Renewable heating virtual Article 6 pilot

Ground source heat pumps in Khovd, Mongolia

Authors:
Leonardo Nascimento, Aki Kachi, Silke Mooldijk, Carsten Warnecke

NEW CLIMATE INSTITUTE

January 2020

Renewable heating virtual Article 6 pilot

Ground source heat pumps in Khovd, Mongolia

Project number
818013

Authors
Leonardo Nascimento, Aki Kachi, Silke Mooldijk, Carsten Warnecke

Disclaimer
This report has been commissioned by the Swedish Energy Agency – Energimyndigheten. The views and assumptions expressed in this report represent the views of the authors and not necessarily those of the Swedish Energy Agency.

Acknowledgements
The authors wish to thank the Swedish Energy Agency for funding this work. The authors also would like to thank Tsolmon Namkhainyam and Romain Brillie from the Global Green Growth Institute for their contribution to the analysis and for sharing their insights and experiences.

Download the report
http://newclimate.org/publications/

Summary

Article 6 of the Paris Agreement provides the framework for a new generation of carbon markets in a context where all countries are supposed to formulate and implement ambitious Nationally Determined Contributions towards a temperature target and ratchet their contribution on a regular basis. Under this new regime, carbon market mitigation activities must account for, encourage and enable, and most importantly not be a disincentive for increased domestic climate action. With the final rules for Article 6 being an issue of ongoing negotiation, virtual pilots can help contribute to the discussion regarding rulemaking for Article 6 and inform new approaches to cooperation. NewClimate Institute has identified the installation of ground source heat pumps in Mongolia as a promising emission reduction option for a virtual Article 6 pilot. Winter temperatures in Mongolia can reach -40°C at night, with even more extremes of -58°C in severe winters on the steppe. Heating in Mongolia is almost entirely coal-based, either with stoves installed in *gers* or through district heating grids. Together these are responsible for high levels of GHG emissions as well as severe levels of air pollution.

The building sector is included in the Mongolian NDC, which primarily focusses on energy efficiency measures. Mongolia does not currently have a plan to shift away from the use of coal, nor a more general long-term strategy for decarbonisation. We propose the installation of ground source heat pumps for large residential buildings in the city of Khovd, Mongolia based on CDM Methodology **AMS-II.E: Energy efficiency and fuel switching measures for buildings**. Buildings in Khovd are primarily heated by two large coal-fired heat plants that supply two district heating networks.

For our virtual pilot, we propose to install ground source heat pumps (GSHPs) in apartment buildings currently connected to coal-powered district heating grids. The successful implementation of the proposed pilot project has the potential to accelerate the retirement of an old heat plant, reduce GHG emissions, familiarise housing construction firms and households with renewable heating technologies, and promote other important sustainable development co-benefits, notably a reduction of air pollution. The proposed project offers a novel alternative to current heating technologies used in Mongolia, since it can be based on clean and Paris-compatible heating supply, and has unexplored synergies with efforts to expand the availability of affordable permanent housing to the ger populations.

We do not foresee any danger of the project becoming a stranded asset in a rapid sectoral decarbonisation scenario. GSHPs do not have direct emissions associated with their operation and can be fuelled by renewable electricity. Because residents pay for heating from district networks based on floor space rather than according to actual heat use, we have developed a baseline based on capacity estimates of the Mongolian government, which would need to be corroborated through sampling in project implementation. Taking into consideration targets and policies included in the Mongolian NDC, we adjust our baseline to include the Mongolian government's goal of 20% reduction in building losses but do not include other policies that impact the buildings sector indirectly.

We consider additionality on both a household and a systemic level because of the age of one of the heat plants in Khovd that will necessitate its replacement in the next few years. Even though heat pumps are likely the best performing clean heating alternative in the Mongolian context, they still need to overcome several barriers. Most importantly a lack of familiarity with GSHP technology, a lack of existing on the ground technical expertise to install and maintain heat pumps, as well as significantly higher upfront costs compared to alternative heating technologies. Depending on the cost of capital however, heat pumps are likely to have lower overall total costs over their expected 20-year lifetime. The high upfront costs and low technological maturity as measured by market penetration in Mongolia and neighbouring countries indicate that the implementation of the project would not provide a disincentive for Mongolian domestic climate action and that Mongolia would not endanger its own NDC achievement if it were to approve the project, export mitigation outcomes, and apply a corresponding adjustment.

We estimate that heating an average household in a multi-unit apartment building from the local district heat grid generates emissions of 6.0 tCO_2e per year (adjusted for NDC efforts to improve energy efficiency). Because ground source heat pumps run on and would increase demand for electricity – and considering that the local grid is not completely decarbonised, we estimate residual indirect emissions of 1.4 tCO_2e per household per year. We note that many heat pumps use refrigerants that have a high global warming potential, and would propose to use natural refrigerants with low (or no) global warming potential while making provisions for professional decommissioning of the heat pumps at the end of their lifetime to avoid other emissions associated with the project.

Emissions reduction per year under baseline and project activity

Emissions per year (tCO_2e)	Baseline	Project activity	Estimated Reduction
Household level	6.0	1.4	4.6
Systemic level	9,210	2,180	7,030

If installations of the ground source heat pumps were to start in 2020, a ten-year crediting period corresponding to the Mongolian NDC would cover the period during which GSHP would not yet have paid for themselves. The expected lifetime of GSHP is 20 years, and emission reductions beyond the crediting period would represent a host country benefit. A potential overall mitigation of global emissions could be included via automatic cancellation, or retroactively implemented to conform with guidance and rules agreed in the UNFCCC.

Although the sale of emission reductions could be used to fund the project in full, this would lead to relatively high per tonne costs for emission unit buyers. On a systemic level, ground source heat pumps represent a cost saving over their entire lifetime in comparison to the technology that the Mongolian government is most likely to install in the next years, so an energy service company model is another possibility. In this case, revenue streams could come from charging residents a reduced price for heat, as well as selling emission units. As GSHPs increase electricity use, such a model could be of interest to the local electric utility.

Mongolia is host to a number of successful CDM projects and participates in the Japanese Joint Crediting Mechanism. Having submitted its original economy-wide NDC to the UNFCCC in September 2015 and ratified the Paris Agreement on the 21 September 2016. Preparations are currently underway for a revision of the NDC. Four national GHG inventories were conducted between 1990 and 2014, but according to the transparency requirements laid out by COP24 decision 77d, Mongolia would require further support to conduct an annual GHG inventory, and establish a registry or other accounting system for "first-transferred/transferred and a subtraction for internationally transferred mitigation outcomes used/acquired". It is assumed that the current Designated National Authority (DNA) would continue to retain authority to issue host country letters of approval, but this mandate would need expanding to carry out corresponding adjustments with important implications for NDC achievement.

Table of Contents

List of Figures

List of Tables

Abbreviations

BAT	Best available technology
BAU	Business as usual
CDM	Clean Development Mechanism Words
CES	Central energy system
CFB	Circulating fluidized bed
CHP	Combined heat and power
CMA	Conference of Parties serving as the meeting of Parties to the Paris Agreement
COP	Coefficient of performance
COP24	Conference of Parties 24 in Katowice
DNA	Designated national authority
EIA	Environmental Impact Assessment
ESCO	Energy service companies
GDP	Gross domestic product
GHG	Greenhouse gases
GSHP	Ground source heat pump
GWP	Global warming potential
HCFs	Hydrofluorocarbons
ITMO	Internationally transferred mitigation outcomes
kW	Kilowatt
kWh	Kilowatt hour
LCOH	Levelized cost of heat
LULUCF	Land use, land-use change and forestry
NDC	Nationally determined contributions
OMGE	Overall mitigation of global emissions
PDD	Project design document
PV	Photovoltaic
SDGs	Sustainable development goals
SOP	Share of proceeds
tCO_2e	Ton of carbon dioxide equivalent
TJ	Terajoule
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

Article 6 of the Paris Agreements provides for a new generation of carbon markets. A number of fundamental changes with the Paris Agreement, notably the universality of Nationally Determined Contributions, the ambition ratchet mechanism, a balance of emissions and sinks by the second half of the century, and the agreed overall temperature target call for a changed approach. Importantly, mitigation activities must account for, encourage and enable, and most importantly not be a disincentive for increased domestic climate action.

The flexibility mechanisms of the Kyoto Protocol evolved over time and policy makers learned about markets as a policy tool through piloting and engaging in them. In a similar manner, virtual pilots can help contribute to the discussion regarding rulemaking for Article 6 of the Paris Agreement. Thinking through emission reduction pilot activities based on real-world contexts, can help inform new approaches to cooperation through carbon markets. NewClimate Institute has identified the installation of electric heat pumps in Mongolia as a promising emission reduction option for a virtual Article 6 pilot. Winter temperatures in Mongolia can reach -40°C at night, with even more extremes of -58°C in severe winters (*dzud)* on the steppe. Residents of *gers* or yurts (the traditional dwelling from nomadic people in Mongolia) use small coal ovens for heating and cooking, while residents of apartment buildings are generally connected to highly inefficient coal-fired district heating – together these are responsible for high levels of GHG emissions as well as severe levels of air pollution.

Important elements when considering a pilot for the future of Article 6 include additionality, baseline setting, inaccessibility and promoting and enabling further climate ambition through a focus on technologies that further sectoral change and enable more host country NDC ambition in the future. Further aspects include compatibility with and contribution to decarbonization around mid-century, congruency with host country priorities, and a contribution towards the achievement of Sustainable Development Goals.

2 Background and Context

2.1 Current situation

Mongolia has extremely harsh climate conditions with average outdoor temperatures of -6°C between September and April and of -20°C between November and January (NOAA, 2019). As a result of the long, eight-month heating season, the housing sector is the country's biggest energy consumer and makes up 42% of the total heating demand, followed by industry and construction with 24% each. In 2015, the buildings sector was responsible for around 43% of GHG emissions from energy demand (Ministry of Environment and Tourism, 2018). In 2017, Mongolia had the fifth worst air pollution in Asia with an annual mean PM2.5 concentration of 75 µg/m³ air (van Mead, 2017), to which coal-based heating is a major contributor.

Mongolia's intended Nationally Determined Contribution (INDC) submitted in September 2015 foresaw a series of policies and measures that Mongolia expects will lead to a reduction of 14% from a Business as Usual scenario by 2030, excluding Land Use, Land-Use Change and Forestry (LULUCF). The Mongolian government proposed to reduce buildings' heat losses by 20% by 2020 when compared to 2014 through the retrofitting of buildings and the introduction of energy efficient and advanced technologies, which would translate to a reduction of 8% in household heating demand (MEGDM, 2013). In their Green Development Policy, the Mongolian government also commits to implement pilot projects that aim to reduce emissions in the buildings sector (Government of Mongolia, 2015; Ministry of Environment and Tourism, 2018). Mongolia is working with several international partners to establish standards for efficiency retrofitting, build eco-districts and provide education and training for energy efficiency. The Ministry of Environment and Tourism is also in the process of updating its NDC, which is expected to be approved by the end of 2019.

Energy efficiency measures alone are not enough to significantly reduce air pollution or GHG emissions and must be complemented with decarbonisation of the heat production sector. The two main sources of heating in Mongolia are fire stoves in smaller dwellings and district heating systems for buildings and houses in urban areas (NSOM, 2016). Neither of which, in their current status, is a sustainable alternative for building heating supply. Fire stoves use mostly coal, wood, and other debris as fuel, which results in significant GHG emissions and air pollution. The heat from the district heating systems is often supplied by outdated and inefficient Combined Heat and Power (CHP) or heat-only coal-fired plants (Ministry of Environment and Tourism, 2018).

Mongolia is rapidly urbanising: between 2000 and 2017 its urban population grew from 57 to 68% (World Bank, 2018b). Rural-to-urban migration is driven by both environmental and economic factors. The transition to a market-based economy after 1990 impacted support to nomadic herders. The central supply of fodder that helped herders feed their animals through harsh winters was gone and the livestock in specific areas close to markets increased, concentrating the animals in smaller grazing areas and reducing feedstock quality (Rao et al., 2015). The change in regime also opened the country to foreign investments and fostered the development of private land ownership (USAID, 2010). The intensification of summer droughts followed by severe winters (*dzuds*), killing over 11 million animals between 1999 and 2002, and 8 million in 2009 alone, also contributed to the growing urbanisation trend observed between 1999 and 2010 (Faraz Shibli, 2017).

Such rapid urbanisation, coupled with a lack of urban planning and affordable housing, has led to a marginalisation of the population that moved to cities and settled in peri-urban regions. Instead of permanent buildings, many move into generally settlements around cities consisting of *gers*, the traditional dwelling of nomadic people in Mongolia. In 2017, the population of *ger* areas was estimated at 850,000 people, representing 30% of the national population (Asian Development Bank, 2018). These areas are generally characterised by poor sanitation and a lack of solid waste collection as well as limited access to civic infrastructure for heating and water (NSOM, 2016). In addition, due to poor insulation, *gers'* heating demand per square meter is up to 60% higher than the demand of buildings (Stryi-Hipp *et al.*, 2018). Considering the need to reduce overall energy use in households, it is a pressing issue to offer affordable permanent housing with modern infrastructure that can be better insulated and combined with more efficient heating technologies.

