change a generic electric heater into a Mongolian electric heater might help for it to be considered as a continuation of Mongolian tradition, rather than a break away from it.

6.3.5 Adjust the electricity subsidy to better address affordability concerns

At present, the annual free electricity during night-time in the cold season (November 1st to April 1st) is beneficial to all ger residents, and it might have motivated some to purchase an electric heater to use during the night. This type of subsidy is an essential component in the transition towards electrification of heating, as it addresses the main concern that ger residents have with regards to electric heating: a significant increase in electricity bills. However, I do think that some adjustments could be made to the subsidy in order to make it more effective at boosting the adoption of electric heaters.
First, consider applying the subsidy to a different period. In the first recommendation (Section 6.3.1), it was mentioned that it might be more feasible for electric heaters to be used during the start and end of the heating season. If that is indeed the case, a subsidy on electricity in those months (both during daytime and nighttime) could further promote that adoption pattern.
Alternatively, the subsidy could more directly address the concerns of unaffordable electricity bills. Possibly due to variation in electric heater performance, ger size and insulation, and daily activity patterns, it is uncertain what the increase in operational costs would be when adopting electric heating. Multiple studies showed that electric heaters can be operated with similar costs to coal stoves (Braham et al., 2022; Pillarisetti et al., 2019), and one resident said there had been no significant increase after adopting an electric heater and improving their insulation (focus group discussion). But some residents estimated that their monthly electricity bills would become unaffordable when using an electric heater.
This widespread concern could be addressed through an electricity subsidy that guarantees operational affordability of electric heaters, for instance by defining a maximum monthly electricity bill that ger households with electric heaters would need to pay. Of course, the subsidy should be designed in a such a way that it cannot be exploited, which might prove difficult or infeasible. However, a step in this direction might already result in many residents feeling financially secure enough to purchase and start using an electric heater.
In addition, as has been mentioned, a part of ger households does not have a individual electricity meter, which is a requirement in order to receive the subsidy. It is logical that this requirement is in place, as the electricity consumption needs to be monitored in order to calculate the bill to which the subsidy is applied. However, relaxing this constraint, or providing an alternative for households without individual meters, could help to spread electric heater usage among real households who are currently barred from the advantages that this subsidy can provide due to a lack of registration.

6.4 Reconciling social practice theory with the three-dimensional energy profile

In her landmark paper *"Beyond the ABC: climate change policy and theories of social change"*, Elizabeth Shove states that it is impossible to merge social practice theory with behaviour-based policy theory, which considers the potential impact of any policy as its influence on individual choice: *"On all the counts that matter, social theories of practice on the one hand, and of behaviour on the other, are like chalk and cheese.* [...] *It is useful to be clear about the incommensurability of these contrasting paradigms, and hence about the impossibility of merger and incorporation. Whatever else it might be, a more holistic approach is not one in which letters like 'S' for system, or 'P' for practice are grafted on to the ABC."* (Shove, 2010, p. 1279)

As mentioned in Section 3, the three-dimensional energy profile does appear to be cut of the ABC-based wood, as it equates a development of individual choices in three dimensions of energy systems with the energy transition. I agree with Shove that it does not make sense to model a transition as driven by a process of active and conscious choices, but instead to consider that new situations passively emerge from a vast, interconnected network of social practices and their elements.

However, I would argue that the two theories are not as misaligned as Shove's claim about the role (or existence) of individual choice makes it seem. Both social practice theory and the three-dimensional energy profile argue that the meanings and competences that individuals perform in relation to energy materials are central to understanding how energy is consumed, and that individuals are not rational agents that will steadily move towards an optimal energy system in purely technical and economical terms.

Furthermore, the three-dimensional energy profile is a useful framework in that it provides concrete avenues of change: it clearly defines four categories of factors that determine the energy systems (albeit through household choice) – four lists of attributes, personal and contextual, that one can aim to change in order to cause a change in energy systems. Compared to social practice theory's vast web of elements in which everything is interconnected to everything else, where it seems no action is made consciously, and where there no hierarchy can be defined (T. Schatzki, 2016), the three-dimensional energy profile provides simplicity, clarity, and boundaries – albeit, perhaps, at the cost of making unrealistic assumptions.

