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STRATEGIC HEATING PLAN FOR MONGOLIA

Integrating renewable energy solutions in district heating systems

Executive summary

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Contributors: The report was prepared under the overall guidance of Gurbuz Gonul (Director, Country Engagement and Partnerships, IRENA) and Amjad Abdulla (IRENA). It was authored by Jack Kiruja and Joong Yeop Lee (IRENA), Michelle Ramirez (ex-IRENA), Steffen Neilsen, Diana Moreno, Frederik Dahl Nielsen and Hamza Abid (Aalborg University) and Erbar Agarjav (Consultant). Valuable input was also provided by IRENA colleagues Simon Benmarraze, Francisco Boshell, Abbie Dean, Jinlei Feng, Ricardo Gorini, Hannah Guinto, Paul Komor, Paula Nardone, Pablo Ralon and Warih Aji Pamungkas. The report was edited by Justin French-Brooks; layout and design were provided by Glendon Bunn.

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Executive summary

The current heat supply in Mongolia is highly reliant on district heating and individual household heating fuelled by domestically produced coal. The coal provides an economical option for the supply of heat to the population but is also a main cause of many challenges in the country. Local pollution due to coal usage is high in cities, causing respiratory-related health issues. It also challenges Mongolia's aim to reduce greenhouse gas (GHG) emissions in line with its Nationally Determined Contribution (NDC) and thus hinders the pace of meeting the global climate change targets set in the Paris Agreement. Most buildings in Mongolia have low energy efficiency, and their heat supply systems are also inefficient. Furthermore, a large share of the population has relatively low purchasing power, which implies that upgrading heating systems and integrating more renewable supply is not a simple pathway. Finally, the population of the country is increasing rapidly, only adding to these problems if the current heating-related challenges are not addressed. Mongolia, however, also has large potential sources of renewable energy - especially wind, solar and geothermal energy.

A strategic heating plan (SHP) is a techno-economic assessment that shows how municipalities, districts, cities or countries can transform their heat supply from fossil-based sources through the integration of renewable energy resources. In the case of Mongolia, IRENA developed a detailed SHP covering the city of Ulaanbaatar to leverage the existing district heating network with the utilisation of locally available renewable energy heat sources, as well as renewable electricity from solar and wind. The assessment comprises detailed mapping of the heat demand of buildings and a detailed energy system analysis of the district heat supply. Since most of the pollution from the heating sector in Ulaanbaatar is generated in informal settlements ("*Ger*" areas) where district heating systems may not be possible, options for individual heating are explored. Less detailed mapping of heat demand in the towns of Khovd and Tsetserleg was also undertaken, but a detailed energy analysis was not possible due to limited availability of data.

The SHP applies the concepts of "energy efficiency first", smart energy systems and fourth-generation district heating. This means that energy efficiency has a significant role, and integration with renewable electricity generation and more efficient district heating systems have an important role too.

The SHP for Mongolia creates a model that spatially maps the heat demand in buildings. The reason to focus on the spatial aspects is that the density of heat demand is crucial in determining the feasibility of developing new - or expanding existing - district heating networks. Highly dense areas in terms of heat demand, such as built-up urban areas, are relevant for district heating, while in rural areas with low-density heat demand, supply of district energy is more costly. Heat demand in new buildings has also been estimated based on the projected population increase and the subsequent need for more buildings. Energy efficiency measures were considered for existing buildings, reducing the demand for heating by approximately 47% compared to the status quo. Regarding renewable energy sources for district heating, the assessment focuses on geothermal, solar, wind and energy from waste incineration.

A comparative heating system assessment was conducted for Ulaanbaatar as the major city and an exemplary case study for heat demand in Mongolia. The assessment involved the formulation and evaluation of three cases: a Reference 2020 case, 2050 long-term case and 2030 short-term case. The Reference 2020 case was established to illustrate the current fossil fuel-based heat supply systems. The 2050 long-term case was formulated to include a Baseline fossil fuel-based system and a 100% Renewable system. From the long-term case, a 2030 short-term case was established through a backcasting approach, also consisting of a fossil-based system and a renewable-based system.