Also, despite the growing migration trend to Ulaanbaatar, most of the population live outside the capital in one of the 21 *aimags* (regional administrative centres or provinces). About 85% of the households in these provinces use coal and biomass fuelled fire stoves for heating and several still lack other basic infrastructure for sanitation and water (NSOM, 2016). Several stakeholders have identified priority regional urban clusters with the potential to become engines of growth and economic diversification in Mongolia. The development of these areas would improve basic urban services and infrastructure, promote the local economy, and enable green urban planning. Such planning is lagging in most Mongolian urban centres (GGGI and Government of Mongolia, 2016a; ADB, 2017, 2018a).

2.1.1 Emission trends and NDC achievement

The ability and willingness to transfer emission reductions depends on the assumption that revenue associated with the emission transfer enables the transferring country to overachieve its NDC. If the country is not able to achieve it's NDC, or if the transfer of emission reductions endangers the transferring country's ability to achieve its NDC, this represents a challenge with regard to participation in Article 6.

The Mongolian NDC does not technically contain a quantified target in terms of overall GHG emissions, but rather commits to implement a number of policies and measures that they estimate will reduce emissions by 14% from projected 2030 levels. Depending on the standing of the ex-ante BAU projection, one could interpret the target to be quantified. Energy is responsible for the largest share of emissions in Mongolia and is expected to continue to be for some time. In its transition from a planned Soviet-style economy in the 1990's, energy-related emissions initially declined steeply from a peak in 1992; however, they started growing again in 1999 and have fairly rapidly increased since then (Ministry of Environment and Tourism, 2018). An analysis of the NDC indicates BAU emissions would continue to grow steadily, and the NDC, although a reduction from BAU, still represents a large increase from present levels. We do not foresee a danger of not achieving the NDC as a risk to the ability to transfer ITMOs.

2.2 Logical framework for theory of change

The objective of the virtual pilot is to build capacity and understanding for international cooperation through Article 6 of the Paris Agreement as well as to build understanding of the potential of ground source heat pumps as an alternative to outdated coal heating plants. Together, these are pursued in order to enable more ambitious future climate policy in the heating sector in Mongolia by helping chart out approaches to decarbonise the building sector and ensure that Article 6 contributes rather than detracts from these efforts. We have sought to do this with research into the feasibility and suitability of an Article 6 approach to promote uptake of ground source heat pump technologies that are not yet common practice in Mongolia. A theoretical exercise of the change that an actual pilot would seek to bring about is also included, but would be dependent on further research and dialog with stakeholders. A logical framework overview of this rationale as well as a potential project are outlined in Table 1.

Table 1: Logical framework describing rationale for Article 6 pilot Renewable Heating in Mongolia

Impact	Virtual pilot	Actual project (if implemented)
Goal	• Increased climate ambition • Decarbonise the Mongolian heating sector • Ensure that Article 6 contributes to climate protection efforts	• Increased climate ambition • Decarbonise the Mongolian heating sector
Objective	• Build capacity and understanding for international cooperation through Article 6 of the Paris Agreement • Build understanding of the potential use of renewable heating technologies for the Mongolian buildings sector	• Reduce GHG emissions • Reduce air pollution • Improve public health • Development of local technical capacity to install and maintain heat pumps • Reduced energy poverty • Leapfrog to BAT heating technology
Outcomes	• Improved understanding of opportunities and challenges of participating in Article 6 • Improved understanding of potential of ground source heat pumps as an alternative heating source	• Reduced GHG emissions • Reduced ppm particulate matter /improved air quality • Reduced incidence of asthma / respiratory diseases • Reduction of coal consumption • Installed heat pumps • Built technical capacity to install and maintain heat pumps • Savings in heating costs • Displacement of coal heating
Outputs	• Virtual pilot report • Presentations on virtual pilot	• Residential buildings heated with heat pumps
Activities	• Desk research • Interviews and consultations • Drafting of virtual pilot report	• Installation of heat pumps in residential buildings in Khovd City, Mongolia

3 Description of project activity

3.1 Purpose and general description of project activity

This virtual pilot activity aims to explore the feasibility of international cooperation through Article 6 of the Paris Agreement to invest in clean and Paris-compatible heating alternatives for urban population currently living in the multi-unit buildings of Khovd city, Mongolia.

For our virtual pilot, we propose to install heat pumps in buildings currently connected to coal-powered district heating grids in Khovd city, centre of Khovd Province. Two coal heating plants[1] currently supply heating to Khovd city, one of which was built over 30 years ago and supplies most of the multi-unit buildings in the city. Displacing part of the heat generated in the old coal-fired plant can accelerate its phase-out and facilitate the transition to other heat sources. Since heating and electricity are decoupled in Khovd, this activity focusses on the heating sector only, which significantly reduces the pilot's complexity.

So far the Mongolian government has focused on reducing energy losses and is still considering building heating-only plants in 9 *aimag* centres (Ministry of Environment and Tourism, 2018). While the improvement of building efficiency helps reduce emissions, it does not lead to decarbonisation.

The successful implementation of the proposed pilot project has the potential to familiarise housing construction firms and households with renewable heating technologies, reduce GHG emissions and promote other important sustainable development co-benefits, notably a significant reduction of air pollution. The proposed project offers a novel alternative to current heating technologies used in Mongolia, since it can be based on clean and Paris-compatible heating supply and has unexplored synergies with urban rellocation initiatives (further discussed in Annex 2 – Emissions reduction potential from exploring synergies between heat pump deployment and relocation initiatives).

3.2 Location of project activity

We propose to implement the pilot in a district of Khovd city, Mongolia

Khovd *aimag* is one of the provinces with potential to catalyse local economic growth due to its high concentration of manufacturing industries but lagging investments (ADB, 2017). It is located in the west of Mongolia with a population of approximately 86,000 people (National Statistics Office of Mongolia, 2017). In 2015, there were 21,706 households in the province, of which, 75% were *gers*, 7% apartments, 17% single-family houses, and the remaining 1% were other types of dwellings. Most households in the *aimag* have access to the regional electricity grid, which includes a local hydro power station but imports significant amounts of electricity from the Russian grid, the latter being comparatively cleaner than the main national Mongolian grid (NSOM, 2016; GGGI, 2019).

Khovd city (the *aimag's* capital) has a population of approximately 30,000 people and an area of 2,550 km^2. Roughly 25% of the households lives in apartments, which translates to approximately 55,000 m^2 of effective area connected to heating plants. The two coal-fired heating plants in the city, one of which was built in 1986, and the fire stoves contribute to high levels of air pollution (GGGI and Government of Mongolia, 2016b).

[1] In contrast to Ulaanbaatar, these plants are not combined heat and power plants.

Imagery ©2019 CNES / Airbus, Map data ©2019 Google 500 m

Figure 1: Satellite view of Khovd City

Decarbonising heat in *aimag* centres would lead to greatly improved air quality. The improvement of life conditions in *aimag* centres could further lighten the urbanisation pressure on Ulaanbaatar, while improving quality of life in other urban centres. In addition, a smaller city with heat decoupled from electricity offers a more favourable environment for the development of an ambitious renewable heating pilot.

Based on the above factors, we proceed with identifying the broad types of measures that could provide renewable heating to buildings in Khovd city.

3.3 Technologies / measures

We propose using small scale distributed ground source heat pumps (GSHP) for the virtual pilot. This proposal is based on an evaluation of several options (see Table 3). Heat pumps transport heat from a reservoir with higher temperature to another with lower temperature using power. In the case of GSHP used for heating, the higher temperature reservoir is the ground which stores heat from the sun in the top layers of the earth's crust without significant temperature variation throughout the year.

A GSHP system can be roughly divided into the three subsystems displayed in Figure 2. The extraction subsystem circulates the antifreeze to extract and transfer the heat stored in the ground, the heat source, to the heat pump subsystem. The heat pump subsystem circulates a refrigerant that undergoes phase change during the process. The power applied to the compressor is used to elevate the temperature of the refrigerant that will finally exchange heat with the circulation subsystem to the consumer, distributing heat to the indoor air and/or water storage.

There are multiple heat exchange configurations options, e.g. ground looped, horizontal and vertical collections, or pond looped collections. The choice depends on several factors including, but not limited to, land area availability, building's foundation type, and whether the installation is to be carried out prior to or after building construction and occupancy (Singh, Sani and Amis, 2018).

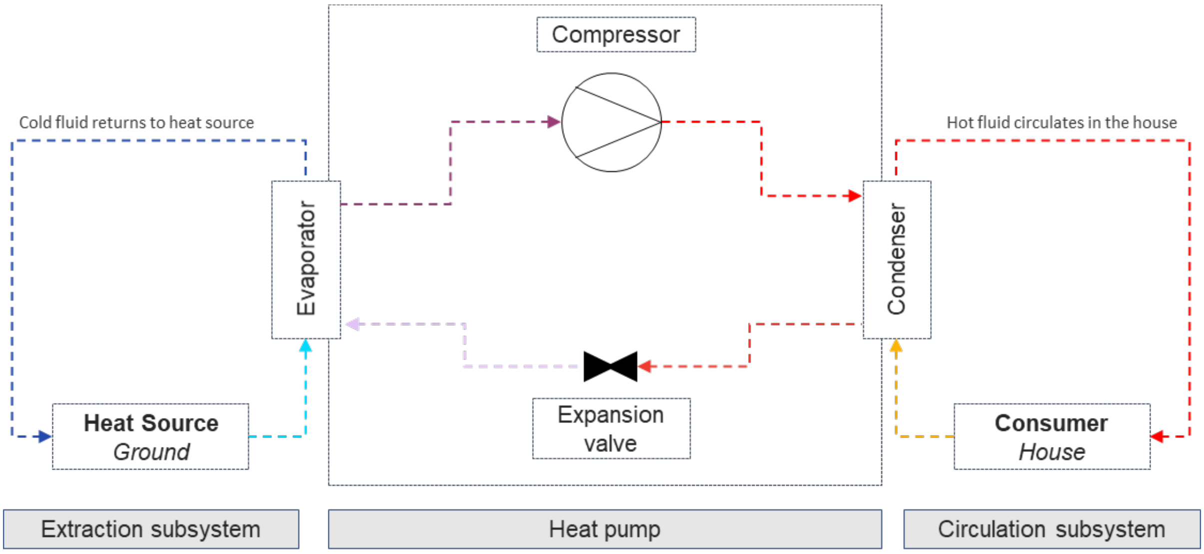

Figure 2: Schematic of GSHP systems adapted from (Wu *et al.*, 2018)

The efficiency of heat pumps is usually described by its coefficient of performance (COP), which is defined as the ratio between the energy output after the heat pump over the energy input for operation. The research of Wu et al. (2018) shows that the COP of closed-loop systems typically stays between 2.5 and 4.0, but newer systems commercially available might reach a COP of 4.3. Other modelling exercises in Mongolia have assumed COP of 3.8 (GGGI, 2018). Starting 2010, a few heat pumps pilots have started in Mongolia; for an overview of systems in operation and on the pipeline please see Annex 1 – Overview of heat pump projects in Mongolia.

Heat pumps present an appropriate technical cleaner heating solution, but some barriers need to be addressed to ensure proper functioning of technology and the full realisation of the mitigation reduction potential. One main issue to be considered is the leakage of the refrigerant. Common refrigerants for GSHP, like hydrochlorofluorocarbons and hydrofluorocarbons (HFCFs and HFCs), have high global warming and ozone depletion potential. Since these refrigerants are scheduled to be phased out worldwide by 2040, natural alternatives are being investigated and implemented (Wu and Skye, 2018). We recommend the use of a natural refrigerant instead of the conventional HFCFs and HFCs. Table 2 presents an overview of the main characteristics and barriers of the most prominent alternatives.

Table 2: Ground source heat pump natural refrigerants alternatives comparison. Green checks indicate acceptable values while red crosses present potential barriers – adapted from Tanaka and Kotoh (2007).

Property	CO_2	Hydrocarbon	Ammonia	Water	Air
Toxicity/flammability	✓	✗	✗	✓	✓
Material deterioration	✓	✓	✗	✓	✓
Chemical stability	✓	✓	✗	✓	✓
Moderate boiling point	✗	✓	✓	✗	✗
Capacity per unit volume	✓	✓	✓	✗	✓
Theoretical Coefficient of Performance (COP)	✗	✓	✓	✓	✗
Moderate discharge temperature	✓	✓	✓	✓	✓
Ozone depletion potential	✓	✓	✓	✓	✓
Global warming potential (GWP)	✓	✓	✓	✓	✓

Some of the challenges presented in Table 2 can be addressed by technology development while others depend heavily on the professional skills of the installation and maintenance workers. Considering that some of the natural refrigerants are flammable, it is important that technicians are certified to operate with such materials to ensure households' safety. To date, most heat pumps in Mongolia have been installed in Ulaanbaatar due to, among other reasons, the presence of more qualified professionals to carry out the installation work (GGGI, 2018). For the proposed project, technical expertise would be brought in from Ulaanbaatar for installation work.

The feasibility study for a GSHP pilot in a kindergarten in Khovd shows that heat pumps are the most suitable technology for baseload heating, but a small coal boiler can be used for peak load or reserve. In this system, the peak boiler would only be required about 15 days a year; other system configurations use electricity heaters as backup generators (ADB, 2018b). Nonetheless, many of the systems presented in Annex 1 – Overview of heat pump projects in Mongolia have been in operation for years without any performance issues (GGGI, 2018). A more detailed analysis of the performance of heat pumps in Mongolia shows that even air-to-air heat pumps have shown good performance (COP>1), even on very cold days (Pillarisetti *et al.*, 2019).Ground source heat pumps represent a large energy improvement over electrical resistance heating, could conceivably be connected to the district heating system or be decentralised, and result in emissions savings compared to heat from heating-only plants and fire stoves. Table 3 presents an overview of other technologies analysed in our desk research. These alternatives were assessed considering their adequacy in the Mongolian context when evaluated by their technical, financial, and environmental characteristics.

