Paving the Way to a Sustainable Heating Sector

A Roadmap for Ulaanbaatar Urban Heating

ESMAP
Energy Sector Management Assistance Program

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Acronyms and Abbreviations

ADB	Asian Development Bank
BAU	Business as Usual
BEE	Building Energy Efficiency
CBB	Consumption-Based Billing
CHP	Combined Heat and Power
DH	District Heating
DN	Distribution Network
ESCO	Energy Service Company
HOA	Homeowners Association
HOB	Heat-Only Boiler
HTW	Hot Tap Water
IFI	International Financial Institution
OSNAAUG	Housing and Public Utilities of Ulaanbaatar City
PCHC	Private City Housing Company
PM	Particulate Matter
SCADA	Supervisory Control and Data Acquisition
SOE	State-Owned Enterprise
UBDHC	Ulaanbaatar District Heating Company

Units of Measure

Gcal	Gigacalorie
GJ	Gigajoule
GWh_{th}	Thermal Gigawatt Hour
kcal	Kilocalorie
kg	Kilogram
km	Kilometer
kW	Kilowatt
m	Meter
m^3	Cubic Meter
mm	Millimeter
MW	Megawatt
MW_{th}	Thermal Megawatt
Tcal	Teracalorie

Acknowledgments

This report has been prepared by a team including Yun Wu (Task Team Leader), Arto Nuorkivi, Pekka Salminen, Peter Johansen, and Celia Rong Cui. It builds on the findings and results of a feasibility study conducted in 2013 under the World Bank's Ulaanbaatar Clean Air Project; a World Bank–financed technical assessment, undertaken in 2017–18 by COWI Company; a 2018 diagnostic assessment of Mongolia's electricity and heat tariffs, conducted by MacroConsulting S.A. for the World Bank; and a consultant's note on building energy efficiency.

The assessment was conducted in close cooperation with the Mongolia Ministry of Energy and Energy Regulatory Commission, Ulaanbaatar District Heating Company (UBDHC), Housing and Public Utilities of Ulaanbaatar City (OSNAAUG), and combined heat and power (CHP) producer companies (CHP2, CHP3, and CHP4). The team would like to thank the management and experts at these companies and the government agencies for their excellent support and contributions to this work.

The financial and technical support provided by the Energy Sector Management Assistance Program (ESMAP) is gratefully acknowledged. ESMAP—a global knowledge and technical assistance program administered by the World Bank—assists low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Canada, Denmark, the European Commission, Finland, France, Germany, Iceland, Italy, Japan, Lithuania, Luxembourg, the Netherlands, Norway, the Rockefeller Foundation, Sweden, Switzerland, the United Kingdom, and the World Bank Group.

Executive Summary

Ulaanbaatar's heating sector is struggling to meet accelerating demand growth. Over the past two decades, population growth in Mongolia's capital city has increased exponentially, mainly due to rapid rural-to-urban migration, and it is expected to reach 1.9 million by 2035. With urbanization and economic growth, new buildings are being built at a rapid pace, requiring connections to the district heating (DH) network. Over the next decade, it is projected that urban heating demand will grow by an average annual rate of 5–6 percent.

At the same time, the DH network—once Ulaanbaatar's principal heat supply—is deteriorating. About two-fifths of the population (some 120,000 households) are supplied from the DH network. However, the system is dilapidated, resulting from a lack of investments for needed rehabilitation and upgrading in past decades. Owing to high water losses, the quality of replenishment water has not been adequately maintained to prevent corrosion; thus, piping is typically quite old and corroded. The total length of transmission pipelines is about 130 km (dual pipe) with pipe diameters in a range of 200-1,200 mm. It is estimated that 50 percent of the transmission pipelines are in poor technical condition, urgently requiring replacement. The secondary (distribution) network, with a total trench length of about 226 km, has a variety of owners and operators and also requires major rehabilitation and replacement.

Tariffs, which are set below cost-recovery levels, exacerbate the sector's financial distress and contribute to its decay. Despite recent adjustments, consumer tariffs remain lower than the cost-recovery level, requiring state subsidies for sector operators and cross-subsidies at various points along the entire heat supply chain. Tariff-related cost allocations between electricity and heat customers lead to indirect subsidies for residential DH customers. The average DH price of 0.8 US$ per GJ (2014 figure) is approximately 10–20 times lower than in such Eastern European cities as Vilnius or Warsaw, and even lower than in other European cities. The sector's 2013 Master Plan estimated that a 130 percent increase in the heat tariff would be needed to achieve full cost recovery. The situation has changed little in recent years.