The formulation of the Renewable 2050 system considers several essential enabling interventions. Implementing energy efficiency measures in buildings is crucial, as it reduces the need for additional heat supply capacity. Not including the efficiency measures would keep the heat demand high and require a significant energy input to balance. Lowering the heat demand in buildings would also have further benefits for heat supply. For example, this would make it possible to achieve lower supply temperature in district heating systems, hence reducing heat losses and improving the efficiency of the supply side. It would also benefit renewable energy sources, such as low-temperature geothermal or solar thermal, which typically provide lower temperatures than the current district heat supply from fossil fuels. In the Renewable 2050 system, the district heating network is improved in two ways: firstly, by gradually replacing old pipes with more energy-efficient pre-insulated pipes, and secondly by lowering supply temperature levels below 100°C, both of which help to reduce heat losses from around 17-18% to around 8-10%.

As regards heat supply, the primary strategy is to incorporate more renewables directly into district heating networks. Geothermal heat could be used to provide baseload heat in the winter months when other renewable sources are insufficient. In areas where geothermal energy is unavailable, industrial waste heat or heat pumps can be applied as alternative solutions, even though there are significant uncertainties due to lack of detailed geothermal investigations in the country. Another important technology is solar thermal collectors, which contribute renewable heat directly to the district heating supply. Waste incineration is also added, as this technology can be used as a significant method of treating waste in the country whilst also providing energy.

In addition to direct heat application in district heating networks, renewable electricity supply - mainly in the form of wind and solar power - could be implemented by increasing the use of air–water heat pumps and direct electric boilers in the heat supply, both for individual heating and district heating. Heat storage is also essential, as it can be used to balance the temporal difference between heat demand and renewable heat generation.

The results of the case study on Ulaanbaatar show that in the 100% Renewable system of 2050, a feasible supply mix for district heating would consist of 23% energy from waste incineration, 3% geothermal heat, 3% solar thermal, 42% air–water heat pumps and 29% electric heat-only boilers (HOBs). Compared to the Reference 2020 system, the Renewable 2050 system achieves a reduction of 55% in primary energy use, while the Baseline 2050 fossil fuel-based system would increase primary energy use by 9%. The implementation of the Renewable systems would significantly reduce annual CO_2 emissions from 6.5 million tonnes (Mt) in 2020 to 3.7 Mt in 2030 to 0.5 Mt in 2050. Looking at annual air pollutant emissions (SO_2, NO_X, $PM_{2.5}$ and PM_{10}), the reduction is also significant, from 81 900 tonnes in 2020 to 2 500 tonnes in 2030 and 1 000 tonnes in 2050 with the renewable energy systems. However, it should be noted that in the baseline fossil fuel-based system, flue gas cleaning is also included, having a significant impact on the reduction of air pollutant emissions. The cost of the district heating systems in the considered cases of 2020, 2030 and 2050 is susceptible to CO_2 costs. If CO_2 costs are omitted, the Baseline 2050 fossil fuel-based system and Renewable 2050 system are both more costly than the Reference 2020 system, but very similar to each other in annual cost at around USD 800 million per year. When the CO_2 costs are included, the Reference 2020 has a cost of USD 1.631 billion per year, while the 2050 fossil fuel-based system increases the cost to USD 2.22 billion per year and the Renewable 2050 system is only USD 852 million per year.

In individual houses and the *Ger* areas, the supply of heat is changed from coal-based stoves and HOBs to a mix of direct electric heating, air–water heat pumps and ground-source heat pumps, supplemented by solar thermal and air-to-air heat pumps. Transitioning to these technologies is estimated to reduce annual CO_2 emissions from 2.98 Mt in 2020 to 1.54 Mt in 2030 and 0.5 Mt in 2050. Air pollutant emissions are also reduced by 41% from 71.9 kt in 2020 to 29.4 kt in 2030; and to zero in 2050. The investment cost to achieve this reduction would increase from USD 22.8 million in 2020 to USD 125.95 million in 2030 and USD 194.23 million in 2050. However, taking a system perspective of the whole individual heating sector, this would provide considerable cost savings due to a reduction in fuel purchases and emissions, reducing total annual system costs from USD 858 million per year in 2020 to USD 568 million per year in 2030 and USD 362 million per year in 2050.