Table 3: Overview of technology alternatives for Paris-compatible building heating in Mongolia. The colours represent the rating of each technology in comparison to the others. Green was attributed to technologies with a positive performance, yellow for a neutral performance, or with ambiguous characteristics, and red for technologies with negative performance.

Heating technology options	Technical	Economical	Environmental	Reasoning
Solar thermal on decentralised systems	Red	Red	Green	For Mongolia seasonal storage is paramount due to its long heating season. Since several Mongolian cities suffer from high air pollution, the operation of the collectors could be compromised. Costs of solar thermal technologies have not decreased at the same rate as solar PV. Also, even though installation complexity can be overcome, complex maintenance might be a barrier depending on local expertise.
Solar thermal coupled with district heating	Yellow	Red	Green	This option has risks for the heat transfer fluid in extreme cold climates. Possibly useful for the establishment of small-scale district heating grids; efficiency of scale would make this alternative costlier when compared to large scale district heating. Considering Mongolia's target to move to efficient buildings, other alternatives are more cost efficient.
Biomass on decentralised boilers	Green	Green	Red	Simple operation and known technology but strict standards to ensure the sustainability of the biomass would need to be applied; biomass supply is limited in Mongolia. Also, other alternatives are more suitable to reduce local levels of air pollution.
Biomass coupled with district heating	Yellow	Yellow	Red	Large scale installations would suffer from the lack of biomass availability in the region. This alternative should also be submitted to strict biomass sustainability standards in order to be considered a renewable and sustainable source of heating.
Air source heat pumps	Red	Yellow	Yellow	Air source heat pumps are powered by electricity but are less efficient than ground source heat pumps and do not work adequately in extremely cold temperature.
Water source heat pumps	Yellow	Yellow	Yellow	This alternative performs well in cold conditions, but is limited by the existence of a water source close to the households.
Electric heaters coupled with renewable electricity	Red	Yellow	Yellow	Only fully renewable if electricity comes from renewable sources but if supplied by variable renewables, heating supply can be endangered without long-term storage. Electric heaters have lower efficiency compared to heat pumps.
Large scale geothermal	Red	Yellow	Green	Dependent on the presence of significant geothermal resources close to the district heating system to avoid heat losses, which is not available near Khovd city.
Small scale ground source heat pumps	Green	Yellow	Green	Have relatively long payback time and low temperature output but high coefficient of performance (COP). Heat pumps also rely on electricity, like electric heaters, so would require renewable electricity for decarbonisation – however, thanks to the higher COP are a more efficient solution. The closed loop solution can be used anywhere and requires little to no maintenance.

4 Methodologies and baseline

4.1 Methodology

The methodologies employed in the analysis of the implementation of GSHP for multi-unit apartment buildings in Khovd city are based on **AMS-II.E: Energy efficiency and fuel switching measures for buildings**, which is a relevant methodology for the following reasons:

- GSHPs reduce the use of fossil fuels (coal) and carbon dioxide emissions. Coal is displaced either from fire stoves or the district heating network.
- The project introduces a new technology that results in energy efficiency improvements in households. The heat pumps have a high coefficient of performance that leads to efficiency improvements when producing heat in comparison to heating-only plants and fire stoves.
- It is possible to directly measure and record the fossil fuel consumption within the project boundary.

4.2 Project boundary and greenhouse gasses (GHGs)

The physical boundary includes the footprint of the multi-family building units (or apartments) with space heating supplied by ground heat pumps.

In addition to the physical boundaries, the energy balance boundary defines the energy use considered. Space heating and hot water are included in our estimation. In Khovd, the heating plants provide not only heat, but also hot water. Therefore, the proposed ground source heat pumps solution would need to be set up to address both space and water heating requirements. The main sources of emissions and GHGs covered in the baseline and project scenario are provided in Table 4.

Table 4: Reasoning for inclusion of Greenhouse Gases (GHGs) in the estimations. Only orange items are included.

Scenario	Source	Gases	Included	Explanation
Baseline	Combustion of coal in heating only plants to produce heat for district heating network supplying multi-unit buildings.	CO_2	Yes	Major pollutant
		CH_4	No	Minor pollutant
		N_2O	No	Minor pollutant
Project	Own heating supply produced from ground heat pumps. No significant direct emissions but indirect emissions due to electricity consumption.	CO_2	Yes	Major pollutant
		CH_4	No	Minor pollutant
		N_2O	No	Minor pollutant
		HFCs	No	Use of natural refrigerants. See Table 2.

4.3 Contribution to decarbonisation (Paris alignment)

We suggest three factors to determine if the contribution of an Article 6 activity is Paris-aligned, i.e. whether it supports the decarbonisation of energy sectors in line with the goal of the Paris Agreement.

1) Does the project involve continued emissions of greenhouse gases?
2) Is there a danger that the project becomes a stranded asset in a rapid sectoral decarbonisation scenario?
3) Does the project contribute to transformational change?

The project operation does not involve direct emissions. There is a minor risk of leakage of refrigerant from heat pumps, which we propose to mitigate through the use of natural refrigerants, and the use of qualified technicians for installation and maintenance. Otherwise, all major emissions are indirect and associated with the use of electricity.

Increased electricity use is associated with additional indirect emissions, considering the role of fossil fuels in the power sector. However, if the electricity is provided by a zero-carbon source, direct emissions are estimated to be insignificant and indirect emissions from the operation of a heat pump operation with natural refrigerant could be considered zero. The decarbonisation of the electricity sector has a realistic potential even under Mongolia's harsh climate conditions; however, the country's current NDC present the ambition to reach only 30% of renewable installed capacity for power generation by 2030 (Government of Mongolia, 2015). Khovd electricity production is already cleaner than the NDC; the Durgun Hydro power covers around 30% of the city's electricity consumption while the rest is covered by imports from the Russian grid, which has a lower emission factor than Mongolia's (GGGI, 2019).

We do not foresee any danger of the project becoming a stranded asset in a rapid sectoral decarbonisation scenario. GSHPs do not have direct emissions associated with their operation and can be fuelled by renewable electricity. Under Mongolian conditions, it is also currently unlikely that the district heating system can be fully decarbonised, due to the high heating demand. GSHPs will therefore remain as a very adequate option to support decarbonisation of heat. Additionally, even if the whole district heating system is decarbonised, the heating network would need to reach all households to ensure full decarbonisation. This type of systemic change is likely to overrun the lifetime of the system proposed in this project.

Furthermore, the pilot can be the role model needed for rolling out zero-emission heating concepts in Mongolia and support sectoral transformation. We use the term 'transformational impact' to reasonably understand if the mitigation activity has a larger effect on the sector and if this effect is in line with the achievement of the Paris temperature goal.

In the heating sector, sectoral transformation must aim for, or at least further, decarbonisation. For that, we identify two main challenges. The first is to move the growing urban population to formal housing with better insulation and more efficient heating devices to reduce demand. Although available technologies are able to reduce heat demand, it is impossible to bring demand to zero in a country with such harsh climate. Working on efficiency is fundamental to reduce stress in the heating supply sector but clear strategies to decarbonise supply are needed to fully align the heating sector with the Paris Agreement.

The second challenge is to shift away from emitting sources of heat and is even more critical because of Mongolia's high fossil fuel dependency. In 2016, 99.8% of the heat supply was produced using coal, via direct combustion or via the district heating network mostly connected to CHPs. The country is locked in the current infrastructure partially because of the co-production of power and heat. Due to the relative inefficiency of electrical resistance heating, large scale renewable power development depends on alternative building heating technologies. In this context, it becomes a priority to identify zero-emissions heat alternatives to help reducing the need for the combined generation of heat and power.

The pilot would foster the systemic transition needed to reach the goals of the Paris Agreement by both lowering fossil fuels use and setting a case for promoting the decoupling of power and heat production, which could enable a faster transition away from the current CHP infrastructure.

4.4 Determination of the baseline

Khovd city has the highest population and population density of all *Soum*[2] in the Khovd province. The city houses 66% of the *Soum* population. We assume that figures of the province's buildings stock are representative of Khovd city and that the urban *gers* don't differ significantly from the rural *ones* in terms of heating facilities since most *gers* are not connected to trunk infrastructure.

Khovd city has approximately 9,800 households of which 2,400 live in apartment buildings and 7,400 in *gers* or private housing. Figure 3 summarises the most important information regarding Khovd's *aimag* buildings stock electricity and heat supply. Considering heat, the supply is divided between district heating and fire stoves for buildings, but exclusively fire stoves in *gers* (NSOM, 2016).

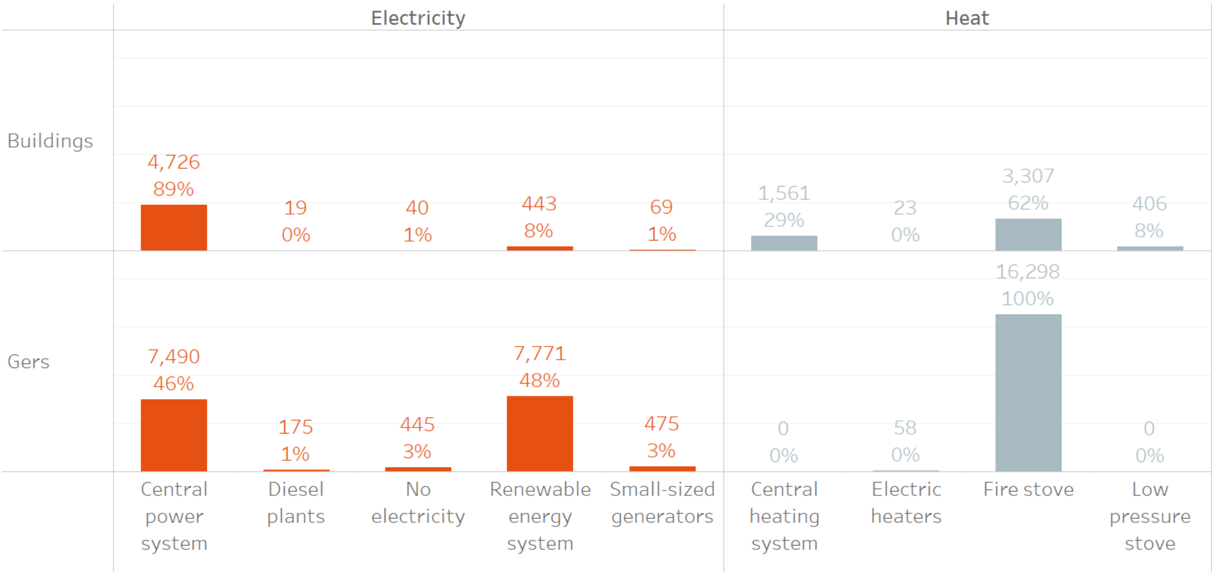

Figure 3: Number of households living in buildings and *gers* by source of electricity and heating in the Khovd *Aimag*

Even though most buildings in Khovd use fire stoves for heating, the use of heat pumps is more suitable to multi-unit dwellings, like apartments, to reduce installation costs and number of heat pumps installed. Also, these apartments are responsible for a more concentrated heating demand and are usually more energy efficient then houses and *gers* (Stryi-Hipp *et al.*, 2018).

In Khovd, multi-unit buildings are supplied by two coal-fired heat plants (GGGI and Government of Mongolia, 2016b). Contrary to the combined heat and power plants in Ulaanbaatar, the heat plants in Khovd only produce heat and no electricity. The oldest of the two plants was built in 1986 and is operated by Badamlakh Ilch LLC. As of May 2019, around half of the apartment buildings' heat is supplied by this plant (GGGI, 2019). The project activity might support an early retirement of the 1986 plant, so the baseline is calculated based on emissions caused by its operation.

The baseline includes emissions due to both space and water heating demand supplied by the district heating network. It assumes that the existing buildings, already connected to the network, will remain connected, therefore requiring no further investments.

[2] Each one of the *aimags* is further divided into *soums*, the second level administrative division of Mongolia.

For the virtual pilot purposes, we estimate a baseline based on detailed information on Mongolian multi-unit buildings heat use supported by coal combustion. In the event of an actual implementation of the project, a baseline based on sampling of energy demand of actual multi-unit residential buildings would be necessary.

Baseline conservativeness

As countries refine existing sectoral policies and define new policies to achieve their NDC, the baselines (and additionality, as discussed later) of Article 6 activities must be defined so that they already account for these policies and the effect of Article 6 activities are indeed additional to current efforts (Fuessler et al., 2014 in Schneider *et al.*, 2017). This would include current policies or policies already in place before a project starts crediting, as well as anticipated policies implemented to achieve the NDC.