Therefore, it does not seem to me that the two theories are truly "incommensurable". Instead, I attempted to embed the three-dimensional energy profile into social practice theory, as described in Section 3.2.3 and illustrated in Figure 3. In doing so, I introduced a fourth dimension, energy usages, which I see as competences that are related to the materials (energy devices and carriers) and meanings (energy services) related to energy systems. Energy systems, consisting of these four dimensions and spread between the three elements of social practices, are placed at the center, but there is no clear demarcation of the energy system. After all, I believe that the main point social practice theorists (and the authors of the three-dimensional energy profile, in their terminology) try to stress to policymakers is that energy consumption is related to, and shaped by, many more social practices than one might think, and that it would be impossible to draw a strict line around "what needs to be considered". In this adapted composite model, I follow the notion that the status quo is defined by the social practices that are being practiced in a society by everyone, and not defined by the conscious choices of individual energy users. As such, I do not think I have given a proper place to the four categories of determining factors proposed by the three-dimensional energy profile. Perhaps, they could be considered as additional social practices, present in the

landscape that gives rise to the current situation.
This is what I consider as a shortcoming of this composite model, and perhaps of social practice theory as a whole: there is no clear strategy of how to change the set of social practices that form an energy system, other than saying that, well, the entire set of social practices has to change. The notion of social practices following a flat ontology means that nothing can be excluded from consideration: everything might be relevant.
Nevertheless, social practice theory has been essential in defining the topic of this thesis, as it emphasizes the importance of aspects that might typically be taken for granted: daily habits, activities, meanings, and competences, rather than schematics of electricity grids, or energy flow analyses. In addition to social practice theory, the three-dimensional energy profile provided two key insights: the realization that energy consumption is driven by a desire or need to fulfil energy services; and by introducing the notion of energy stacking, which features heavily in my primary recommendation to consider electric heating as a supplement to the coal stove, with the latter to remain used occasionally in the fulfilment of certain practices.
The adapted model which embeds the three-dimensional energy profile and social practice theory might have been underutilized in the construction of the recommendations, which do not contain any explicit reference to it. This might be a sign that this model has not been worked out solidly enough, or that it fundamentally falls short. However, the process itself of going through various iterations of this model, of integrating the various theories, might have contributed to a better understanding of the issue overall.

6.5 Limitations and future research

As is the case in any piece of research, the research of this thesis was subject to several limitations. One limitation is that I did not have the opportunity to speak to anyone representing the Government of Mongolia or a central department in the municipality of Ulaanbaatar. As a result, any attitude or governmental action could only be described using second-hand sources. An exception to this was my conversation with the employees of the *khoroo* office, but they work at a very local scale, and were not in charge of any central planning or policy-making.
Another limitation is that the group of ger residents I have spoken to might not fully represent the opinions of the overall ger residents of Ulaanbaatar, owing to the methods through which I encountered ger residents. This research was produced in collaboration with several NGO's who had existing ties with residents, who formed the majority of the ger residents I spoke to. These residents had often been selected for programmes because of their prior interest in the issue of air pollution and coal stove, suggesting that most of my conversations have been with residents who had an increased awareness of the issue, or had additional reasons to switch to an electric heater. Some of the conversations which are used as sources for this research were the result of approaching residents on the street. While these conversations might be assumed to be more representative of the average ger resident's opinions, it is important to keep in mind that not all of the approached residents were willing to talk, which again might have an impact on the range of opinions captured in this research.
Because this research was highly qualitative, it remains necessary to quantitatively analyze how common some of these social practices are among ger residents. For instance, while fire spirit rituals in which the coal stove plays a role definitely exist, it is unclear what fraction of people continue to find value in this practice. Or, while the perception of coal (briquettes) as

unhealthy might prove a valuable argument for coal stoves, the question remains how many residents indeed have this perception. More quantitative research in which these social practices and their prevalence are explored further would be an important step towards finding the truly important social practices that need to be accounted for in the transition from coal stoves to electric heaters.

Despite preliminary evidence that electric heaters can be employed for similar operational costs as coal stoves, and some anecdotal evidence from ger residents supporting this, the general perception around electric heating seems to be that it will cause electricity bills to become unaffordable. Further research on the actual expected increase in bills based on differences in ger insulation, size, electric heater capacity, and daily activity patterns, and effective dissemination of such findings, is necessary to dispell any inaccurate perceptions around electric heater-induced bill increases.

In this thesis, changes to the current subsidy providing free electricity at night during the heating season were recommended, in order to make the subsidy more effective at promoting electric heater adoption. However, while it has been reported that the existing subsidy was ineffective (Cardascia et al., 2022), it is important to note that no detailed evaluation of this subsidy could be encountered. Further research on residents' reactions to this subsidy and how it impacted electric heater adoption could provide valuable input for improvements of the subsidy.

But, on a personal note, while research is always important, I believe that the time has come and gone for pilot programmes and research projects that only cause marginal change. Future research is important, but it is no reason to delay more substantial action. There is enough knowledge to be found in existing literature, among local actors, and especially, among the residents of ger areas themselves, to be able to implement projects at scale, in the right way. Otherwise, air pollution will linger over Ulaanbaatar for many more winters than necessary.