The SHP proposes several technological solutions that can be summarised into the following focus areas in terms of technological solutions:

Figure 1 **General recommendations by technology focus**

Implement energy effciency measures in buildings	**Set high thermal performance standards for new buildings and refurbish existing ones to improve their energy performance**
Expand and improve district heating systems	**Expand coverage of district heating systems in dense areas and lower the supply temperature level**
Expand renewable energy capacities	**Expand renewable energy utilisation in district heating systems such as geothermal heat, solar thermal, waste incineration and industrial excess heat; as well as renewable electricity for heating based on wind and solar energy**
Use heat pumps and electric boilers outside of district heating coverage	**Use ground and air-source heat pumps supplemented by electric boilers**
Use heat storages	**Use daily and seasonal heat storages depending on heat sources to balance demand and generation of renewable heat**

In the SHP, implementation challenges for renewable systems have been identified and are summarised in Figure 2.

Figure 2 **Challenges for implementation of renewable energy in district heating systems**

General

- Emissions from heating, transportation and industry sectors cause significant air pollution
- Inaqeduate local policies and investments for supporting renewable energy and strong support for coal development
- Large energy subsidies on the coal-based energy system result in low energy taxation
- Low-income households may not afford the cost of decarbonising their heating system
- Limited assessment of renewable potential for district heating

Energy efficiency in buildings

- High heat demand due to inefficient and insufficient thermal insulation in the building stock
- Buildings do not use heat metering as a measure for their heat consumption and billing
- There is a lack of financial incentives for building developers for the refurbishment and construction of energy-efficient buildings

District heating

- Expansion of the current district heating systems is geographically limited by the proliferation of *Ger* areas
- Current low heat tariffs represent a threat to district energy infrastructure cost-recovery
- Lowering of supply temperatures in Ulaanbaatar district heating can be achieved only after buildings are renovated to improve their energy efficiency

***Ger* areas**

- Limited data on energy demand in the *Ger* areas
- Lack of spatial planning as rural-to-urban immigration develops
- Overlooked planning of potential renewable powered rural heating networks

One of the major challenges to the implementation of the energy transition in Mongolia's heating sector is the low price of coal, which hinders the financial feasibility of renewable energy options. This could be solved by including externalities such as air pollution and the emission of GHGs in the heat tariff in the form of taxation. The increasing population is leading to a rapid increase in heat demand, which adds pressure to build more heat supply plants. Here, it is important to ensure that new buildings are energy efficient, for example through building regulation measures. Low heating tariffs is a major barrier hindering the implementation of energy efficiency measures in existing buildings since the cost of building renovation may not be recovered through the associated energy savings. This could be solved by introducing an appropriate tariff scheme based on consumption billing, and one that reflects the cost of the heat production.

Regarding new renewable sources, further investigation into geothermal and excess heat sources would be worthwhile for the district heating sector, as there are limited detailed surveys on the potential of these sources. Figure 3 shows recommended measures that could be implemented to promote renewable energy deployment in Mongolia's heating systems under four categories: general, energy efficiency in buildings, district heating and *Ger* areas.

Figure 3 **Recommendations for implementation of renewable energy in district heating systems**

General

- Target **increased investment** in renewable energy development and the decarbonisation of the heating sector
- Develop **enabling regulations** for renewable technologies in the Mongolian context
- Set ambitious, specific **targets for coal phase-out** to meet the 2050 vision
- Undertake **assessment of renewable potential** (*e.g.* geothermal potential)

Energy efficiency in buildings

- Provide heating installations with **energy meters and heat cost allocators**
- Implement measuring instruments to **assess development of heat demand** in buildings
- Improve **thermal insulation** in buildings
- Revise **construction standards** for new building regulations regarding energy efficiency measures
- Introduce **energy performance certificates** for new and renovated buildings