Mongolia's NDC presents policies and measures to be implemented up to 2030 in all sectors except LULUCF (land use, land-use change, and forestry). Therefore, our proposed ground source heat pump heating pilot is within the scope of the NDC. The policies and measures listed in the NDC are expected to lead to a reduction of 7.3 $MtCO_2e$ annually and correspond to a 14% reduction compared to a business as usual (BAU) scenario, excluding LULUCF, which is still an increase compared to current levels. To align the emissions pathway with the Paris Agreement, Mongolia would also need to rapidly curb its emissions. There is however a measure of uncertainty regarding the future of the NDC target, as the Mongolian government is currently in the process of updating its NDC with new data, better sectoral coverage, and a new baseline calculation.

Some of the targets are also currently considered out of reach by the government. The NDC presents the target to reduce buildings heat losses by 20% in 2020 and 40% in 2030 compared to 2014 values. This target is based on a study that identified that heating losses reach about 40% in old Mongolian houses and buildings, which would translate to a reduction of 8% in household heating demand in 2020 (MEGDM, 2013). In addition, the NDC presents the possibility to reduce fuel use in individual households through improving stove efficiency but without providing quantification of impact or target efficiency improvement, nor presenting clear policies to reach those targets.

Table 5: List of Mongolia's NDC target directly or indirectly related to the buildings heating sector

Sector	NDC target	Impact	Reasoning
Energy (power & heat)	Reduce building heat loss by 20% by 2020 and by 40% by 2030, compared to 2014 levels	**Direct**	Reduction of building heat losses directly reduces heating demand and emissions from heating, independently of their source.
	Reduce internal energy use of Combined Heat and Power plants (improved plant efficiency) from 14.4% in 2014 to 11.2% by 2023 and 9.14% by 2030	**Indirect**	Efficiency improvements in coal-fired power plants might reduce demand for fuels and total emissions. More relevant for buildings connected to networks supplied by CHPs but also impacts households that receives electricity from the central grid.
	Implement advanced technology in energy production such as super critical pressure coal combustion technology by 2030	**Indirect**	Introduction of new technologies improves overall efficiency of heating in households connected to the district heating network. Impacts buildings connected to all district networks or that use small scale coal boilers. But does not impact households using fire stoves.

All policies mentioned in the NDC, with direct or indirect impact on the buildings' heating sector, focus on efficiency improvements as can be seen in Table 5. Efficiency improvements can potentially reduce emissions but do not lead to decarbonisation. The introduction of renewable energy sources for heating could increase the NDC ambition and contribute to further emission reductions.

Our emission reduction potential estimation already includes the 20% reduction in building losses but does not account for the other two policies impacting the buildings sector indirectly. CHP plant improvements would only impact emissions marginally due to the heat pump use of electricity from the central grid, but Khovd's electricity is not supplied by the Central Energy System (CES). Further, supercritical coal combustion is only assumed to be implemented around 2030 and it is unclear if that would reach the *aimag* centre by that time.

4.5 Demonstration of additionality

An inventory from 2018 showed there is only about 3 MW of ground source heat pumps installed in Mongolia (GGGI, 2018). Although exact figures are not available, these 3 MW represent a tiny fraction of the overall heating demand. The World Bank (World Bank, 2018a) estimates that less than a quarter of the population has access to central thermal energy provided by Combined Heat and Power plants, which reach 1,142 MW in 2019, and heat-only boilers through district heating networks – the vast majority of the rest of the population relies on individual coal-fired boilers in buildings located in urban areas or coal-burning stoves in suburban and rural areas. GSHPs are not common practice in the Mongolian heating sector and no laws in the country mandate a shift to renewable sources of heating, including heat pumps.

Barrier analysis

Even though heat pumps are likely the best performing clean heating alternative in the Mongolian context, they still need to overcome several barriers.

Mongolia has been using coal-fired options for heating for decades; the coal heating technologies are reliable and function even in harsh winter conditions. Houseowners and policymakers are familiar with the local prevailing technology and are sceptical about other alternatives. In Khovd, 64% of stakeholders strongly support the gradual replacement of coal technologies for heating with other alternatives. But when asked about options to do it, over 50% said they did not have enough knowledge to define if heat pumps are a good replacement to coal boilers (GGGI and Government of Mongolia, 2016b).

Khovd's government wants to improve heating systems between 2020 and 2025 and green development is one of the *aimag*'s strategy pillars. However, there is no clear mention on how these two goals come together (Khovd Aimag and Mongolia's Western Development Bank, 2015). Due to the lack of a clear mandate to rollout renewable heating technologies, the region risks further investment in coal technologies to fulfil heating demand. The need to define such investments is approaching as a result of the age of existing coal-fired heat plants.

Local market availability is a barrier as the default heating technology for multi-unit residential buildings is to connect to the local district heating network. There is no local installation market for heat pumps in Khovd and, although there are some heat pumps in some buildings in Mongolia, these are usually one-off projects paid for by donor agencies for public buildings, including schools.

Related to the predominance of connection to the local district heating grid is the lack of local technical capacity for installation. Ground source heat pumps do not require constant maintenance unlike, for example, solar thermal systems, but still need to undergo proper installation and to be checked about once a year to ensure the safe and smooth operation of the heat pump.

In urban centres, there is often a lack of space which limits the options for horizontal boreholes. In Khovd, this is aggravated by the fact that the ground freezing level can be over 3 metres deep (ADB, 2018b). Vertical holes can be used to mitigate this issue and are the least space intensive option but are also more expensive and might be subject to stricter digging permits. Further exploration of financial barriers is discussed in next section.

Financial additionality

Financial additionality directly assesses whether the project would take place without the financial incentive from the market intervention – if there are large potential cost savings or potential revenues in taking the action anyway, it is unlikely to be financially additional.

The analysis considers two options: 1) households or building owners invest in a GSHP to meet their own heating demand; and 2) a project developer invests in GSHPs at a systemic level, i.e. for all households that are currently connected to the district heating. Regarding the first possibility, we evaluate how different heating alternatives compare considering household-level costs and answer if, under current circumstances, the household occupants would be likely to invest in a heat pump. With respect to the second possibility, we assess whether heat pumps at a systemic level are cost-competitive with other large-scale alternatives.

Household level

The household-level analysis considers the alternative prevailing heating technology option of connecting to the local district heating network and compares it to heat pumps. The local prevailing technology is to connect to the local grid and buy heat directly from the district heating network. In this case, it is assumed that the users already have a working system in place, so the only costs are the heating fees paid monthly. The current heating prices are 500 MNT per square meter per month (GGGI, 2019). Considering the project activity, the user would invest in a heat pump, pay for the additional electricity consumption, and yearly maintenance of the device under the project alternative. Figure 4 presents an overview of the costs considered under each alternative.

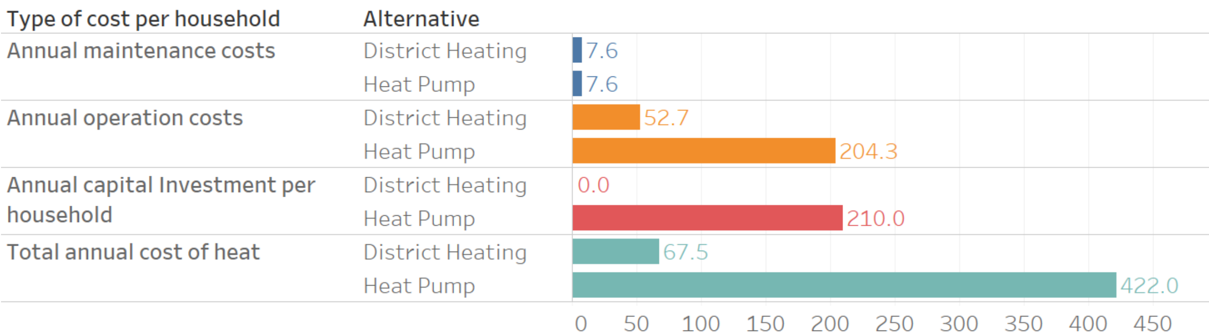

Figure 4: Costs in EUR comparison between the baseline and the project activity.

Heat pumps are an expensive option in terms of upfront investment costs and while international donors and investors have provided loans and credits for new coal fire plants, Mongolia lacks the financial resources for the upfront costs of alternative renewable heating technologies (GGGI and Government of Mongolia, 2016a).

Operation costs are the costs associated with the purchase of heat and electricity; both payments are collected by the energy utilities. The maintenance costs consist of the salary costs of maintenance workers. Heat pumps and household heat exchangers are assumed to need maintenance about once a year. The maintenance technician would need to check the condition of the heat pump in the building and the heat exchangers within each apartment. We assume that both systems, district heating and heat pumps, have approximately the same maintenance requirements and costs need to cover one full working day.

The heating fees for household connected to district heating systems are so low that privately owned utilities cannot afford to invest in retrofits and improve current infrastructure. In Khovd, this is identified as one of the main reasons for the highly inefficient heating network system (GGGI and Government of Mongolia, 2016b).

Compared to the low socialised cost of heat delivered from the district heating system, the high cost of GSHPs mean that it would not make financial sense for an individual household to invest in GSHPs instead of connecting to the district heating grid. Without additional finance, it is highly unlikely that heat pumps would penetrate the Mongolian market in the short or medium term. Further it is likely that, if and when heat pumps become more common, their use will be concentrated in Ulaanbaatar before they become common practice in smaller regional cities and towns.

Systemic level

The analysis on the systemic level compares costs of building a circulating fluidized bed (CFB) coal-fired boiler, supplying heat to *all* households living in apartment buildings and supplied by the 1986 plant, to the costs of installing heat pumps in the same buildings.

The question of how to replace the current plant is likely to become relevant in the near future because of the age of the plant. CFBs have already been introduced to the Mongolian market (GGGI and Government of Mongolia, 2016a); plants in the cities of Ulaanbaatar, Tavantolgoi, and Oyu-tolgoi are for example equipped with CFB boilers (GGGI and Government of Mongolia, 2016a). Also, according to its NDC, Mongolia intends to introduce efficient advanced technology in coal energy production. China is the largest market of CFB boilers (Ryabov, 2016) where they came to dominate the heat co-generation market around 2005 (Yue *et al.*, 2010). In 2008, total power capacity was 63 GW, which was more than 10% of the total Chinese coal-fired power installations (Yue *et al.*, 2010). Given the technology progression in China and the advent of CFBs in several Mongolian cities, we expect them to be the most likely option considered for the replacement of existing heat plants at the end of their lifetimes.

As air pollution is a major problem in Mongolia, the government should take it into account in a cost-benefit analysis when assessing any alternatives to be built from now onwards. Cost-benefit analysis including air pollution as an externality is however not systemically integrated in Mongolian investment decision-making. CFB coal-fired boilers, although powered by coal, reduce air pollution compared to the currently installed boilers (GGGI and Government of Mongolia, 2016a).

We assume that the new system would need to supply all 56 buildings currently connected to the 1986 plant, resulting in a total heating demand of 13 MW_{th}.

Only the boiler upfront investment is considered in the cost calculation in the case of a new investment in a heat-only plant, since we assume that the new boiler would be built on the infrastructure of the existing plant. In the case of the heat pump, drilling costs are also considered since they represent a high share of initial costs and because these costs were not covered by previous projects. In the absence of data, we do not consider decommissioning costs in any of the cases.

As presented in Figure 5, the initial investment costs of heat pumps are much more expensive than those of coal-fired boilers, but operation costs are lower. Annual operation and maintenance costs for the medium-scale coal-fired plant amount to almost 20% of the upfront investment costs per year (GGGI and Government of Mongolia, 2016a). We assume an investment in both a new coal-fired boiler or GSHP to be debt-financed with a cost of capital of 8.75%[3]. This is likely a conservative estimate but corresponds to the interest rate on government bonds as of June 2019. The costs are mostly made up of fuel and labour costs. In the case of heat pumps, operation costs are lower because they require fewer employees to operate the technology while fuel costs are reduced. Due to this cost dynamic, coal-fired boilers become more expensive than heat pumps after 10 years, meaning that the sum of

[3] BondEvalue (2019). "Mongolia (Government)". Available at: https://bondevalue.com/bond-market/Government-USY6142NAA64 (Retrieved 3 June 2019).

investment plus operation costs of coal boilers surpass the ones for heat pumps before the end of their lifetime.