Despite low residential tariffs for customers connected to the DH network, heating expenditures for households without access to the network remain high. Customers connected to the DH network benefit from subsidized heat tariffs. However, households in traditional *ger* districts, where nearly half of the city's population live, have limited access to the network. Rather, these mainly low-income households rely predominantly on traditional solid fuel–fired stoves (coal and wood) and small water-heating boilers. Supplying fuel for these stoves during the winter heating season is expensive, in a range of US$200–500 per household (i.e., generally a few times higher than the urban household's heating expenditure)[1].

Houses and buildings with low energy efficiency add to heat losses and the corresponding high heat demand in the residential sector. In the urban area of Ulaanbaatar, a large number of people live in old pre-cast panel buildings with insufficient thermal insulation of walls and roofs and poorly-sealed windows. Lack of maintenance has led to the current dilapidated condition of the building envelope. In turn, customers increase their heating use to compensate for high heat losses and to maintain warm room

[1] For example, the annual heating cost for a 50m^2 apartment would be around US$72, compared to approximately US$240-300 for similar size of detached or ger house, assuming 8 months for one heating season.

temperatures. One GIZ project estimates that concrete panel buildings, through improved insulation, could reduce customers' heat demand by 25 percent.

Norm-based billing practices, instead of invoicing for actual consumption, contribute to overall malfunctioning of the DH system. The normative approach invoices based on square meters of space (for heat) and number of customers (for hot water). The absence of control valves on radiators prevents customers from controlling their heat consumption, inadvertently discouraging conservation practices. The lack of building-level heat metering and consumption-based billing (CBB) practices at the building level, combined with poor building heat control and insulation, have led to wasting heat energy.

Based on the current heating infrastructure, the DH sector will not be able to keep pace with urbanization and economic growth. Failure to provide reliable heating service and pipeline repair could lead to a much larger share of underserved and unserved urban populations. In the face of further deterioration of the DH network, existing customers might abandon the DH system for alternative heating solutions. In the case of Ulaanbaatar, this would inevitably mean fuel-inefficient, coal-burning stoves and coal-fired boilers as no other sources are available in the medium term. The weak financial status of the DH companies leads to increased air pollution and its associated health risks, along with further deterioration of DH services. Europe offers instructive examples of what happens once such a vicious cycle materializes. In the case of Romania, DH network customers dissatisfied with service and prices switched to alternate heating modes.

The Government of Mongolia recognizes that improving the efficiency and sustainability of the heating sector has great potential to meet Ulaanbaatar's growing heating needs and reduce air pollution. The State Policy on Energy, released by the Ministry of Energy in 2015, sets forth efficiency, environment, and safety as the three priority areas and strategic goals for the energy sector. In June of that year, Mongolia's parliament approved Resolution No.63, which outlines the government's 2030 vision for developing a reliable, adequate, sustainable, and self-financed heating sector. The Government's National Program on Reducing Air and Environmental Pollution, initiated in March 2017, and Decree No. 49, released in February 2018, place great emphasis on insulation improvements for houses to reduce overall heating demand and DH network rehabilitation and expansion.

To realize the Mongolian government's vision for a sustainable heating sector, a roadmap was developed for Ulaanbaatar. The roadmap lays out a path to a more financially sound and efficient heating sector through a framework of institutional and policy/regulatory reforms and supply-and-demand side investments. The overall objective of the recommended institutional and policy actions is to increase the sector's financial sustainability, transparency, and efficiency. The recommended infrastructure investments aim to (i) reduce heat losses in primary and secondary heating networks, (ii) reduce heating-related air pollution by eliminating small heat-only boilers (HOBs) and connecting new customers to DH, (iii) increase transmission capacity in order to connect new customers and eliminate the expansion of small HOBs, and (iv) optimize combined heat and power (CHP) plant operation by using heat accumulators and pooled DH network operation to reduce overall fuel consumption and costs.

Institutional reforms should start by improving arrangements between key stakeholders in the DH sector. Proposed near-term actions include revising contracts between the Ulaanbaatar District Heating Company (UBDHC) and heat distributors—Housing and Public Utilities of Ulaanbaatar City (OSNAAUG) and the Private City Housing Companies (PCHCs)—to provide clear incentives for energy and water savings, as well as preventive maintenance. It is important that all stakeholders focus on the improved sustainability, optimization, and energy efficiency of the Ulaanbaatar DH system.