District heating

- Introduce **renewable energy solutions** (including thermal storage) that supply domestic hot water
- Create **district heating investment plans** supported by regulation to upgrade, increase capacity, and maintain district heating systems
- **Structure heating tariffs** to be composed of both fixed and variable costs
- Create district heating cost-covering systems by revising heating tariffs and ownership models

***Ger* areas**

- Investigate **heat pump potential** for buildings in *Ger* areas
- Assess the electrification of heating supply in *Ger* tents and plan alongside electricity distribution grid reinforcements
- **Improve insulation** capacity in *Ger* tents where possible

Assessment of renewable energy potential for district heating, such as geothermal energy, and the establishment of enabling regulations and ambitious targets to phase out coal in the heating system could be implemented to promote renewable energy usage in Mongolia's heating system. Improving energy efficiency in buildings through retrofitting the building envelop of existing buildings would decrease primary energy demand in the heating sector and make it possible to deploy locally available low temperature renewable energy sources for heating. Furthermore, the implementation of consumption-based billing and energy metering in buildings would further promote efficiency in the utilisation of heat at the building level.

Technical and regulatory barriers, and recommendations

A compilation of the regulatory and financing frameworks working in the Mongolian context is provided in this section. It is based on the information taken from the project activities and other sources of information available through the literature review.

The 2030 and 2050 cases presented in this report require significant change in the existing heating system. Energy efficiency measures in buildings need to be implemented, both outside and inside the district heating system coverage areas. District heating systems should expand to cover a larger share of the heat demand, also due to increasing heat demand from population increase. Furthermore, large parts of the district heating infrastructure in Ulaanbaatar needs retrofitting to improve efficiency and allow the transition of the current system to lower supply and return temperatures. The district heating supply should change from a single fuel system towards a system combining several renewable energy technologies, such as waste incineration, heat pumps, electric boilers, solar thermal and potentially geothermal and excess industrial heat. As many of these sources have variable production, heat storage also becomes essential. Outside the district heating systems, buildings need to switch to heat pumps, electric boilers and solar thermal. The change towards a more electrified heating system requires increased renewable electricity production, primarily wind and solar PV. Technical and regulatory barriers must be addressed to allow these changes to be implemented. The following section presents the implementation challenges and solutions; both sections are divided into general, energy efficiency in buildings, district heating systems and *Ger* areas, as illustrated in Figure 4.

Figure 4 **Main structure of presentation of challenges and solutions**

1. Implementation challenges

The following list identifies the main challenges:

General

- The heating sector in Mongolia is characterised by significant air pollution which is as a result of coal-based heating supply, combined with low-efficiency buildings.
- Coal is the main fuel input for CHPs and HOBs in the current district heating systems. Besides being the primary source for air pollution, smoke accumulates and contributes to smog formation due to the thermal inversion effect of the city, which at the same time reduces solar energy potential.
- The recent ban on raw coal usage has contributed to a reduction in local pollution from the heating sector. This measure can be seen as a mitigating strategy while plans for decarbonisation and eventual complete coal phase-out are developed. However, detailed, reachable and actionable targets for decarbonising the energy system are largely lacking.
- Despite the formulation of some policies focusing on the decarbonisation of the energy sector in Mongolia, there is little focus on decarbonising the district heating systems. This could partly be as a result of the continued use of coal CHP plants as one of the major sources of heat supply to these systems.
- Large energy subsidies result in low energy taxation, causing the energy companies to have no incentive to switch to renewables and continuing the carbon cycle (Integration and Ekodoma Ltd., 2020). This underutilisation of energy taxation causes large environmental problems due to the widespread use of coal.
- The local support for renewable energy policies and investment in Mongolia is limited. Instead, strong support for coal power development exists (Edianto, Trencher and Matsubae, 2022).
- There is limited funding for renewable energy projects in Mongolia. During the period 2013-2017, financing for coal from foreign government-affiliated organisations amounted to around USD 1 billion, while the funding for renewables was less than a quarter of this (Natural Resources Defense Council, 2017).
- Due to the relatively low-purchasing power for many households, their ability to investment in the decarbonisation of their heating system is limited.
- The current ownership model of district heating systems, which is dominated by government-owned entities, focuses on providing cheap heat at the expense of recovering the operating costs. This limits further investment into the heating systems.