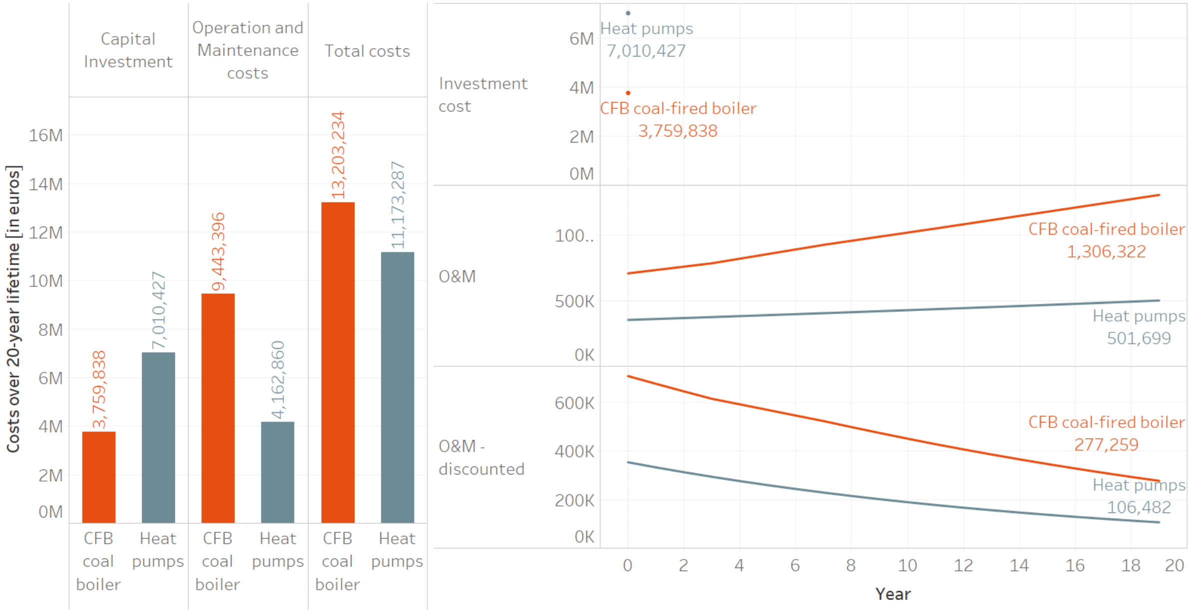

Figure 5: Comparison of heat pumps and CFP coal-fired boilers' total upfront investment costs at present value (left) and operation and maintenance (O&M) costs per year (right)

The increase in electricity consumption caused by GSHP heat supply for multi-unit apartment buildings is equivalent to an increase in power capacity of about 3 MW. The total installed capacity in Mongolia as of 2019 is around 1,200 MW. We assume that the current infrastructure would be able to cope with the increase in demand without new investments. If the use of GSHPs for heating is implemented on a larger scale and eventually becomes mainstream, the increase in electricity consumption cannot be neglected and the systemic analysis needs to take new investments in power capacity into account. Nonetheless, investments in renewable energy, e.g. solar photovoltaics or onshore wind, should not be financed under Article 6 since the technology is common practice and could be supported by alternative mechanisms including domestic resources.

4.6 Demonstration of inaccessibility

To ensure that the option to trade emission reduction units under Article 6 of the Paris Agreement does not disincentivise increased Mongolian NDC ambition, the project activity must be otherwise “inaccessible” for Mongolia even in the most ambitious reasonable scenario possible. Inaccessibility contrasts with additionality in that additionality considers if the project activity would have happened without the Article 6 intervention given current legal framework, access to finance, common practice and technological trends. Many potential indicators of additionality and inaccessibility may be shared, but there are many activities that may be additional but are in fact readily accessible and therefore within easy reach of a host country given factors like cost and technology maturity. Easily accessible technologies should be left for domestic action towards the host country’s NDC or a future ratcheted NDC (Warnecke *et al.*, 2018). Technology costs could consider both upfront costs and overall lifetime costs compared to the costs of the current technology or the most likely new technology that would be employed if built new. Technology maturity can be accessed via market penetration rates both at a global and regional level. If a technology is mature and proven in one country as well as cheap, it may be considered accessible whether or not it has reached a similar level of market penetration in the given host country. Equally, if a technology is expensive, but has reached a high market penetration in the same region, it may still be considered accessible despite its high cost.

Technology costs

Since Mongolia has been able to install, operate and maintain the current coal-fired heating plants, we assume that any technology equal in cost, cheaper, or slightly more expensive than the existing plant is accessible to Mongolia. Considering the age of the current coal-fired heating plants, and the fact that one will need replacement in the near term, we also consider a cost comparison between heat pumps and the most likely technology that would be built today if the local heat plants were to be replaced.

Although not likely an option in perpetuity, we calculated costs for maintaining the existing heat plants based on operation and maintenance costs as provided by the GGGI and Government of Mongolia (2016b) and assumed that no upfront investments are required. We calculated the costs of heat pumps and CFB boilers with data based on both upfront and maintenance, as well as operation costs (GGGI and Government of Mongolia, 2016b, 2016a; GGGI, 2018, 2019).

Upfront costs of a 13 MW capacity heating system, supplying all apartment buildings connected to the 1986 plant, amount to 3.8 million EUR using a CFB boiler, and 7.0 million EUR for heat pumps. We assume the maintenance costs would be the same for the existing plants and plants using CFB boilers, which leads to total costs presented in Table 6. Upfront costs for heat pumps are significantly higher than the CFB alternative. However, over a twenty-year timespan, heat pumps are economically more attractive than CFB boilers.

Table 6: Estimated upfront costs and present value of total costs in million EUR from existing plants, heat pumps, and CFB coal-fired boilers.

Costs	Existing plant	Heat pumps	CFB boilers
Upfront costs (million EUR)	-	7.0	3.8
Total costs (million EUR)	9.4	11.2	13.2
LCOH (EUR/kWh)	0.028	0.033	0.039

Technology maturity

GSHPs are a well-tested and developed technology in Europe, particularly in Sweden, where approximately 20% of all single-family houses are heated by GSHPs (Gehlin and Andersson, 2016). In Mongolia, however, only few case examples of the technology exist, often not in residential buildings. These have been mostly pilot projects supported by international donors (Dorj, 2015; GGGI, 2018). Although an overall study on various heating technologies has not been carried out, we estimate market penetration in Mongolia to be less than 1% of overall building square meters and number of buildings. The situation is similar in neighbouring countries. GSHPs have become progressively more common in China but with a growth slowdown since 2013 (Yuan *et al.*, 2012; Zhao, Gao and Song, 2017); the area heated using GSHPs is projected to be 500 million m^2 in 2020, which is around 1% of total floor space that requires heating (Ma, Kim and Hao, 2019). In Russia, although heat pumps are a feasible option to provide heat to residential buildings (Vasilyev *et al.*, 2016), approximately 78% of Russian buildings depended on district heating and 22% of buildings had individual boilers, gas heaters, traditional stoves around 2011 (Nekrasov *et al.*, 2011; Lychuk *et al.*, 2012). Moià Pol, Morzhukhin and Nazmitdinov (2018) characterise the heat pump market as “in its infancy”. For this reason, we estimate market penetration to be insignificant in both the Chinese and Russian residential heating markets.

Inaccessibility determination

At approximately 7 million EUR, the total upfront costs of installing heat pumps for households currently connected to the 1986 heating plant district grid are significantly more expensive than the status quo and significantly more expensive than installing CFB boilers, which would cost approximately 3.8 million EUR. The Levelized Cost of Heat or LCOH is 0.033 EUR/kWh for the heat pumps and 0.028 EUR/kWh for the coal-fired CFB boilers, assuming a discount rate of 8.75%, which is the interest rate on government bonds as of June 2019 and lifespans of 20 and 40 years, respectively.

Since GSHPs are a novel technology for Mongolia, with low market penetration rates, and both upfront costs and the LCOH substantially higher than the costs associated with the existing heat plants, heat pumps are very likely inaccessible to Mongolia. Even though heat pumps outperform CFB boilers in terms of costs over their lifetime, the high upfront costs combined with the fact that heat pumps are not common practice, pose a significant barrier for their implementation in comparison to CFB coal-fired boilers. Accordingly, the proposed pilot would not lead to a disincentive for future NDC ambition and would ideally contribute to a long-term shift from coal-based district heating to GSHPs in Mongolia allowing for increased NDC ambition.

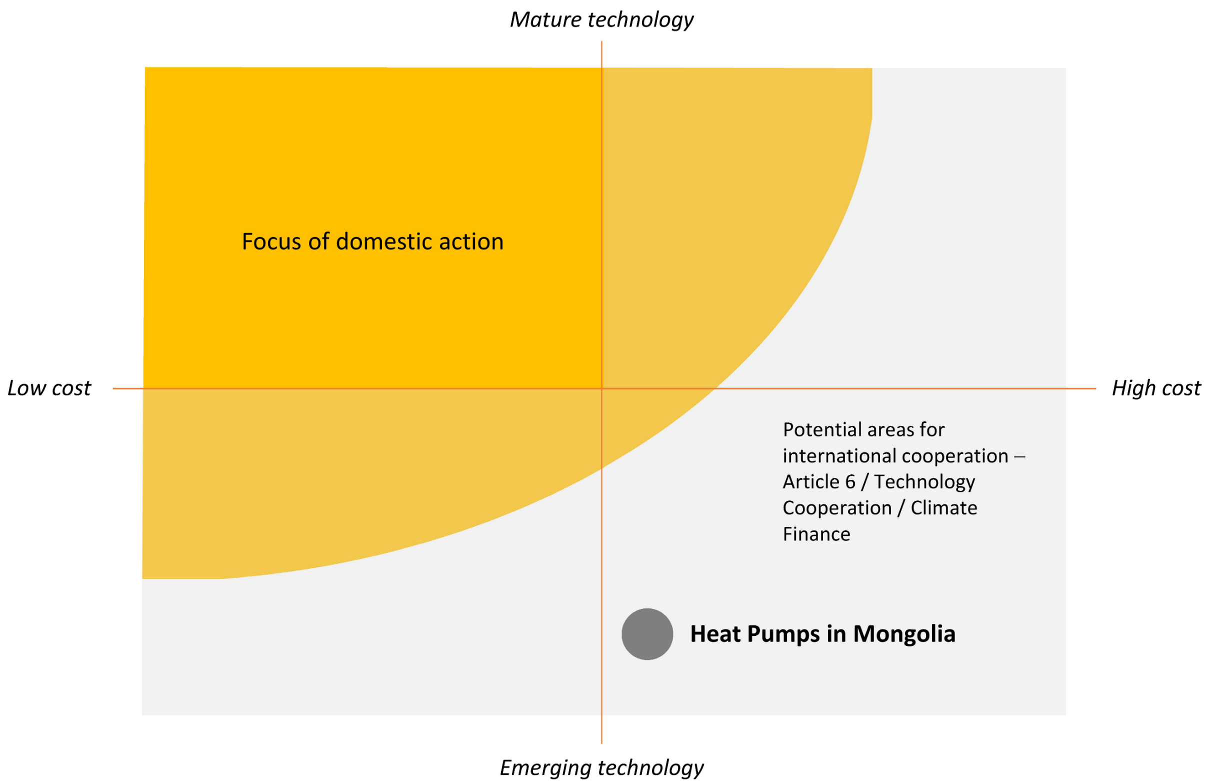

Figure 6: Heat pumps in Mongolia are classified as high-cost, emerging technology quadrant

4.7 Ex ante estimation of emission reductions

Baseline emissions

Heating from district heating network in a household living in a multi-unit apartment building – emissions of 6.0 tCO_2e per year (adjusted for Mongolian government efforts to improve energy efficiency).

The emissions per household in multi-unit buildings are estimated based on average heating demand and the coal combustion in the heating-only plant built in 1986. Figure 7 shows the design heat load for the 93 residential apartment buildings and private houses connected to the plant.

As of May 2019, there were 56 apartment buildings connected to the 1986 heating plant. The size of the apartment buildings varies significantly: the two smaller buildings have 2 apartments while the largest three have 80, the average being 31 apartments per building (GGGI, 2019).

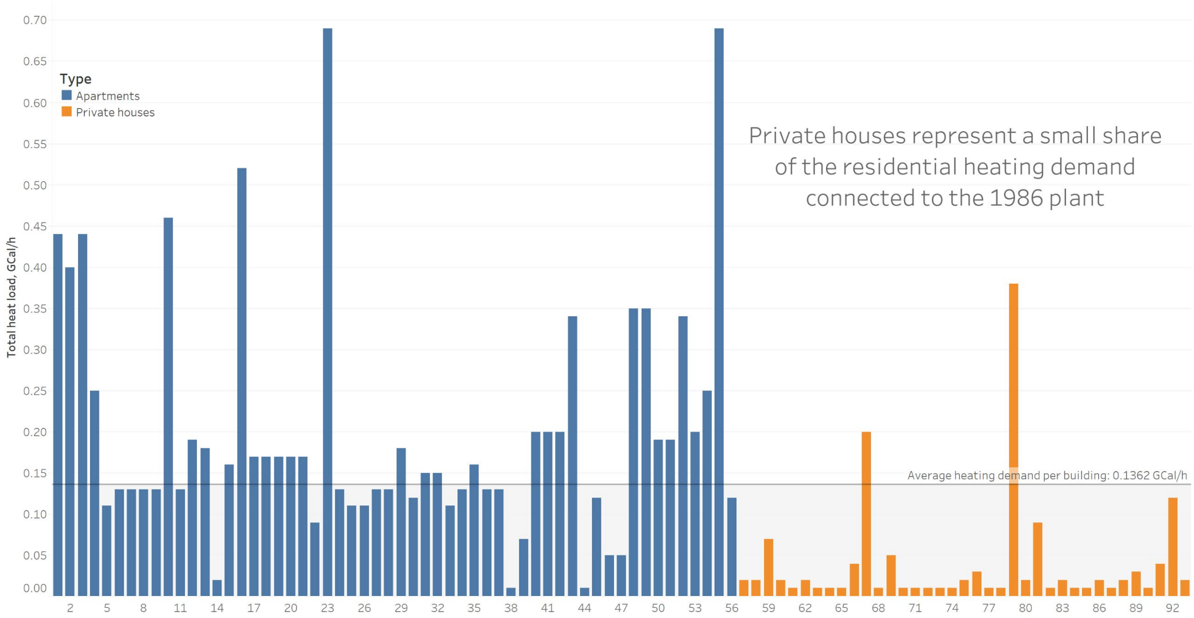

Figure 7: Total heating demand from the 93 resistential private houses and apartment buildings connected to the 1986 heating plant

The heating demand used for the baseline is calculated using the weighted average of total heat load of the building considering the number of apartments per building (information on the number of households per building was available for only 55% of the buildings). This leads to an approximate annual heating demand of 23,600 kWh.