Over the next five years, a water management program should be introduced. The program should be jointly established by UBDHC and OSNAAUG. An expert water management team would identify the location of water leaks, thus creating the water balance, targeting of leak repairs, and water quality improvement. Water management should be carried out in a working group of the DH transmission and distribution companies with a detailed action plan for improved water management. The overall objectives would be improving water quality to meet international standards for best practices and reducing water losses within the DH system, which are vital to the longevity and reliability of pipeline operation and heat metering and control systems.

Comprehensive capacity building is needed to familiarize DH company managers and their technical and financial staff in modern DH practices. These include operation and maintenance (O&M), as well as technical and financial aspects. Capacity-building programs should be tailored to Ulaanbaatar's conditions and implemented over several years. In addition to capacity building for DH staff members, universities should be provided training in modern DH systems.

Investments in the capacity of heat production, transmission, and distribution are urgently needed to maintain the DH system's operational safety and reduce emissions. Priority investments include replacing primary and secondary pipes in worst condition, strengthening and extending the network to ger areas on the outskirts of the city so that an increasing number of households currently using coal stoves and boilers for heating can switch to DH, and hydraulically separating the directly connected buildings from the primary network.

All new buildings connected to the DH system should have building-level substations. UBDHC and city authorities should approve new regulations requiring all new buildings connected to the DH system to have building/staircase-level substations with modern heat meters and thermostatic radiator valves. Heat meters at the building/staircase level would be the first step toward consumption-based billing (CBB). Tenants would pay their heating bills based on real meter readings of the building, allocated to each apartment. This would also create understanding and incentives about energy savings.

A facilitated transition to CBB is recommended over the next five years so that customers can control their consumption and match it with what they can afford. Building-level CBB should proceed stepwise, considering the current lack of favorable technical, institutional, and regulatory conditions. The initial focus of CBB development should be limited to metering of heat and hot tap water (HTW) at the building/staircase level to collect data on customers' actual heat consumption, which is important for CBB tariff design. At a later stage (i.e., once tariffs approach the actual cost-coverage level), CBB implementation can be introduced at the building/staircase level based on meter readings distributed to apartments based on floor area or number of inhabitants.

Over the medium and longer term, pooled operation of the CHP plants is recommended to improve the availability of heat generation and transmission capacity. At present, each heat source serves its own network, and these four networks overlap in the city center. Merging them into one would release production and transmission capacity for connecting new customers.[2] Adjustments are most urgently needed in the existing substations, pumping stations, and control systems to allow different heat sources to supply heat simultaneously to the unified network. Pooled operation could start in the summer, and, based on lessons learned, extend into spring and autumn and finally year-round for the entire system.

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[2] A major technical study is needed to assess the adjustments of the DH system to enable pooled operation.

A number of additional institutional and policy reforms should be implemented over the longer term. These include (i) ongoing simplification of the tariff structure and elimination of various subsidies in order to reach sufficient cost-coverage levels, (ii) empowerment of homeowners associations (HOAs) to initiate energy efficiency improvements and carry out other building maintenance measures, and (iii) phasing out of the scattered responsibilities of the more than 30 larger companies currently responsible for O&M of the DH system through corporate mergers.

Tariff reforms should include the gradual phasing out of subsidies while protecting the poor. Tariff reforms should include structural changes, incentives, and simplifications to make them easily understood by all consumers. Simultaneous social protection measures that effectively target the poor will pave the way. The tariff reform should also go hand-in-hand with CBB. Also, a communication strategy and plan should be developed and implemented alongside the reforms.

The DH system should be extended into ger areas that have been undergoing redevelopment and will eventually be replaced by high-rise buildings. There is a large potential and urgent need to connect new customers to reduce emissions and improve energy efficiency. To connect new heating customers, additional production capacity should be commissioned at the CHP4 plant, where some idle capacity still exists. Moreover, heat transmission should be strengthened to remove bottlenecks.

Financing mechanisms, including commercial financing, should be established for the larger residential buildings connected to the DH network. Decision-making structures for investments and mechanisms for financing more capital-intensive upgrades should be well-established, with higher tariffs and CBB in place to incentivize investing in energy efficiency generating energy savings. For residential energy-efficiency programs, international experience indicates four major financing options: (i) energy efficiency funds, (ii) commercial bank financing, (iii) partial credit guarantees, and (iv) utility-managed programs.