Energy efficiency in buildings

- Buildings and houses generally have low energy efficiency and insufficient thermal insulation, which results in a relatively high heating demand. With the current fossil supply, this also generates high levels of local pollution. This challenge is considerable for buildings dating from older construction periods, but also for new construction that does not comply with energy-efficient building standards.
- Buildings do not use heat metering as a measure for their heat consumption and billing. Space heating bills are based on the property area, while DHW is according to the number of people within the household. This disincentivises customers from making heat savings via their behaviour as well as adopting potential energy efficiency measures.
- The documentation and auditing of the building stock and its heating demand are not well documented. This represents a barrier for estimating not only current heat demand, but also future demand.
- Due to highly subsidised energy supply, there is a lack of financial incentives for building developers to construct energy-efficient buildings, as well as for building owners to undertake private renovations and retrofitting.

District heating

- The current district heating system is geographically limited by *Ger* area expansion located either on the fringe or between areas within the city. This limits the system's capacity for expansion and possible new connections to attractive district heating customers.
- There is a lack of investment in current infrastructure for optimal operation. Heating infrastructure is put under pressure by rapid growth in heating demand while needing repair and renovation.

- Current low heat tariffs represent a threat to the whole district heating infrastructure due to their lack of performance in achieving system cost-recovery to a balanced or positive level. Additionally, these subsidised tariffs for the connected users increase energy accessibility and inequality issues in unserved areas such as *Ger* areas.
- Actors in the Ulaanbaatar district heating context are diverse, but dispersed and disconnected across the whole district heating actor network. The disinvolvement of such actors poses a barrier to the strategic planning of the heating system (Energy Sector Management Assistance Program, 2019).
- The current district heat networks in Mongolia rely on high temperature supply. On the other hand, the SHP suggests lowering the supply temperature of the district heating network to below 100°C over time, in order to utilise the locally available renewable energy sources. Lowering the temperatures in the Ulaanbaatar district heating would be a challenge in the current situation and should only be done when buildings are renovated to a level where they can be heated with reduced district heating temperatures. It should also be underlined that in very cold winters, it may still be necessary to increase temperatures above 100°C. However, in general the benefits of reduced temperatures make it a key focus point for the future.

***Ger* areas**

- The lack of spatial planning and redevelopment strategies in the *Ger* areas is a challenge as rural-to-urban migration develops. District heating generation for *Ger* areas is poorly regarded due to the uncertainty of their development.
- Actors representing these areas are scarce, which is a barrier to their participation in the strategic planning of rural heating development. In addition, there is limited documented information about the energy demand in the *Ger* areas, leading to estimations of their magnitude, location and distribution.
- The *Ger* areas are considered low-income areas, which usually represents a challenging panorama for renewable business strategies yet a viable target for public subsidies and other forms of financing for increased affordability, such as energy communities in which citizens collectively organise local renewable production.

2. Potential solutions

The following potential solutions to the challenges are proposed.

General

- In Ulaanbaatar, current efforts focus on introducing energy performance certificates for new and renovated buildings, which will be integrated in the building permit process. The initiative should be expanded to existing buildings and eventually be part of a nationwide strategy that enables audits and metrics.
- Decision making should consider the use of different instruments such as energy system modelling for scenario assessment. The use of the system's socio-economic indicators can aid the alignment of specific Mongolian environmental goals while promoting low-cost environmental and societal energy systems.
- Robust institutional capacity is key for supporting energy planning. Hence, strengthening skills through capacity building at relevant institutions is needed in terms of financial, technological and planning skills. This capacity development addresses improving the production, performance and deployment of energy.
- Investments in the Mongolian energy sector should be targeted primarily at renewable energy development and the decarbonisation of the heating sector, as they align with the current climate priorities of the government.
- Regulation for renewable technologies should be implemented in the Mongolian context. This regulation should encompass a framework for addressing technology barriers, cost-recovery analysis, quality standards, impacts of the introduced technology, financial and fiscal measures including subsidies, grants and a reduced levy on renewable technologies and projects (Jayawardena, Rivera and Ratnayake, n.d.).
- Ambitious specific targets for coal phase-out should be introduced into the 2050 vision. This as a complimentary goal as the share of renewable energy increases following the investment roadmap.
- Significant investment should be allocated to renewable potential exploration, specifically for technologies that are not fully or thoroughly assessed in Mongolia such as geothermal, as this could provide valuable baseload production in future district heating systems. In addition, it should cover the potential for low-temperature