We use the floorspace distribution of households living in buildings in the Khovd *aimag* (NSOM, 2016) to calculate the average size of apartments. We assume that the heat demand is not dependent on the total floor space. We then multiply the floorspace by its associated probability to obtain the approximate average floorspace of 45 m^2 per household in Khovd city.

Including the NDC target to reduce buildings losses, the heat demand per household would be reduced to 21,700 kWh or 490 kWh/m^2 per year. An efficient multi-unit household in Mongolia is expected to have average demand of approximately 150 kWh/m^2 per year (ADB, 2015). Other research shows heat demand in the range of 350-450 kWh/m^2 per year for apartment buildings in Ulaanbaatar (Stryi-Hipp *et al.*, 2018).

The emissions intensity is calculated based on the total coal consumption in Khovd city. The whole district heating system uses in one year around 14,000 tons of coal, resulting in emissions of 19,150 tCO_2/year. We use the share of heat production between the two plants to estimate the emissions from the 1986 plant. Finally, we divide the emissions by the energy production to calculate the emission factor per unit of heat produced for the 1986 plant, 77 tCO_2/TJ. The result is in line with country-reported values for lignite coal, 78 tCO_2/TJ (Ministry of Environment and Tourism, 2018).

Under these assumptions, the emissions per household in the multi-unit buildings is 6.00 tCO_2 per year.

Project emissions

Residual emissions from GSHP use reach 1.4 tCO_2e per household due to the additional electricity consumption

The proposed project leads to two main types of emissions: the potential leakage of the refrigerant and residual indirect emissions from the use of electricity generated with fossil fuels.

The emissions from leakage depend on the final refrigerant choice, refrigerant charge, and leakage rates. Hydrocarbons are the natural refrigerants with highest global warming potential (GWP) among the ones presented in Section 3.3. Both propane and butane have a GWP of three, in comparison to one for CO_2 and zero for water, ammonia, and air. A heat pump of 5 kW running on propane has a charge of 200 g (Wu and Skye, 2018). So, even if the refrigerant discharges completely in one year, the associated emissions would be in the order of 1 $kgCO_2e$. We consider this unlikely with proper maintenance, and even in the event of damage, we consider such leakage to be negligible in comparison to the baselines presented. Also, heat pumps can operate their whole lifetime without complete discharge of the refrigerant, so these emissions are only relevant if there is leakage. The proposed pilot intervention would need to set aside funds for dismantling / recycling of the heat pumps at the end of their usable life. Without such provisions, the risk that the refrigerant is released at the end of the life of the equipment is relatively high, which is one reason we propose to use natural refrigerants.

The electricity consumption is the main residual emission consideration with regard to heat pumps in Mongolia. We multiply the heating demand by the emission intensity of the local electricity grid to obtain the total residual emissions from the project.

Even considering the high COP of ground source heat pumps, about a quarter of the energy for heat would come from electricity. Khovd's buildings electricity supply comes mostly from a hydro power plant (30%) and Russian imports (70%) (GGGI, 2019). Using the emission factor from the Russian grid of 0.356 $kgCO_2/kWh$ (IEA, 2018) and assuming that hydro power electricity does not result in emissions, we estimate that the emission intensity of the electricity used in Khovd is 0.250 $kgCO_2/kWh$. Additional hydro capacity in the Khovd region was included in the Mongolian government's electricity planning for 2016 to 2020 (Jamsran, 2018).

Using results from the PROSPECTS tool[4], we calculate an average emission intensity of power generation in the Mongolian central grid is 0.573 $kgCO_2/kWh$ for the next 20 years under current trends. The standard emission factor for Mongolia's national electricity grid proposed under CDM is 0.859 $kgCO_2/kWh$ for all project activities (UNFCCC, 2018). The emission factor in Khovd is therefore already considerably below national estimates.

Using the calculated emission factor of 0.250 $kgCO_2/kWh$, we estimate that the residual project emissions are 1.4 tCO_2e per household per year. We also estimate the potential emission reductions from the baseline that can be attributed to the project. Figure 8 shows the emissions level before and after the project.

[4] The PROSPECTS tool for Mongolia is under development in the project Capacity Development for climate policy in the countries of South East, Eastern Europe, the South Caucasus and Central Asia, Phase III. The emissions intensity is calculated based on historical data from IEA Energy Balances and projected power generation mix up to 2030 based on Mongolia's mid-term energy development plan.

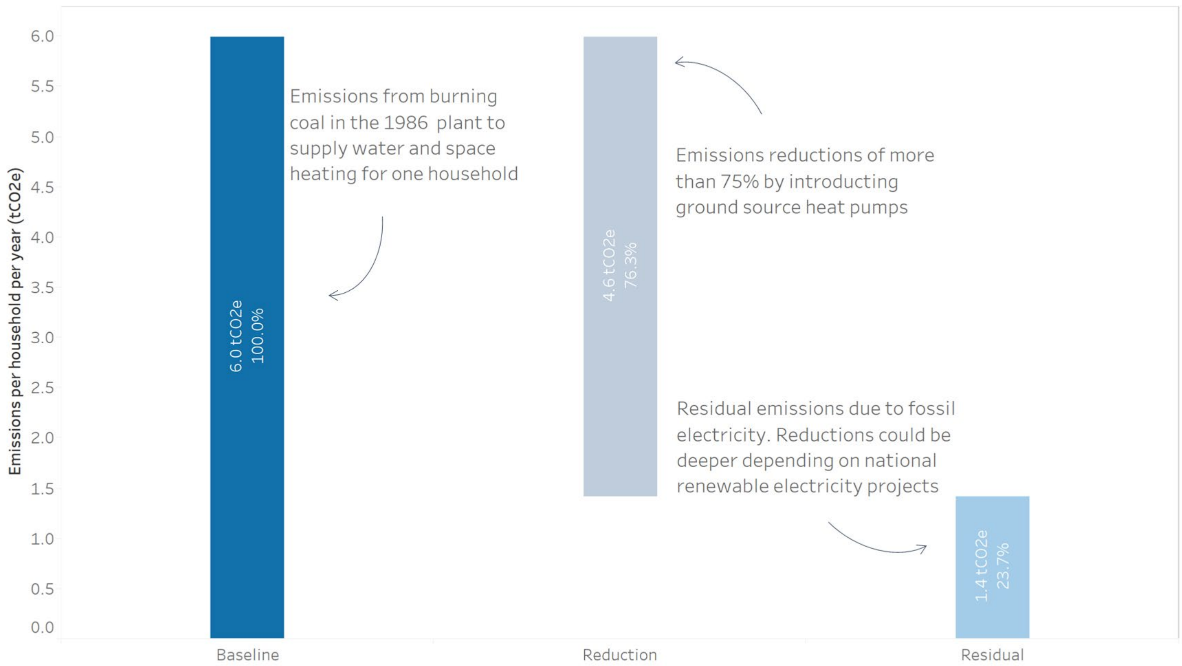

Figure 8: Project residual annual emissions compared to the baseline.

On a systemic level, emissions reach 9,210 tCO_2e/year in the baseline scenario while the project activity leads to emissions of 2,180 tCO_2e/year. The emissions level under the baseline is calculated by adding the heat demand from all apartment buildings connected to the 1986 plant and multiplying the result by the emissions factor calculated in the previous section – 77 tCO_2/TJ. Under the project activity, the emissions level is calculated by considering the additional electricity demand in the same households multiplied by the grid emission factor in Khovd city – 0.250 $kgCO_2$/kWh.

Table 7: Emissions reduction per year under baseline and project activity

Emissions per year (tCO_2e)	Baseline	Project activity	Reduction
Household level	6.0	1.4	4.6
Systemic level	9,210	2,180	7,030

4.8 Data parameters

Heat consumption in Khovd city is currently not metered and residents pay 500 MNT per square meter of their residential unit rather than based on actual consumption. Baseline emissions and estimates of required GSHP capacity are based on estimations to heat the residential units. More robust baseline determination would require sampling to assess actual heat consumption but would significantly increase costs.

4.9 Monitoring plan

Estimates of emission reductions are based on capacity calculations made for the construction of the local heat plant in Khovd and government statistics. Because residents pay for heat by square meter of residential space and not according to actual heat consumption, robust data on heat consumption and, for example, heating loss between the heating plant and residential buildings are not known. For a more detailed calculation, heat meters would need to be installed at the heating plant and for individual residential buildings at significant cost, but a representative sample could be made to form a baseline to confirm the order of magnitude of our assumptions. The installation of heat metering has multiple benefits; it could for example create awareness of household heating consumption, thus potentially incentivising future savings. This incentive is however likely to be limited unless the pricing structure for heat moves from a square meter basis to a system based on consumed heat. For the utilities, metering could create the circumstances for better pricing and consequently better infrastructure. This could however create resistance among residents if there is a perception that metering may increase their heating costs in the future. To estimate residual emissions, increased electricity consumption due to the use of the heat pumps would also require monitoring.

5 Start date, crediting period type and duration, host country benefit, OMGE, SOP and ITMOs

Although Parties were not able to agree on rules for Article 6 at the 2018 COP24 in Katowice, project activities to promote GSHPs could conceivably already start in 2019. If first installations were to be completed by 2020, a ten-year crediting period corresponding to the Mongolian NDC would cover the period during which GSHPs would not yet have paid for themselves. The expected lifetime of GSHPs is 20 years, and emission reductions beyond the crediting period would represent a host country benefit. Operationalising an overall mitigation of global emissions (OMGE) would require a share of emission reductions to be cancelled (Schneider *et al.*, 2018) and several countries have called for a share of proceeds (SOP) from Article 6.2 transfers to also raise funds for adaptation (Grimm *et al.*, 2018). We propose a significant share of emission reductions be cancelled for overall mitigation. Omitting OMGE and SOP would create an uneven playing field in global carbon markets between Art 6.2 and Art 6.4. If the pilot or an ERPA for the pilot starts implementation before the adoption of guidance for Article 6.2 and rules, modalities and procedures for 6.4, any agreement between project parties should include a clause that requires retroactive adjustments to comply with Article 6 rules for OMGE and SOP.

6 Business model for project implementation

The cooperation between the project developer and the parties can be structured around different business models. These models vary with respect to who is the project developer, the costs for each party, the duration of the intervention, and the potential barriers in the specific context. Therefore, the model presented in this chapter is meant as one possible alternative.

In considering business models, there are a number of parties, whose interests need to be taken into consideration. These include the residents of the buildings, the heat and electricity utility (owned by the state), the Mongolian government, the potential credit acquirer, and the project developer. We briefly explore them in the following.

The **building residents** currently receive a significant subsidy with regard to their heating costs as they pay for heat based on the square meter of their apartments or houses rather than based on actual heat consumption. For an average apartment size of 45 m^2, a household pays approximately EUR 70 a year. This does not incentivise efficiency as the residents have no price signal to do so.

Because of the pricing structure, the **utility** running the older heat plant and district heating system is not able to pay for sufficient maintenance of the system, and is reliant on the Mongolian government to maintain and expand services (World Bank, 2018a). This also poses challenges for the heating utility to pay for a new heating plant although the existing plant is very old, inefficient, and will likely need to be replaced soon. Utilities selling electricity also do not always cover their costs because of government-controlled prices.

It is a stated objective of the **Mongolian government** to transfer the state-dominated electricity sector into a private-based, competitive market, to support innovation and advanced technology in the energy sector and to implement conservation policy (Jamsran, 2018). The financial state of utilities is a further fiscal burden on the Mongolian central government.

It is the challenge of the potential **project developer and credit acquirer** to establish a business model to install and run ground source heat pumps in Mongolia that reduce GHG emissions and air pollution, without leaving any party worse off.

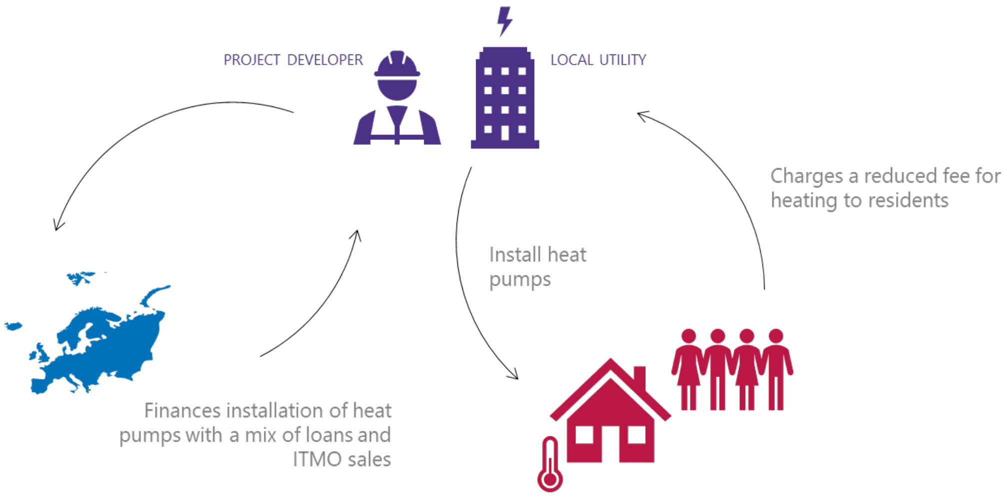

Figure 9: Potential business model for implementation of renewable heating in Mongolia

The project developer could form a partnership with the local utility and finance the upfront costs of the heat pump installation through a soft loan and an Emission Reduction Purchase Agreement. The operation and maintenance of the heat pumps is cheaper than the operation and maintenance costs of both the current heat plant as well as the cost of replacing the current heat plant with a new CFB coal-fired boiler. Thus, while the upfront costs of heat pumps are higher, during the operation they would lead to savings for the utility. This situation could however make the residents worse off since electricity costs to run the heat pumps exceed the cost that they are currently paying for heat. With some of the savings from not having to operate and maintain the coal-based heat plant, the electric utility could charge the residents a reduced price for the electricity associated with the heat pump to ensure that the residents are not burdened with much higher monthly costs.