7 Conclusion

While air pollution in Ulaanbaatar is an issue that is well-recognized by residents, government, and international organisations, previous attempts to address the issue have been deemed ineffective, and existing research has focused on economical and technical requirements and limitations. According to social practice theory, the underlying network of social practices defines and shapes society, and this is often under-investigated, limiting the possibility of addressing problems in an effective manner. Therefore, this study has attempted to answer the question, *"How are ger households in Ulaanbaatar's ger areas adapting their social heating practices in the transition from coal stoves to innovative heating solutions?"* To this end, the following research questions were formulated:

1. What are the common social heating practices among coal-stove households in Ulaanbaatar's ger areas?

2. What heating innovations are being adopted by ger area households, as influenced by governmental and non-governmental actors in the socio-political landscape?

3. How are households changing their social practices to accommodate these adopted heating innovations?

The coal stove is not just a tool for heating a ger that is used out of convenience, but it is part of the Mongolian cultural heritage: a nomadic society that has become sedentary only very recently, with a long history of heating a ger from its center, using a limited set of available solid fuels, in a climate with extremely cold winters. In this context, the coal stove has been an important tool that provides not just the strong thermal performance that is required for poorly insulated gers and the necessity to go outside frequently, but also is commonly used for cooking, with some typical Mongolian dishes being linked to the coal stove in particular. In this way, the coal stove has become a cornerstone in the social practices of ger dwellers and fulfils a role in fire spirit rituals.
Due to the recognition of the severity of air pollution in the capital city, and the contributing factor of coal stove usage in ger areas, several efforts have been made to try to stem the impact of coal consumption on air quality. The Government of Mongolia has mainly focused on changing the type of stove and type of coal used. While international researchers and global health organisations have stressed the importance of replacing the coal stove with an alternative fuel source like electricity, the focus of the government on a coal-based solution is perhaps not surprising given the fact that the stove, burning a real flame at the center of the ger, is such a centrepiece in Mongolian society, tradition, and culture. A cornerstone is not easily replaced.
However, several pilot projects and electrification initiatives by NGO's and small companies have been met with a positive reaction from ger residents. After adopting electric heaters, ger residents have indicated that the heating process has become much easier and more convenient, leading to more consistent temperatures, less dust from coal inside the ger, and more free time. Furthermore, electric heaters are considered to have a positive health impact on children, including by having a lower burn risk than coal stoves. Finally, a fear of CO poisoning from coal briquettes, a new type of fuel that has replaced raw coal, might provide additional support for non-coal-based heating.

But perhaps the most important observation is that many of the ger residents that have adopted an electric heater have still kept their coal stove, for occasional uses, most of which are not related to heating at all. This has led to the recommendation that, following the energy stacking theory, electric heaters should be considered as a supplement to coal stoves, not a full replacement. In addition, it was recommended to prioritize the improvement of insulation, to adjust electric heater design to become more aligned with Mongolian culture, and to adjust the electricity subsidy to be more effective at assuaging affordability concerns. Beyond heating practices, it was observed that family networks and Facebook are two social networks prevalent in ger areas, and that they can be utilized to spread the benefits of, and information regarding, electric heating.

Ulaanbaatar presents a unique instance of the metropolitan challenge of urban energy, which many cities face, due to the severity of local health effects, and the unique context in which the city is situated. Nevertheless, a successful reduction of coal consumption in Ulaanbaatar could provide valuable insights for global efforts to reduce harmful effects from coal use.

This thesis has focused on social heating practices of ger residents living in the ger areas of Ulaanbaatar. Hopefully, the appreciation of the coal stove as a tool that is used for more than just heating, and to which several cultural meanings are attached, can help contribute to the design of better strategies of reducing coal consumption in service of improving air quality in a heavily polluted, but also beautiful and fascinating, city and country: Ulaanbaatar, Mongolia.

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A Observation frame for ger visits

Below, the observation frame that was consulted during ger visits is included. Its structure was not rigidly followed, but it should be considered as a loose collection of topics that served as reminders of points for the author to focus on in the course of a ger visit. This means that not every point was considered in every ger visit. It was partially drafted prior to the period of fieldwork in Ulaanbaatar, as part of the thesis proposal, and later expanded on, based on research and interviews.
Specifically, if a point or question is prepended with [UUP], this indicates that this point was inspired by either the publications by, or interview with, Uelun-Ujin Purev (see Section 5.2.4).

Household characteristics

- How long have you lived in this ger?
- How many people live here?
- Who is the main person responsible for heating?

Multiple gers on *khashaa*

- Do you or your family use multiple gers or *baishins* on this *khashaa*?
- Where do you usually sleep? Where do your family members usually sleep?
- Where do you and/or your family members usually spend the day?
- Where do your children stay during the day, and where do they usually sleep?