Based on a comprehensive list of recommended measures to improve the reliability and efficiency of Ulaanbaatar's heating sector, items evaluated as having the highest economic return or critical importance to DH operations were selected for priority investing. Results of a cost-benefit analysis estimate the total cost of the priority investment plan (PIP) at approximately US$50.3 million. The investment items and their costs include (i) pipeline replacement and extension to eliminate small HOBs by CHP heat ($15.6 million), (ii) heat accumulator to supply more heat from CHP4 to downtown Ulaanbaatar ($4.0 million), (iii) heat and HTW balancing in buildings ($1.3 million), (iv) replacement of selected secondary networks ($5.2 million), (v) mixing loops ($6.0 million), (vi) separation of buildings currently with direct connection ($0.4 million), (vii) SCADA ($0.2 million), and (vii) critical substation components ($4.5 million). The internal rate of return (IRR) of each investment item is listed in Table 4.1.

The PIP can be expected to reduce Ulaanbaatar's annual coal consumption and pollutant emissions, while providing households better DH services and access to the network. By implementing the proposed PIP, the system would be expected to generate fuel-energy savings totaling 296 Tcal (344 GWh_{th}) per year and reduce network losses from approximately 144,000 to 53,000 Gcal per year for the pipes included in the proposed PIP. The total coal savings represent around 15 percent of the heat energy delivered by UBDHC. The reduction in carbon dioxide (CO_2) emissions would amount to 117,058 tons per year, with significant emissions reductions for other pollutants (e.g., 591 tons per year for sulfur dioxide [SO_2], 418 tons per year for dust, 153 tons per year for nitrogen oxides [NOx], and 105 tons per year for carbon monoxide [CO]). In addition, some 88,000 households (23 percent of all households in Ulaanbaatar) and businesses would enjoy improved DH services, while about 2,000 ger households would gain access to the DH network.

Section 1. Introduction

Overview

Photo 1.1 Ulaanbaatar, November 2017. Credit: COWI

Ulaanbaatar, the world's coldest capital city and among its most polluted—especially during the winter heating season—is home to nearly half of Mongolia's more than 3.1 million people. Over the past several decades, the city's population has grown exponentially (from 586,228 in 1990 to more than 1.4 million in 2017), owing mainly to migration from the countryside, and is expected to reach 1.9 million by 2035 (photo 1.1). More than half of the city's 376,400 households (54.8 percent) live in urban buildings, while the other 45.2 percent live in *gers*[3] (2015 figures). Most urban buildings have access to district heating (DH); however, most ger households rely on smaller boilers and traditional heating stoves that burn coal and wood inefficiently (box 1.1). The scope of this report focuses on improving service of the urban (centralized) heating systems for existing DH network customers in urban buildings and extending service to currently non-connected homes in ger areas when possible[4].

Box 1.1 Mongolia's Heating Sector at a Glance

Located in the heart of central Eurasia, Mongolia is a landlocked country of mountains and plateaus, featuring a sunny, arid climate. During the country's long winter-heating season, temperatures regularly fall below −30 °C, making the capital city of Ulaanbaatar the coldest one in the world. Combined heat and power (CHP) plants, via district heating (DH) networks, provide heat and hot water to Ulaanbaatar's urban centers and smaller cities. Heat-only boilers (HOBs) are used for small central networks at the provincial (*aimag*) level and for county-level (*soum*) centers, while smaller fuel-inefficient boilers are commonplace in traditional ger areas. Individual ger residences in Ulaanbaatar's expanding peri-urban areas rely mainly on solid fuel–fired heating stoves (coal and wood). Emissions from fuel-inefficient stoves are a major contributor to ground-level air pollution, making Ulaanbaatar one of the world's most polluted cities, especially during the winter when $PM_{2.5}$

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[3] A *ger* is a traditional Mongolian dwelling.

[4] The focus is selected based on the urgency of the issues, feasibility of measures to be undertaken to improve it, and the importance of the subsector to the sustainability of entire heating sector. In the short and medium term, the priority is to improve the overall efficiency of the DH network and the transmission capacity. It also has great potential to reduce air pollution by switching households away from traditional stoves and HoBs and paves the way for potential integration of decentralized heating solutions using renewable sources.

levels can reach up to 20 times those considered safe. Poor air quality in Ulaanbaatar has been linked to an increased risk of respiratory disease and even mortality (World Bank 2011).