sources for future district heating systems, namely waste heat from industry and commerce, and waste-water treatment plants, amongst others.

- Privatisation or community ownership of new energy developments could be a viable solution. A thorough assessment of possible ownership models for the Mongolian context should be developed. Experiences from other countries where non-profit or consumer-owned forms of ownership are favoured should be considered.
- As the suggested changes are fundamentally different from the current energy supply in Mongolia, a public campaign to improve knowledge of transitioning to renewables is also recommend. Such a campaign should focus on both public and private stakeholders, as well as high-level decision makers in Mongolia.

Energy efficiency in buildings

- To encourage energy savings and manage heat demand at the user end, heating installations with energy meters and heat cost allocators should be provided. This will also assist with better energy planning.
- The adoption of assessing and measuring instruments would further enhance understanding of the development of heat demand in buildings. This can come in the form of a rating or classification system for buildings, as well as the implementation of energy auditing, and should be allied directly to a measurable indicator aligned with the national climate targets.
- Thermal retrofitting of buildings, such as whole-house retrofits, better insulation and double window glazing, can help retain heat and keep the indoor climate comfortable (Geels *et al.*, 2017).
- The implementation of strict regulations surrounding building codes could support efforts toward energy efficiency measures in buildings.

District heating

- For district heating systems served by HOBs (which are usually turned off during the summer months when space heating is not required), renewable energy solutions can be introduced initially to supply DHW during the months the HOBs are turned off, and later expanded with the inclusion of thermal storage to cover more space heating load during the winter with clean energy.
- Regulations should enable the establishment of investment plans that not only concern the upgrading and increased capacity of district heating systems, but also the maintenance of these investments throughout their lifetime so as to ensure their operability and stability (IRENA and Aalborg University, 2021).
- Regulations and the infrastructure should enable district heating billing to be measured based on consumption rather than on the heated space to promote energy efficiency (Energy Sector Management Assistance Program, 2019). In this case, the tariff structure for heating could be composed of two elements: fixed and variable costs. The fixed costs include all the investment in equipment and consider its depreciation. Variable costs are based on the actual heat consumption. An example of a variable tariff scheme is being implemented in Aalborg, Denmark, where the plan is to phase out coal CHP plants. The situation is similar to the one in Mongolia, where the primary fuel used for CHP is coal (medium-quality lignite), (Djørup *et al.*, 2020).
- To ensure that the new tariffs set are applied uniformly, third-party inspection of the district heating companies can be done to verify that there is no variation in the costs. This will ensure impartial inspections. (Energy Community Secretariat, 2021).
- Heating tariffs should be revised so that they are cost-covering with respect to the system. This will allow investment in new technologies when the supply is balanced. When reviewing tariffs, it is important to consider the impact on low-income households to avoid increasing energy poverty.

***Ger* areas**

- In *Ger* areas heat pumps and their potential for heat supply need to be investigated as this would help to reduce local emissions. They could be supplemented with photovoltaics, solar heating and heat storage. As these solutions are very investment heavy, some sort of subsidy scheme or financial support would require.
- Only about 5% of *Ger* area households have electric heating. Increasing this share is important but needs to be planned together with electricity distribution grid reinforcements.
- *Ger* tents suffer heavily from heat loss since they are not adequately insulated. They lose about four to five times as much heat as regular houses. If possible, measures should be taken to improve their insulation.