Air pollution cause & effect

- What causes air pollution (in the winter)?
- (and) How much is caused by coal stoves? What %?
- What do you think the effects of air pollution are?
- Are your children sick more often in the winter or in the summer?

Electrification

- [If the resident does not own an electric heater] Have you considered buying an electric heater? Why haven't you done so?

Ger interior organisation

For gers with electric heaters

- Where are the electric heater and related materials (e.g. batteries) located?
- [UUP] Does this impact the traditional/previous interior organisation into zones?
- Have you moved anything (cooking equipment, bed) because of the electric heater?

Materials: insulation and lifespan

- What kind of insulation is present, how do you interact with it?
- [UUP] What was the last time you replaced *esgii*?

For gers with coal stoves

- [UUP] Do you replace the floor because of the dirt from carrying coal?

Cooking

- What do you use to cook?
- Do you use the coal stove to cook? Always, or in particular scenarios?
- Check for presence of electric kettle, rice cooker, electric hot pot, electric stove, oven, portable gas stove, microwave.

For gers with electric heaters

- What did you previously use to cook?

For gers with coal stoves

- Do you use this to cook or heat anything?

Clothing

- What kind of clothes do you wear in the winter?
- When you go outside briefly (e.g. to the toilet), which clothes do you wear?

Thermal comfort

- What is the indoor temperature?
- [UUP] Is the indoor temperature comfortable? Is it occasionally too hot? Is it occasionally too cold?

B Focus group discussion notes and post-its

B.1 Guideline for facilitators

We have four topics. For each topic, we will take about 25 minutes.
It is most important to guide the discussion in a neutral manner, encouraging everyone to contribute, and not lead the discussion in a particular direction. Make sure to keep the conversation on track and ensure that the group doesn't get stuck on one topic for too long. But it's not necessary to go through all the questions one by one! If people are talking about something you think is relevant, it is okay to let them talk for a bit. Some questions can be skipped, that's okay.
Some questions have other questions between brackets; those questions can be used to start the discussion a bit if people don't really know how to answer/talk about that topic.

Installing CHIP package

This first topic is quite concrete and practical, it's to get feedback for People in Need and Breathe Mongolia. We want to figure out what the installation process was like, and whether the parts and the support (installation and instructions) was adequate and complete.
If people indicate any problems they had, check with other participants if they had the same and solved it already.

- Initial discussion (15 min)

  The first topic is about the delivery and the installation of the CHIP package: if there were any problems, and how they can be improved.

  - How did the delivery go (what time, who was home, etc.)? (Let a couple people share their experience.)
  - Were there any problems with the delivery?
  - Did the delivery people install the CHIP package for you? Which parts did they install? Were there any difficulties doing so?
  - Were there clear instructions; was it possible to ask questions?
  - Electric heater: has it worked well this winter, are there any problems?
  - In the past winter, has it been cold when using the electric heater? How did you deal with it?
  - Insulation: did you reassemble your ger since the extra insulation was installed, and was it easy to re-install the insulation? Are there any problems with the insulation's performance?
  - Air ventilation: is it installed? Do you use it? Do you prefer to open the door instead of using the ventilation (and why)?

- Post-its (10 min)

  For ten minutes, allow people to write down suggestions on how to improve the CHIP package, for instance in the delivery process, the installation, or the components. They should write them on the post-its that are distributed to them. Paste the post-its on the wall, at the relevant section ("CHIP package").

Thermal comfort

Thermal comfort is: when do people feel that the temperature is comfortable? Here, we consider indoor thermal comfort. There is no "objective" thermal comfort, but it depends on someone's culture and societal context.
Many ger residents have a pretty high temperature as thermal comfort. They are used to heating their home to the maximum, and they open the door when it gets (way) too hot. This behaviour is probably due to the fact that a coal stove burns for several hours at variable temperatures.
But heating the home to the maximum is not good, because you use a lot of coal. What are the underlying factors that cause people to have this heating pattern, and can we do anything to change that?

- Initial discussion (15 min)

  For the second topic, we will talk about thermal comfort. Thermal comfort means: when is the temperature of a ger comfortable for you? This is a feeling that can be different for different people. First, we want to learn about the thermal comfort of ger residents by asking you some questions.

  Many ger residents make their ger really hot, almost too hot, and then manage the temperature by opening the door. First, let's talk about before CHIP was installed.

  - What is the reason that many people heat their ger to a maximum?
  - Do people have such hot gers because of the way the coal stove works? If so, why?
  - Are there reasons to keep the ger extra warm? (for instance, when you have young children?)
  - It is difficult to regulate the temperature of a coal stove, right? Besides opening the door, do you have any other ways in which you control the temperature?
  - When it is not so cold outside, how do you heat your home without making it very hot inside?