The World Bank has been engaged in the DH sector of UB for the past decade mainly through technical assistance. Key achievement and lessons learned from heating sector reforms include the following:

Despite progress made, the institutional structure of UB heating sector remains fragmented and a holistic optimization of DH supplies is needed. The World Bank conducted a feasibility study for the rehabilitation and sustainable expansion of district heating in UB and organized study tours on district heating policy, regulation and management for government officials. Some key institutional recommendations were endorsed and adopted by the government. The public housing companies were consolidated into one public entity (OSNAAG) in 2014 to provide heating and water services to urban households, as a first step toward addressing the significant fragmentation of the district heating market especially in distribution. Meanwhile, the number of private housing companies has more than doubled over the past few years and many unregistered private companies are operating without license. In addition, many companies are involved in daily operation of the DH system which compromises holistic optimization of the DH.

The heating sector still confronts challenges in institutional capacity and would benefit from a tariff structure that enables full cost recovery and encourages energy conservation. As a major component of Asian Development Bank (ADB)'s Ulaanbaatar Heat Efficiency Project completed in 2008 (ADB, 2008), a pilot program was launched to install water meters, thermostatic valves and heat allocators on radiators in individual apartments so that consumers could individually control the heat supply and measure heat and hot water consumption. However, the project did not fully succeed in introducing a new billing system based on heat consumption due to the lack of an automatic data collection system and difficulties in making necessary adjustments to some of the installed equipment. The electricity and heat prices are relatively low, which does not provide adequate incentives to improve energy efficiency and introduce CBB.

Report Organization

This report is organized into four sections. This section introduces the main stakeholders in Ulaanbaatar urban heating, key sector challenges, the Mongolian government's vision for the sector, and a recommended roadmap for achieving it. Section 2 describes the urgently needed institutional and policy/regulatory reforms and supply-and-demand measures identified in the roadmap. The institutional and policy recommendations focus on both sector reform and institutional capacity building. Section 3 turns to reform and supply-and-demand issues that the roadmap recommends addressing over the medium and longer term to ensure sustainable development of the heating sector. Finally, Section 4 presents the priority investment plan (PIP).

Stakeholders in Urban Heating Sector

Four state-owned enterprises (SOEs), comprising three coal-fired, combined heat and power (CHP) plants and one HOB plant, produce heat for Ulaanbaatar's district heating (DH) system. The four producers are CHP2, CHP3, and CHP4 (commissioned in 1961, 1968, and 1983, respectively) and the Amgalan HOB plant (commissioned in 2016). Currently, heat production capacity totals 2,350 Gcal per hour (2,736 MW_{th}), with the three CHP plants accounting for 90 percent.[5]

Ulaanbaatar has three types of DH distributors: Ulaanbaatar District Heating Company (UBDHC), Housing and Public Utilities of Ulaanbaatar City (OSNAAUG), and Private City Housing Companies (PCHCs). UBDHC is an SOE, responsible for heat transmission in the primary network. It serves 43.7 percent of residential customers and 8 percent of entities and factories, including buildings with individual heat substations. Approximately 3,200 customers pay their heating bills directly to UBDHC.[6] OSNAAUG is a municipally-owned company, responsible for heat distribution in the secondary networks. It serves 38.1 percent of residential customers and 25.7 percent of entities and factories. It is responsible for public central heating with approximately 140 group substations. The small PCHCs (about 100 in number), which also have responsibility for secondary network distribution, serve the remaining 18.2 percent of residential customers. The PCHCs and buildings with individual substations are owned by the private owners themselves. Currently, the PCHCs have approximately 40 group substations, but that number is increasing along with new districts to be built.

Key Sector Challenges

Mongolia's heating sector is struggling to keep pace with ever-increasing demand, resulting from Ulaanbaatar's population growth, economic development, and urbanization. Construction of an additional heat production capacity of at least 1,200 Gcal per hour is needed to meet this demand growth. The current peak heat demand amounts to about 2,300 Gcal per hour; however, demand continues to rise as more newly constructed buildings require connections to the DH network. Over the next decade, heating demand in Ulaanbaatar is projected to grow by 5–6 percent a year. On the supply side, the total connected load to the DH system is currently stated at 1,625 Gcal per hour (UBDHC 2015), with an annual heating sale of 5,000 Tcal per year.