On a systemic level, upfront costs of the installation of the heat pumps is estimated to be approximately EUR 7.0 million, which we estimate would reduce 7,000 tonnes of CO_2 per year. For a crediting period of 10 years, this would equal to an emissions reduction cost of approximately 100 EUR/tCO_2. It is however conceivable that the upfront installation cost could in part be financed through soft loan. The loan would partially be repaid by the local utility financed through the savings resulting from the lower O&M from the heat pumps adjusted to reflect the difference between the heating costs residents had previously paid and the increased electricity used to run the heat pumps. If the equivalent of what would have been the upfront investment cost of a new CFB coal-fired boiler – EUR 3.8 million – is financed through a loan, this could reduce the price per tonne of reduced emissions to approximately 46 EUR/tCO_2.

Other financial options could be explored but some are considered unrealistic for Mongolia. For example, business models such as loans for housing residents for the installation of heat pumps, or a one-off installation of heat pumps without longer engagement with the local utility, would leave residents financially worse off as their costs in switching from the district heat to electric heat pumps were considered to be a prohibitive barrier to the implementation of the model.

7 Environmental impact assessment and sustainable development goals co-benefits

Normally, project developers carry out an Environmental Impact Assessment (EIA) prior to PDD development, but as our project is a virtual pilot, we have not done so. As a result, an EIA might provide us with new information and may lead to changes in the sections above.

An EIA provides both project developers and the Governments of Mongolia and Sweden with information of possible environmental effects of the project, including transboundary impacts. Accordingly, we can anticipate these consequences and limit negative environmental impacts to the greatest extent possible. In addition to an EIA, we propose to regularly monitor the project and its environmental impacts in order to anticipate problems that may arise during the project cycle and to prevent adverse consequences to the environment as much as possible. Further, the Government of Mongolia needs to monitor purported sustainable development contributions.

Article 6 provides that the international transfer of emissions, and other cooperative actions, should promote sustainable development. Heat pumps would contribute to the realisation of a number of SDG goals, but in particular to Goal 3 regarding good health and well-being and Goal 7 regarding affordable and clean energy. As a result of the country's dependence on coal and wood for heating, air pollution is a major problem in Mongolian cities, leading to an estimated 2,424 premature deaths per year (The World Bank; and Institute for Health Metrics and Evalution, 2016). In addition, air pollution is associated with lung cancer and cardiorespiratory diseases (Arden Pope *et al.*, 2002). Replacing heating demand from the coal fired district heating with GSHPs would not only significantly reduce GHG emissions and support Mongolia on its pathway toward decarbonisation, it would also improve air quality and public health. Human health co-benefits of reducing CO_2 emissions in China fall in the range of 70-800 USD/tCO_2 (West *et al.*, 2013). Because the method to estimate health co-benefits is based on GDP, benefits are likely to be lower in Mongolia. Nevertheless, this range gives an indication of the magnitude of health co-benefits of reduced air pollution. Indeed, recent studies indicate that the health benefits of climate policy outweigh the mitigation costs (West *et al.*, 2013; Markandya *et al.*, 2018). This is likely to be true for Mongolia, which suffers from extreme air pollution, caused by old, inefficient coal-fired power plants and fire stoves for cooking and heating purposes.

In addition to improved human health and well-being, the proposed project also contributes to affordable and clean energy for Khovd's population. Table 8 presents an overview of the SGDs impacted by the project activity.

SDG Indicators

Table 8: Overview of SDGs and targets impacted by the project activity, positive links are highlighted in green and negative in red.

SD Goal	Target	Target text	Link	Description of link
3. Good health and well-being	3.4	By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being	(green)	GSHP heating can reduce air, water and soil pollution and thus non-communicable diseases when displacing polluting energy sources, such as fossil fuels and bioenergy.
	3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals as well as air, water and soil pollution and contamination	(green)	GSHP heating can reduce air, water and soil pollution and contamination when displacing polluting energy sources, such as fossil fuels and bioenergy.

SD Goal	Target	Target text	Link	Description of link
6. Clean water and sanitation	**6.3**	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally		GSHP heating can reduce thermal and non-thermal water pollution when fossil fuel generation plant is displaced.
	6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity		Contributes to water-use efficiency when replacing electric water heating (reduced generation from water intensive thermal power plants).
7. Affordable and clean energy	**7.1**	By 2030, ensure universal access to affordable, reliable and modern energy services		GSHP heating contributes to increasing access to basic affordable and modern energy services.
	7.2	By 2030, increase substantially the share of renewable energy in the global energy mix		Electrifying heating means that it can be sourced with renewable energy.
8. Decent work and economic growth	**8.2**	Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors		**Indirect link:** Deployment of new energy technologies can support economic productivity by creating new industrial activity, supply chain development, and innovation.
	8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services		**Indirect link:** Investment in renewables supports productive activities, job creation in the sector, supply chain development, innovation, and enterprise development.
	8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead		GSHP heating supports increased resource efficiency and reduces environmental damage vs conventional water heating.
	8.5	By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value		Deploying GSHP heating can support full employment through creation of decent jobs.
	8.5	By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value		Deploying GSHP heating may lead to job losses from displaced alternative power generation activity.

SD Goal	Target	Target text	Link	Description of link
9. Industry, innovation and infrastructure	**9.1**	Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all		Deployment of GSHP heating supports development of sustainable, reliable and resilient infrastructure by replacing outdated infrastructure.
	9.2	Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries		Deployment of renewables supports sustainable industrialisation through increased sustainability of power supply and development of sustainable industries related to heat pump energy project construction and operation.
	9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities		Deployment of GSHP heating upgrades infrastructure, increases sustainability of industry, increases resource-efficiency and supports adoption of clean technologies.
	9.5	Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular in developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending		**Indirect link**: Deploying GSHP heating technology upgrades technological capabilities.
11. Sustainable cities and communities	**11.3**	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries		**Indirect link**: Deployment of GSHP heating supports sustainable urbanisation.
	11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management		GSHP heating can contribute to reducing the environmental impact of cities by reducing the amount of GHG emissions and air pollutants compared to other traditional technologies.
12. Responsible consumption and production	**12.2**	By 2030, achieve the sustainable management and efficient use of natural resources		Using heat pump for heating contributes to sustainable management and efficient use of natural resources.
15. Life on land	**15.2**	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally		GSHP heating could help displace wood fuel use, contributing to reducing deforestation.
	15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species		GSHP heating can help reduce degradation of natural habitats through reduced air and water pollution and reduced water consumption, if displacing more polluting or intensive alternatives.

8 Mongolian readiness for Art 6 engagement

Mongolia is host to a number of successful CDM projects and participates in the Japanese Joint Crediting Mechanism. Mongolia submitted its economy wide NDC to the UNFCCC in September 2015 and ratified the Paris Agreement on the 21 September 2016. National Communications were submitted in 2001, 2010 and 2018. Four national GHG inventories were conducted between 1990 and 2014. Preparations are currently underway for a revision of the NDC.

The "Paris Rulebook" COP24 decision (CP24 para 77 d) calls for Parties participating in cooperative approaches that involve the use of ITMO's (here understood to be potentially both cooperative approaches under Article 6.2 and Article 6.4) to provide:

(i) *The annual level of anthropogenic emissions by sources and removals by sinks covered by the NDC on an annual basis reported biennially;*

(ii) *An emissions balance reflecting the level of anthropogenic emissions by sources and removals by sinks covered by its NDC adjusted on the basis of corresponding adjustments undertaken by effecting an addition for internationally transferred mitigation outcomes first-transferred/transferred and a subtraction for internationally transferred mitigation outcomes used/acquired, consistent with decisions adopted by the CMA on Article 6; must provide the "annual level of anthropogenic emissions by sources and removals by sinks covered by the NDC on an annual basis reported biennially";*

(iii) *Any other information consistent with decisions adopted by the CMA on reporting under Article 6;*

(iv) *Information on how each cooperative approach promotes sustainable development; and ensures environmental integrity and transparency, including in governance; and applies robust accounting to ensure inter alia the avoidance of double counting, consistent with decisions adopted by the CMA on Article 6.*

As negotiations are ongoing, in the absence of further guidance or rules modalities and procedures adopted by the CMA, the reporting requirements of the Paris Rulebook already represents a challenge for Mongolia, requiring increased institutional capacity and resources to conduct annual GHG inventories, and establish a registry or other accounting system for "first-transferred/transferred and a subtraction for internationally transferred mitigation outcomes used/acquired."

In order to apply corresponding adjustments, Mongolia may need to update its NDC or issue a clarification that the projected reduction from BAU constitutes a quantified target. The current formulation is not clear in this area, though it may be changed in an NDC update.

It is assumed that the current DNA would continue to retain authority to issue host country letters of approval, but this mandate would need expanding to carry out corresponding adjustments with important implications for NDC achievement.

References

ADB (2015) 'Mongolia : Ulaanbaatar Affordable Housing and Urban Renewal Project'. Manila.

ADB (2017) *Mongolia : Preparing the Aimag and Soum Centers Regional Development Investment Program (Financed by the Japan Fund for Poverty Reduction)*. Available at: https://www.adb.org/projects/49430-001/main#project-overview.

ADB (2018a) *Mongolia : Green Urban Planning*. Available at: https://www.adb.org/projects/51100-001/main#project-overview.

ADB (2018b) *Mongolia: Upscaling Renewable Energy Sector Project (Final Report)*. Ulaanbaatar, Mongolia.

Arden Pope, C. *et al.* (2002) 'Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution', *Jama*, 287(9), pp. 1132–1141. doi: 10.1001/jama.287.9.1132.

Asian Development Bank (2018) *Ulaanbaatar Green Affordable Housing and Resilient Urban Renewal Sector Project: Project Administration Manual*. Available at: https://www.adb.org/projects/documents/mon-49169-002-pam (Accessed: 20 February 2019).

Dorj, P. (2015) *Geothermal Development in Mongolia: Country Update*, *Proceedings World Geothermal Congress*. Melbourne, Australia.

Faraz Shibli (2017) 'Steppes and the city: rural to urban migration in Mongolia', *International Migration Institute Network*, March. Available at: https://www.imi-n.org/blog/steppes-and-the-city-rural-to-urban-migration-in-mongolia (Accessed: 20 February 2019).

Gehlin, S. and Andersson, O. (2016) *Geothermal Energy Use, Country Update for Sweden*, *European Geothermal Congress*. Strasbourg.

GGGI (2018) *Low Carbon Heating for off-grid buildings of Mongolia - Business Case of 122nd Public School*. Ulaanbaatar.

GGGI (2019) *Number of buildings and energy suply in Khovd (Personal Communication)*. Ulaanbaatar, Mongolia.

GGGI and Government of Mongolia (2016a) *Investment analysis and prioritization of alternative options of heating systems*.

GGGI and Government of Mongolia (2016b) *Situation analysis of heating systems in Arkhangai, Bulgan and Khovd aimag centers*.

Government of Mongolia (2015) 'Intended Nationally Determined Contribution (INDC), Mongolia', pp. 1–10. doi: 10.1007/s13398-014-0173-7.2.

Government of Mongolia (2017) *Mongolia's Initial Biennial Update Report*. Available at: https://unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/application/pdf/mongolia_bur1_resubmission_and_annexnir.pdf (accessed on 7 March 2018).

Grimm, J. *et al.* (2018) *The future role of the Adaptation Fund in the international climate finance architecture*. Available at: https://newclimate.org/wp-content/uploads/2018/10/The-future-role-of-the-Adaptation-fund-in-the-internatinal-climate-finance-architecture.pdf (Accessed: 18 June 2019).

IEA (2018) *World Energy Balances (2018 edition)*. Paris, France: International Energy Agency.

Jamsran, J. (Ministry of E. G. of M. (2018) 'Energy Sector of Mongolia, Country Report'. IEEJ. Available at: https://eneken.ieej.or.jp/data/8016.pdf.

Khovd Aimag and Mongolia's Western Development Bank (2015) *Khovd Aimag Development Strategy*. Khovd.

Lychuk, T. *et al.* (2012) *Analysis of the Russian Market for Building Energy Efficiency*. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22110.pdf (Accessed: 27 June 2019).

Ma, W., Kim, M. K. and Hao, J. (2019) 'Numerical simulation modeling of a GSHP and WSHP system for an office building in the hot summer and cold winter climate: A case study at Suzhou , China', *Sustainability*, 11, pp. 3282–3299.