  Now, you have a CHIP package with an electric heater:

  - Did your thermal comfort change when you switched to the CHIP package? Did the general temperature change? Are there moments when it's less warm, or when it's warmer, with electric heater than with coal stove?
  - And did your behaviour change? (Do you open the door less or more often? Do you wear different clothes?)

- Post-its (10 min)

  During ten minutes, people should write the following on post-its: write down 3 main suggestions you would give for someone to improve thermal comfort.

  Again, stick the post-its to the wall in the second section.

Break (15 min)

Let's have a short halftime break.

Popularity of ger & information availability

People's perceptions often change once they see that something (in this case, CHIP package) works in real life. We want to investigate how we can make people more enthusiastic about the CHIP package.

- Initial discussion (15 min)

  We want more people to be enthusiastic about the CHIP package! In this topic, let's talk about how people learn about the benefits of the CHIP package.

  - Did the opinion of your family members and neighbours about electric heaters change after you started using the CHIP package?
  - Were there family members who were skeptical before, and who are now more enthusiastic about CHIP?
  - Do you think there is enough information available about CHIP; where should this information be available?
  - What do you think are good reasons to convince other households that they should get the CHIP package?
  - What are the best ways to reach those households? (Is it through family members; Facebook; *khoroo* office; or other ways?)
  - We heard from a woman (not part of the project) that she wouldn't want to have an electric heater because she believed that it could easily cause a fire. Do you think this danger exists? How would you convince her that it's safe?

- Post-its (10 min)

  During ten minutes, allow people to write down any recommendations or suggestions they have on how to make people more enthousiastic about the CHIP package. Maybe it's a way to make people who are skeptical more convinced; or maybe it's a way to make people more familiar with the CHIP package if they don't know it yet.

  Again, stick the post-its to the wall in the third section.

Insulation

Gers are often not properly insulated. Part of this might be due to materials (availability and price), but another important factor is maintenance.
Also, it is an assumption that improving the insulation will automatically reduce the amount of coal used. But is this actually a valid assumption?

- Initial discussion (15 min)

  - What are the main ways to insulate a ger?
  - What is wrong with current insulation? Which parts of ger are poorly insulated?
  - Which things are good about current insulation? What about current insulation do you think is important to keep?

  - What aspects of insulation materials are important? For instance: price, made in Mongolia, traditional design, using natural elements.
  - What is the main limitation for current insulation? like:
    * Price: maybe it's just too expensive to buy the necessary insulation?
    * Material: maybe the available material is just not effective enough?
    * Habits of maintenance: maybe people just don't know how to, or don't bother, maintaining their insulation?
    * Other reasons...
  - Is it possible to improve insulation without increasing the price?
  - What are the good and bad things of the insulation part of the CHIP package? Are there improvements that you made or that you want to make?
  - Is it easy to use the insulation for CHIP? Do you know how to reassemble it properly when you reassemble your ger? Do you know how long it will lasts? Do you need to do anything to keep the insulation in a good state (maintenance)?
  - Where do you buy insulation? If a company would produce a really good new insulation material, how can this company make it available in the best way? Market/зах, online (Facebook), etc?

- Post-its (10 min)

  During ten minutes, allow people to write down answers to the following questions on post-its: What advice would you give your friend to improve the insulation of their ger?

  Again, stick the post-its to the wall in the fourth section.

B.2 Conversation notes

Below are the notes that were taken of the discussions of each topic, for each group. For each group, a volunteer of Breathe Mongolia was taking notes live. For Narangerel's group, names were not noted down.

Narangerel's group

- CHIP package & delivery

  - The delivery people gave instructions on installing the package. We ordered the night before and it came in the morning. Some households installed the whole package by themselves.
  - We wanted it to be delivered in the evening but they refused and brought it to my mother's house. They came to set up the electricity connection 2 months after bringing the package. Air ventilation is still not installed.
  - The cables were short and it would be better if they were longer.
  - The instructions in the booklet were clear and easy to understand.

- It is difficult when the electricity is blacked out. We open the door when the air ventilation was not installed. But opening the door flows the cold air into ger rapidly. It seemed too difficult to install the whole package gadgets ourselves.
- The ger was constantly warm and comfortable because we installed the CHIP package's insulation fully. The floor insulation was kind of floating which was difficult. When not installed correctly, it was getting frosty.
- We used the insulation for 6 wall ger and there was about 50 cm of area not covered. We complained about this but they ignored us.
- The households with air ventilation don't have to open the door. Those who didn't have the air ventilation installed needed to open the door.
- Some households waited with their ger's seasonal reassembly until the insulation material arrived.
- There should be professional electricians who help with setting up the electric heater and cables.
- The whole package should come around 15th september to 15th october.
- One person didn't install the air ventilation on the door because she thought it would be bad luck to make a hole in their door.