At the same time, the DH network—once the principal heat supply for Ulaanbaatar—is deteriorating. Much of the DH infrastructure is quite old and in poor condition. Thirty percent of the pipes in operation were commissioned between 1979 and 1988, while the oldest ones were commissioned in 1959. Pipes commissioned in 1989–2007 are in fair condition; but only a small length of new pipes was commissioned during this period (representing about 10 percent of the total length). This means that only half of the total pipe length (i.e., pipes commissioned in 2008 or later) is in good condition. On the heat generation side, the Amgalan HOB plant is the only one that has been recently commissioned (230 MW, representing about 9 percent of total capacity). As previously mentioned, all three CHP plants were commissioned in 1983 or earlier.

Due to insufficient maintenance, the DH system has operated with high heat and water losses for many years. Heat losses in production, transmission, distribution, and end-user buildings are all high. Distribution network equipment and buildings with high-energy losses without heat meters account for 13

[5] In addition, some 100 coal-fired HOBs with a capacity range of 0.3–12 Gcal per h service schools and hospitals in ger areas, and their number is increasing.

[6] Nearly 3,000 of these consist of various types of entities, while the remainder are residential customers.

percent of losses, while poor pipe insulation accounts for another 4 percent[7]. Incentives to improve energy efficiency are little or none, owing to subsidies, lump-sum payments, and lack of building-level metering. Table below compares network heat losses of cities similar to UB in terms of cold climate conditions and network structures. Helsinki and Stockholm are the coldest capitals in the European Union and Harbin the coldest provincial capital in China where the DH networks are modern and efficient.

Network heat losses	
UB	17 %
Helsinki, Finland	6 %
Stockholm, Sweden	7 %
Harbin, China	9 %

Water treatment capacity is inadequate to treat the enormous need of replenishment water, which means that pipes are corroded and devices are malfunctioning. For many years, the DH system in Ulaanbaatar has operated with large water losses. This has exposed pipes to high levels of oxygen because of large water replenishment needs and use of partially untreated water, which, in turn, has corroded steel pipes and destroyed meter and control devices. Little has been done to reduce water losses and improve water quality to prevent corrosion of pipes, valves, and other armature, as well as blocking of heat exchangers, pumps, and heat meters.

The DH system is in urgent need of rehabilitation and extension; the costs of non-action, including the adverse effects on human health, are enormous. If no action is taken to improve service levels and extend the DH system, water and heat losses will rise further, and the number of system failures will increase (e.g., in 2017, a total of 42 failures were recorded, of which 27 were in the main pipe network). Also, customer complaints about heating services will increase, and air quality will worsen (photo 1.2).

Photo 1.2 Air pollution in Ulaanbaatar's ger areas. Credit: UBDHC, Erbar Agarjav

The fragmented institutional structure of the UB heating sector limits incentives for efficiency improvements and constrains long-term investment planning. The requirements and benefits of modern DH are not generally understood, and inadequate incentives and contracts between organizations limit system optimization. The contracts should motivate parties to save heat and fuel energy, reduce return-water temperature, improve water quality, and reduce water losses by means of stipulated "carrots and sticks." This means that any party improving DH performance should be rewarded for the improvement according to the contract. The DH distribution companies have long been unable to balance revenues and costs, which has led to poor maintenance and under-investment in their networks. Also, they have lacked

[7] The 17% network loss is higher than Helsinki (6 percent) and Stockholm (7 percent) which are the coldest capitals in the European Union and Harbin (9 percent), the coldest provincial capital in China. The heat losses in UB could be reduced by means of replacing the pipes, re-insulation of the pipes, revising the hydraulic scheme to avoid overlapping of pipelines, converting 4 to 5 pipes to 2 pipe systems, and reducing water losses, as recommended in the proposed PIP.

integrated investment management, as well as tools and skills for monitoring operation of the DH system. These shortcomings have constrained their capacity to attract financing for investments.

At present, heat tariffs do not fully cover the costs of generation and operation. This results in a shortage of funds to cover routine maintenance and capital improvements in both the heat and electricity sectors, and exacerbates the poor operational and financial performance of energy-sector companies. Also, there are cross-subsidies between electricity and heat consumer segments. In addition, the complex tariff structure reflects the heating sector's segregated structure, which makes it difficult to track appropriate costs and compensation for each of its services and functions. In turn, this results in many inefficiencies in distributing cash proceeds from end-users. It also makes the tariff structure for various customers difficult to understand, thereby hampering an overall sense of fairness in the system.