Markandya, A. *et al.* (2018) 'Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study', *The Lancet Planetary Health*. The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY-NC-ND 4.0 license, 2(3), pp. e126–e133. doi: 10.1016/S2542-5196(18)30029-9.

van Mead, N. (2017) 'the Cities With the Most Dangerous Air – Listed', *the Theguardian*, 13 February, p. 1. Available at: https://www.theguardian.com/cities/datablog/2017/feb/13/most-polluted-cities-world-listed-region.

MEGDM (2013) *Technology needs assessment. Vol 2 - Climate Change Mitigation in Mongolia*, *Ministry of Environment and Green Development of Mongolia*. Ulaanbaatar, Mongolia: Ministry of Environment and Green Development,. Available at: https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNR_CRE/e9067c6e3b97459989b2196f12155ad5/606a61fadbf64207b0b7c730c08beb3c.pdf.

Ministry of Agriculture and Rural Development (MARD) (2013) *MicroEnergy Credits – Microfinance for Clean Energy Product Lines - Mongolia*. Available at: https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/QF6PYE8DBOKW1UC7TV549023AGLZXN/view.

Ministry of Environment and Tourism (2018) *Mongolia Third National Communication*. Available at: https://unfccc.int/sites/default/files/resource/06593841_Mongolia-NC3-2-Mongolia TNC 2018 pr.pdf.

Moià Pol, A., Morzhukhin, A. and Nazmitdinov, R. (2018) 'Analysis of a heat pump market in Russia - prospects of combined system for small buildings', in *GL2018 CONFERENCE. 13th IIR-GUSTAV LORENTZEN CONFERENCE ON NATURAL REFRIGERANTSAt: Valencia*. Valencia. doi: 10.18462/iir.gl.2018.1368.

National Statistics Office of Mongolia (2017) *Mongolian Statistical Information Service*. Available at: http://www.1212.mn/ (Accessed: 7 March 2019).

Nekrasov, A. S. *et al.* (2011) 'State-of-the-art of Russia's heat supply systems', *Studies on Russian Economic Development*. SP MAIK Nauka/Interperiodica, 22(1), pp. 20–30. doi: 10.1134/S1075700711010072.

NOAA (2019) *NNDC Climate Data Online*, *NOAA Logo, National Environmental Satellite, Data, and Information Service*.

NSOM (2016) *2015 Population and Housing By-Census of Mongolia - National Report*. Ulaanbaatar.

Pillarisetti, A. *et al.* (2019) 'Advanced household heat pumps for air pollution control: A pilot field study in Ulaanbaatar, the coldest capital city in the world', *Environmental Research*. Academic Press. doi: 10.1016/J.ENVRES.2019.03.019.

Rao, M. P. *et al.* (2015) 'Dzuds, droughts, and livestock mortality in Mongolia', *Environmental Research Letters*, 10(7), p. 074012. doi: 10.1088/1748-9326/10/7/074012.

Ryabov, G. A. (2016) 'Development of the Circulating Fluidized Bed Combustion Technology: Studies of CFB Technology at VTI and the Justification for its Use in Russia', *Power Technology and Engineering*, 50(4), pp. 413–418. doi: 10.1007/s10749-016-0723-6.

Schneider, L. *et al.* (2017) *Discussion Paper: Environmental Integrity under Article 6 of the Paris Agreement*. Available at: https://www.dehst.de/SharedDocs/downloads/EN/project-mechanisms/Discussion-Paper_Environmental_integrity.pdf?__blob=publicationFile&v=2.

Schneider, L. *et al.* (2018) *Operationalising an 'overall mitigation in global emissions' under Article 6 of the Paris Agreement*. Lambert Schneider and NewClimate Institute. Available at: https://newclimate.org/2018/11/21/operationalising-an-overall-mitigation-in-global-emissions-under-article-6-of-the-paris-agreement/.

Singh, R. M., Sani, A. K. and Amis, T. (2018) *An overview of ground-source heat pump technology*, *Managing Global Warming*. Elsevier Inc. doi: 10.1016/b978-0-12-814104-5.00015-6.

Stryi-Hipp, G. *et al.* (2018) *Energy Master Plan for Ulaanbaatar*. Freiburg im Breisgau.

Tanaka, N. and Kotoh, S. (2007) 'The current status of and future trends in heat pump technologies with natural refrigerants', *Mitsubishi Electric Advance*, 120, pp. 2–5.

The World Bank; and Institute for Health Metrics and Evalution (2016) *The Cost of Air Pollution: Strengthening the Economic Case for Action*, *The World Bank Group and Institute for Health Metrics and Evaluation*. Washington D.C. doi: 10.1787/9789264210448-en.

UNFCCC (2018) *CDM: Standardized baselines*. Available at: https://cdm.unfccc.int/methodologies/standard_base/2015/sb4.html (Accessed: 9 April 2019).

USAID (2010) *Mongolia*, *LandLinks*. Available at: https://www.land-links.org/country-profile/mongolia/#land (Accessed: 20 February 2019).

Vasilyev, G. P. *et al.* (2016) 'The effectiveness of low-grade geothermal heat usage under the conditions of the Russian climate', *Geothermics*. CNR-Istituto di Geoscienze e Georisorse, 62, pp. 93–102. doi: 10.1051/matecconf/20153005002.

Warnecke, C. *et al.* (2018) 'Opportunities and safeguards for ambition raising through Article 6 The perspective of countries transferring mitigation outcomes'. Berlin: NewClimate Institute. Available at: https://newclimate.org/wp-content/uploads/2018/05/180508_AmbitionRaising-Article6Paper.pdf (Accessed: 18 May 2018).

West, J. J. *et al.* (2013) 'Co-benefits of Global Greenhouse Gas Mitigation for Future Air Quality and Human Health', *Nature Clim. Change*, 3(10), pp. 885–889. doi: 10.1038/NCLIMATE2009.Co-benefits.

World Bank (2018a) 'MONGOLIA: Systematic Country Diagnostic'. Washington, D.C: World Bank. Available at: http://documents.worldbank.org/curated/en/576101543874150141/pdf/mongolia-scd-final-version-november-2018-11282018-636792121231072289.pdf.

World Bank (2018b) 'World Development Indicators 2018'. Available at: https://data.worldbank.org/indicator/SP.POP.TOTL.

Wu, S. *et al.* (2018) 'A review of ground-source heat pump systems with heat pipes for energy efficiency in buildings', *Energy Procedia*, 152, pp. 413–418. doi: 10.1016/j.egypro.2018.09.167.

Wu, W. and Skye, H. M. (2018) 'Progress in ground-source heat pumps using natural refrigerants', *International Journal of Refrigeration*. Elsevier, 92, pp. 70–85. doi: 10.1016/J.IJREFRIG.2018.05.028.

Yuan, Y. *et al.* (2012) 'Ground source heat pump system: A review of simulation in China', *Renewable and Sustainable Energy Reviews*. Elsevier, 16(9), pp. 6814–6822. doi: 10.1016/j.rser.2012.07.025.

Yue, G. *et al.* (2010) 'Latest Development of CFB Boilers in China', in *Proceedings of the 20th International Conference on Fluidized Bed Combustion*. doi: 10.1007/978-3-642-02682-9.

Zhao, H., Gao, Y. and Song, Z. (2017) 'Strategic outlook of Heat pump development in China', in *12th IEA Heat Pump Conference 2017*. Rotterdam.

Annex 1 – Overview of heat pump projects in Mongolia

This annex presents heat pump projects in operation in Mongolia. The current table is not meant to be extensive but to provide evidence that the use of ground source heat pumps is a working concept in the Mongolian climate.

Table 9: Overview of heat pump projects in Mongolia based on GGGI (2018) and Pillarisetti *et al* (2019)

Facility	Type	Location	Installed capacity (kW)	Start of operation
Achit Ikht LLC	**GSHP**	Erdenet	40	-
Ireedui Complex (3 heat pumps)	**GSHP**	Zuunmod	250	2010
Sod kindergarten	**GSHP**	Ulaanbaatar	17	2009
Yargaitiin am, Chingeltei district	**GSHP**	Ulaanbaatar	300	-
Detached house in Gachuurt	**GSHP**	Ulaanbaatar	13	-
Apartment building Khuushiin am	**GSHP**	Ulaanbaatar	68	-
Detached house, Khuushin am (8 heat pumps)	**GSHP**	Ulaanbaatar	320	-
Mongol tulsh Exhibition Hall	**GSHP**	Ulaanbaatar	12	2017
Apartment building Enkhjin	**ASHP**	Ulaanbaatar	94	-
Asem villa (55 heat pumps for detached houses)	**GSHP**	Ulaanbaatar	1,588	2013 (demo), 2016
Detached house in Chuluun Ovoo	**WSHP**	Ulaanbaatar	75	2014
Chingeltei district	**GSHP**	Ulaanbaatar	35	-
Terelj	**GSHP**	Ulaanbaatar	25	-
Sukhbaatar District	**ASHP**	Ulaanbaatar	12	2017
Khovd Kindergarten	**GSHP**	Khovd	132	2018-2022

ASHP = air source heat pump, GSHP = ground source heat pump, WSHP = water source heat pump

Annex 2 – Emissions reduction potential from exploring synergies between heat pump deployment and relocation initiatives

The current project activity proposes installing heat pumps in multi-unit buildings to displace part of the heat generated in coal-fired heating plants. Nonetheless, most of the air pollution in Mongolia comes from the use of fire stoves in *ger* areas. The use of GSHPs in *gers* is not indicated due to the high thermal losses, small floorspace (that does not justify the high investment) and the lack of reliable electricity supply in several of these households.

There are initiatives to relocate people from the *ger* areas into buildings in Ulaanbaatar (ADB, 2015). These initiatives aim to build energy-efficient housing and provide affordable loans to Mongolian people. In this annex, we investigate the impact of coupling these initiatives with clean and Paris-compatible heating technologies to calculate the potential emission reduction potential.

Heating from coal-fired stoves in household living in a *ger* – emissions of 9.1 tCO_2e per year

The emissions resulting from coal combustion in *gers* are estimated using a methodology developed in the CDM context. Several households in Ulaanbaatar were surveyed regarding their heating and cooking habits in order to credit the introduction of more efficient cookstoves (Ministry of Agriculture and Rural Development (MARD), 2013).

The model uses the local wind speed and temperature to estimate the yearly household coal and biomass consumption in *gers*. While coal is the main source used for heating, biomass was found to be the main source for lighting purposes and is not included further. The coal consumption across the seasons follows following expression:

$$C_{coal,s} = \sum_{s} (4.57681 - 0.67248 \cdot WS_s - 0.01124 \cdot T_s + 0.11955 \cdot D_{songinokhairkhan} - 0.36234 \cdot D_{Bayangol})$$

Variable	Description
s	*s* refers to the season: Fall, Winter or Spring. The total consumption is the sum over the 3 seasons.
$C_{coal,s}$	Mean coal consumption during the heating season
WS_s	Mean wind speed in Knots for season *s*
T_s	Mean Temperature in Celsius for season *s*
$D_{songinokhairkhan}$	*Ger* location is *Songinokhairkhan* (1=yes, 0=no). District with higher coal consumption.
$D_{Bayangol}$	*Ger* location is *Bayangol* (1=yes, 0=no). District with lower coal consumption.

We assume that the average consumption of a *ger* household in Ulaanbaatar is the same as in Khovd city if we factor for distinct weather conditions and assuming that the demand is comparable to a common district in Ulaanabatar.[5]

The exact coal type used in the *gers* of Khovd is not known. We used the emissions factors reported by the Mongolian government in their Biennial Update Report for bituminous and lignite coal (Government of Mongolia, 2017) combined with the historical share of these two types from IEA from 1985 to 2016 (IEA, 2018) to estimate emissions factors. The results are shown in Table 10. The average values across the five years is considered as the baseline emissions level per household.

Table 10: Summary of emissions results per household (coal combustion in Ger fire stoves)

Indicator	unit	2013	2014	2015	2016	2017
Coal consumption	**tons**	**3.44**	**4.51**	**4.80**	**4.75**	**4.57**
From which bituminous	tons	2.24	2.93	3.12	3.08	2.97
From which lignite	tons	1.20	1.57	1.68	1.65	1.60
Emissions per household	**tCO_2**	**7.10**	**9.30**	**9.90**	**9.78**	**9.43**
From which bituminous	tCO_2	5.46	7.16	7.62	7.52	7.26
From which lignite	tCO_2	1.64	2.14	2.28	2.25	2.17

If households from *gers* are relocated, they would probably move into new buildings with lower heating demand. We assume the heating demand is the one from the ADB AHURP project: 150 kWh/m^2in contrast to 490 kWh/m^2 calculated for the project baseline. Installing heat pumps in these efficient buildings would results in emissions reduction of approximately 70%. Therefore, residual emissions would reach 0.43 tCO_2e/year and the use of heat pumps in new buildings would result in an emission reduction of 8.97 tCO_2e/year per household.

[5] If we consider the population in the Ulaanbaatar districts with distinctive behaviour (*Songinokhairkhan* or *Bayangol*) to calculate a weighted average consumption, the emissions results are slightly (1%) reduced.

NewClimate – Institute for Climate Policy and Global Sustainability gGmbH

Cologne Office
Clever Straße 13-15
50668 Cologne
Germany

T +49 (0) 221 999833-00
F +49 (0) 221 999833-19

Berlin Office
Schönhauser Allee 10-11
10119 Berlin
Germany

E info@newclimate.org
www.newclimate.org