- Thermal comfort
  - We open the door and *toono* [to regulate temperature]. When using a traditional stove the temperature inside gets too hot or too cold suddenly. To make a comfortable temperature we fire the stove often with a small amount of coal. When using an improved stove the thermal comfort is better.
  - We fire 3-4 times a day when using a traditional coal stove and 2 times with an improved stove.
  - The electric bill was about 200,000MNT without the electricity discount.
  - When using the CHIP package, the temperature was constant and comfortable, like it is in apartments.
  - The daily duties have become easier and our clothes are cleaner. Also, I'm not afraid our kids will get burned.
  - We don't have to change our clothes often to accommodate to ger temperature. Also, we no longer have dirty clothes which were used when getting coal. Now we have more free time. We are playing with kids and scrolling social media using that time. When we get home after work we no longer have trouble choosing who will fire the stove.
  - Before the electric heater, some of the family members had to wake up early to fire and make ger warm. Now we are all waking up at the same time.
  - If the ger is insulated well the electric bill is going to be lower.

- Encouraging people to get CHIP

  - People say they want to get it. People living in the countryside are also interested in this. It would be nice if CHIP was available for the *baishin* as well.
  - People who see us using CHIP are really interested in the CHIP package. Older people don't like to get rid of their traditional stoves and younger people are loving this.
  - Some people are afraid of adjusting to an electric heater because the cables are not safe enough.
  - People have very little information about this. *Khoroo* office only works with the people they know closely. Its information should be distributed through media and facebook. [The CHIP team] should also check whether the *khoroo* offices are giving information evenly.
  - Other households should definitely get it because it's saving so much time.
  - What to say to the person who has negative thoughts about it: You should check and fix your cable and other electricity things because it is one's own responsibility.

- Insulation

  - Before getting the CHIP package, we had 2 layers of *esgii*. Now it is still same.
  - One older participant said it is bad luck to make a hole in the door.
  - CHIP package's insulation is a little problematic. They should work on their floor covering.
  - Our insulation doesn't have any problem.
  - Buying insulation materials is hard for us [financially]. Some households don't really care about their insulation.
  - We will use more *esgii* to make our insulation better.
  - It is not possible to make insulation better without spending money.
  - We don't know what to do with the CHIP package's insulation when we assemble the ger in summer. I guess I will take floor covering and wall bottom covering.
  - When we were using the stove, we used 3 layers of *esgii*.
  - We are using our old insulation things with the CHIP package.
  - We put the stove out. Some people's stoves are still inside. But we will never throw away our stove. We will use it during summer outside or stove is needed for some religious ritual.

Amarjargal's group

- CHIP package & delivery

  - Batkhuu: It came exactly on time.

- Battsooj: They set up the electricity in an inconvenient way (I have knowledge about this topic). There was a gap in the capacities. The cable was set under the floor directly, I think there should have been some covering. We reassembled the ger again on the 10th of November. It would have been better if it came earlier. The air ventilation and floor insulation need to be different.
- Lkhamsuren: I broke the air ventilation on the door by my shoulder. It is distracting my way when going out and in. I think it should have a different placement.
- Davaa: It didn't come on time. We ordered the package in September but the heater came in December. The floor insulation was parching and wasn't comfortable. I fixed it by cutting it by myself. The floor insulation should be thin. It seems that the expenses when using an electric heater are higher but in reality, compared to buying coal and wood every week. There is no big difference.
- Ganbold: We couldn't spend the winter in ger, because it was getting moldy. There should be an alternative package for *baishins*.
- Jigmed: Now I am already used to the constant temperature the electric heater is producing. I am worried about the electric heater breaking down. Is its spare material available in the markets of Mongolia?
- Questions from participants: How long is this project going to last? What kind of heating system are we going to use in the coming years? We want detailed information about this project's implementation.