Since residential DH consumers are not billed for actual consumption, heat and water conservation practices have been unintentionally discouraged. Heating bills are based on square meters of floor area, and hot water is billed according to the number of people living in households rather than actual consumption. Although heat energy meters are found in private housing at the building/staircase level, the meter readings are not used for billing purposes.

Implementing heat metering at the building/staircase level faces both regulatory and physical constraints. The existing building code does not require installations prepared for CBB (e.g., a double-string system in the radiator piping inside buildings). Also, building basements may not even exist, and staircases have only restricted space. In addition, since the walls between apartments are not insulated, inaccurate measurement may question the economy of individual apartment-level metering. Old buildings with unbalanced piping and radiator systems distribute heat unevenly to apartments, which would lead to unfair billing of apartment owners. In short, the existing DH infrastructure in housing (i.e., single-string systems with multiple vertical risers) makes introducing apartment-level metering virtually impossible.

Building energy efficiency (BEE) measures would help reduce the demand, but would proceed quite slowly due to inadequate financing and lack of incentives. To improve demand-side efficiency, the Mongolian government has undertaken BEE improvement initiatives. In 2014, the Building Construction Norms and Standards were revised and new energy efficiency norms were developed to ensure that all new buildings are constructed in compliance with energy efficiency designs and principles. A top priority under the Master Plan of Ulaanbaatar is rehabilitation of concrete panel buildings for which pilot projects have been identified. The government's action plan for 2016–20 emphasizes efforts to improve energy efficiency in buildings to reduce heat losses and thereby reduce air pollution by burning less coal. However, the absence of control valves on radiators prevents customers from controlling their heat consumption. Because the tariff level is too low, customers lack the incentive for heat savings. The financial market is not geared to investments in improved energy efficiency in housing, and no substantial funding is available for BEE investments.

Homeowners associations (HOAs) in Ulaanbaatar lack the power and capacity to obtain loans on the financial market and enter into contracts. In Mongolia, as in other countries in transition, the publicly-owned rental housing stock has been privatized without paying sufficient attention to establishing an institutional and legal system for its maintenance and exploitation. As a result, renovations coverage for housing stock outside of apartments, including energy efficiency investments, has been virtually absent, and proper maintenance is even an issue. HOAs are not legal bodies, no standard articles exist, and membership is not mandatory. Therefore, they are not strong enough to assume responsibility for implementing BEE and financing maintenance and repairs. Also, they possess limited technical installation and maintenance skills (e.g., for heat meters).

Implementing Mongolia's Vision for the Sector

The Government of Mongolia recognizes the great potential that improving the efficiency and sustainability of the heating sector has for meeting burgeoning heating needs and reducing pollution. As a top energy-sector priority, the Mongolian government and the Municipality of Ulaanbaatar have together passed many policies tackling heat efficiency. The State Policy on Energy, released by the Ministry of Energy in 2015, sets forth efficiency, environment, and safety as the three priority areas and strategic goals for the energy sector. The government also set its nationally determined contribution (NDC) target to achieve 40 percent of emissions reduction from the energy sector by 2030.

In June 2015, Mongolia's parliament approved Resolution No. 63, "On Adoption of State Policy of Energy," for the period ending in 2030, which states the following: "The vision of the development policy is to become [an] electric energy exporting country with efficient, economic, and environmentally friendly technology based on [a] private-sector, competitive market scheme while supporting economic growth, sustainable development, and energy safety and reliability of the country. Resolution No. 63 provides a clear vision for the energy sector, highlighting the need to improve efficiency and productivity and ensure sustainable financing. For the heating sector specifically, the government envisions reliable, adequate, sustainable, and self-financed development without the need for subsidies from the budget.

To realize its vision by 2030, the Government of Mongolia has identified three priorities: (i) reliability and safety of energy supply, (ii) efficiency and productivity, and (iii) environmental sustainability and green development. Major objectives, among others, are to (i) increase heat access and quality in cities and villages and develop heat-supply infrastructure, (ii) establish a tariff structure based on actual cost and profit level and maintain sustainable sector financing, and (iii) build the conditions for sustainable energy-sector investment and increase private-sector participation. This vision enjoys the full support of international financial institutions (IFIs) and donors active in Mongolia.