- Thermal comfort

  - Erdene: People get pleasurable feelings from the burning fire. People would start to use electric heaters when they overcome that mental state. Secondly, using coal is cheaper. So people can't take action to use electric heaters even when they have the intention.
  - Munkhzul: The electric heater is so much easier. When we are burning coal it gets too hot.
  - Munkhbayar: The insulation has to be good no matter if it is a *baishin* or ger. We can control the temperature when using electric heaters. But the only thing that is important is insulation. The problem with the CHIP package's insulation was it came late in cold winter after we have already reassembled the ger. This project should improve the insulation by listening to people's suggestions.
  - Jigmed: The atmosphere feels cold even when the electric heater is set to its maximum number. We are used to a hotter atmosphere likewise it was with coal stoves. So 20 Celsius of warmth doesn't seem comfortable. But the advantage of the CHIP package is it is keeping a constant temperature.
  - Jigmed's wife: If we keep using an electric heater in the long term, I think it would benefit my family members' cardiovascular health, because when it is too hot or too cold the heart works harder. We saw some improvements in our daughter's health. She is growing rapidly and getting more energetic. Her headache has become better and there was a drop in her hospital visits. We take our daughter

out for some fresh air [depending on] the equipment's measurements. We spoke about CHIP to the parents at my daughter's kindergarten. They were so happy and interested in the CHIP package. I was able to know where to ventilate the air and where the humidity is lower after setting Air visuals at home.

  - Batkhuu: We moved to our *baishin* because our ger was frosting. We are used to the temperature now because we didn't use to burn coal that much.
  - Munkhbayar: Ger loses its heat mostly through tuurga (wall). I am very satisfied with the CHIP package's insulation.
  - Ganbold: We should insulate our ger by seeing some measurements on equipment that checks where heat is being lost the most.

- What things would you say to people who will use the CHIP package in the future?
  - Davaa: I want to let everyone know about this. People have inadequate information about the CHIP package. We just bought it and the project's people are not contacting us again and we are just getting information from people's talk. The advantage of the CHIP package is that it has its own insulation. Otherwise, there are many options for electric heaters. Some people are not using the packages at all and it should be checked. Even though it is really child-friendly and people have good feelings about it the project people don't answer any of my calls and dont accept the feedbacks I am giving.
  - Munkhbayar: All the work should start early [before the cold season really starts]. People who are living in ger should be the main target of this project.
  - Ganbold: I told all my relatives and people who live in ger. It should be implemented in the countryside too. The heating system of the CHIP package should be improved and get support from the government. So that more people will get to know about this. Also, I want to use it in the *baishin* too.
  - Erdene-Ochir: We couldn't use it for a year. The whole package came after we already disassembled the ger. My husband and I couldn't solve it just by ourselves.
  - Battsooj: I bought an electric heater with WiFi for 750,000MNT. I can control the temperature of my home when I am at work. The bird built its nest in our electric pole and it burned. [The electrical gear] has to be sealed tightly and there should be 20 meters of cable additionally at home.
  - Erdene: I want to make some changes to the CHIP packages' parts. I want it to be emitting heat at night and keeping the heat in the daytime.
  - All: Everyone in Mongolia can make a contribution to make the CHIP package improve.
  - Questions from participants: Will you deliver our feedback to the people who are in charge of this project?

- Insulation
  - Jigmed's wife: I watched this video named "Зөв хөдөлгөөн". In that video, they insulated the ger for 100,000MNT. We should take an example from that. We should make the floor of concrete and build our ger on it.

- Munkhbayar: Choosing the materials is the most important part.
- Battsooj: We should build the ger on high ground. This would also prevent the flood to get in ger in the summer.
- Munkhbayar: Living in ger makes me feel that I am a Mongolian person.

Post-it notes with recommendations and comments

Below are the contents of the post-it notes that residents were asked to write recommendations on at the end of each topic's discussion.

- CHIP package & delivery
  - Narangerel's group
    1. We are living in ger right now and planning to move to a *baishin*. What do I do with the CHIP package then?
    2. The cable was not long enough. The wooden shelf that comes with the electric heater was not of good quality. The floor insulation is getting molded.
    3. The insulation materials should have other options for 6, 7, and 8 wall ger. CHIP package should be delivered to residents in September or early October. They should be exact with the timing.
    4. Insulation sizes should have various options. They should make it available to a large number of people. It should be delivered early when the weather is not cold.
    5. Air ventilation equipment should be changed. The insulation for the floor was kind of floating.
    6. Air ventilation is not that good. In the winter the temperature of the ger wasn't comfortable enough. Now it is working really well and heating enough.
    7. CHIP package should be delivered when there are people at home. The insulation and electric heater were delivered at different times. They should be delivered at once. The delivery people were angry. I think they should have a better attitude. The package should come around September. CHIP package should come with a good air purifier. I truly believe that this project should stay being implemented in the long term.
    8. This project is really beneficial. I wish everyone could have a CHIP package. This winter our home was clean and warm. I am satisfied.
    9. There should be contact information of the professionals who can give advice on using the electric heater.
  - Amarjargal's group
    1. The residents should unite and vote by seeing the statistics to decrease air pollution. The government should inform all the pieces of information about air pollution publicly.
    2. I am so satisfied with the CHIP package. People should support each other and solve their problems by discussing them and collaborating with many people.

3. I think it can be improved in a lot of ways. For example, They should let more people know about CHIP packages. Also, CHIP packages should be sold in other places.
4. CHIP package doesn't have any sensors. That is the one downside.
5. CHIP package should be not only available for gers but also available for the *baishins*. It would be nice if there were an electric heater that uses less electricity.
6. They should improve the quality of the shelf that holds the electric heater. We should be open-minded and welcoming towards other projects with a mission to decrease smog.
7. The CHIP package would be more convenient if it is cheaper and available at any market. Then, more people would use it. There also should be a discount on electricity costs.
8. There should be a covering around the cable. Where can I buy its spare parts? The shelf should be improved.
9. How can I use the number inside the CHIP?
10. CHIP package team should organize seminars and training for people who use it.

- Advice for first-time users
  - Narangerel's group
    1. Change the old cables. Make your ger better insulated.
    2. People should insulate their ger fully and use good quality cable. It is really good to have a little hut in front of the ger's door.
    3. Order the CHIP package as early as possible and adjust everything that comes with the package in your ger. Check the cables and change them if necessary.
    4. Adjust all parts of the CHIP package at once to experience its full benefits.
    5. Change the cables. Insulate the floor well. Prepare all the insulation that is used in gers. Get the CHIP package within September. I would recommend people to change their door because the air ventilation would be installed there.
    6. All residents should get the package and to do that they have to check their cable quality first.
  - Amarjargal's group
    1. Prepare the insulation materials and learn the techniques to insulate your ger well enough.
    2. Make your ger's insulation really well. By not losing heat, it would be better for the electricity bill.
    3. Keep in mind that the temperature inside the ger shall be around 20-25 Celsius when using the CHIP package.
    4. Prepare extra insulation material to put on the CHIP package's insulation.

5. The only way to lower the monthly electricity bill is to improve your ger's or house's insulation. When heat loss is great the expenses will be higher.
6. There should be some equipment that senses heat and cold.

- Encouraging people to get CHIP
  - Narangerel's group
    1. The CHIP package is such a convenient and easy thing especially if you have kids. You don't have to worry that your kid is going to get burned. You get to have free time and a comfortable environment when you have a CHIP package.
    2. If you get the CHIP package it would be a good investment for your health and it would give you some time to yourself. Also, you and your ger would be clean.
    3. This package's health and financial advantages should be promoted through media.
    4. CHIP package has many good impacts such as health benefits and cleanliness. When you have to leave your kids at home, you will not worry about if they get cold or mess up with the coal. Also, this project organizes many seminars and discussions. You would learn a lot from them. Through seminars and workshops, you will meet many people.
    5. Promote this CHIP package through media by showing the people who are using it and the way they are living with this so comfortably. I think the media promotion is not enough.
    6. I really like its connection with people.
    7. I would definitely recommend it to others. Because if all the households use electric heaters the air pollution will decrease and benefit our health.
    8. This package will have a good impact on your finance and health.
  - Amarjargal's group
    1. CHIP package's electric heater keeps the constant temperature inside and I would definitely recommend it to other people.
    2. This project gives really valuable information to the people who are using it.
    3. The whole package has come when it was already cold outside. We couldn't experience its full advantages because we had an infant at that time.
    4. The insulation material has good quality and the electric heater is safe and economical. I think the household should have a fire extinguisher.

- Insulation
  - Narangerel's group
    1. You should insulate your ger's wall, floor, and roof. The outer white coverage should be made of waterproof material.
    2. Consider if your insulation is made of good quality material and if it is available to use in summer

3. Use 2-3 layers of *esgii* for your ger's warmth and insulation.
4. Use parquet floor when insulating your ger's floor and buy *esgii* and *berzent* for the wall and roof's insulation.
5. Use thick material that doesn't lose heat through itself on the door.
6. Insulate the bottom of the wall well and build a little hut in front of the door.

– Amarjargal's group

1. The wall *esgii* should be 3 layers thick. The floor mat should be standing up leaning to the wall. The insulation around the door and the *toono* should be considered thoughtfully.
2. Use breathable insulating materials.
3. Change the cables.
4. Do some good research about insulation. Use the right source of information. So that the electricity use and coal use would be decreased.
5. Insulation for ger should use materials that are eco-friendly and water-proof. The intersection between the bottom of the wall and the floor should be close tightly. The bottom of the wall outside should be closed with soils.
6. *Toono*, door, and the bottom of the wall-these are areas that lose the most. People should pay more effort there.
7. Be careful when choosing insulating materials. The material should be non-frosty.
8. The floor should be thick. Add the wall /esgii/s. Build a little hut in front of the ger's door.