In response to the Government of Mongolia's stated vision for the heating energy sector, a roadmap and priority investment plan (PIP) have been developed. The roadmap—the main output of technical assistance provided under the World Bank–supported Ulaanbaatar Efficient Heating Project—assesses the key issues and challenges currently facing Ulaanbaatar's heating sector and identifies viable DH options and related investment measures to meet demand growth while reducing air pollution. The recommended actions—encompassing interconnected technical, institutional, and financial issues—include urgently needed measures and priority investments, as well as phased measures to be implemented over the medium and longer term. The recommendations build on the findings and results of earlier World Bank–supported work, including a 2013 feasibility study conducted under the Ulaanbaatar Clean Air Project (World Bank and Seureca 2015), an updated technical assessment undertaken in 2017–18 (COWI 2018), and a diagnostic assessment of the electricity and heat tariffs in Mongolia (MacroConsulting S.A. 2018).

Section 2. Recommended Actions: Next Five Years

To put the heating sector on a more sustainable path, the roadmap identified a number of interconnected issues calling for immediate action. This section describes the institutional and policy/regulatory reforms and supply- and demand-side measures proposed for near-term implementation.

Institutional Reforms

The two major publicly-owned companies should be organized to support incentives to meet the overall objectives of efficient and sustainable heat supply and hot tap water (HTW). To the extent possible, the organizational design of both the Ulaanbaatar District Heating Company (UBDHC) and the Housing and Public Utilities of Ulaanbaatar City (OSNAAUG) should ensure that system optimization efforts and investments benefit the organization responsible for the investment and its repayment.

Initially, both UBDHC and OSNAAUG should establish a joint Water Management Expert Team, which would report to the managements of both companies. The team would aim to identify the location of water leaks, thus creating the water balance, targeting of leak repairs, and water quality improvement (i.e., identifying the causes of observed oxygen in the primary pipe network). Its first step would be to develop a detailed action plan for improved water management, covering both primary and secondary pipe systems. In addition to funding for leak identification, funds should be available to launch rectification actions and pipe replacements, if needed.

Contracts with heat sources should be revisited to provide appropriate incentives to lower return temperatures, reduce primary water consumption, and improve overall energy efficiency. Heat supply to the district heating (DH) transmission company should be regulated by contracts (e.g., specifying obligations for purchase of heat, tariffs, technical limits, and water quality). Incentives should be provided for low-temperature operation to reflect the operational costs of the combined heat and power (CHP) plant. The basic payment from the DH company to the CHP company should be based on meter readings of supplied heat, supplied volume of replenishment water, and the average return water temperature relative to the set target value per outdoor temperature. The Private City Housing Companies (PCHCs) must be better integrated to ensure holistic optimization of the DH system by means of more sophisticated contracts comprising the above-mentioned issues.

Comprehensive capacity building in modern DH practices—technical, financial, and institutional—is also needed. Examples include demand-driven and pooled operation, preventive maintenance and water management, customer relations and tariff setting, operational analysis, cost-benefit analysis, and the establishment and functioning of HOAs. Capacity-building activities should be implemented to ensure that modern practices are adopted in Ulaanbaatar; these include traditional training, twinning, expert exchange programs, and study tours. Such activities should cover both employees of the current companies and relevant senior students of Ulaanbaatar universities.

Policy and Regulatory Reforms

Tariff reform, including redesign of the tariff structure, is needed. The current tariff regime is complex and discourages cost-saving behavior. Tariff structure redesign, including redefinition of tariff consumption blocks, would make it easier for end-user customers to understand how their payments correlate with the amount of heat they consume.

Tariff-setting procedures should be improved to ensure all company costs are eligible and offer enough investment margin for internal accumulation of funds among DH and CHP companies. Cost-efficiency improvements with substantial impact on tariffs should include optimizing planning of the procurement process and performing a first optimal planning exercise. Specific recommendations are as follows: (i) perform an optimal and forward-looking planning of the overall generation, transmission, and distribution process; (ii) introduce long-term tariffs (five years or more) to encourage cost savings; (iii) introduce incentives supporting optimizing the system design and operation, such as low-return temperature (high cooling of the DH water); and (iv) review the margin-setting practice for sale of heat to the PCHCs.

The legal framework should be further improved to ensure that all stakeholders comply with international standards for best practices. All DH producers, transmitters, and distributors (both public and privately-owned companies) must comply with internationally recognized standards for accountability and transparency. This recommendation is fully aligned with the Government of Mongolia's June 2015 policy goal of improving the energy sector's efficiency and productivity (Resolution No. 63, "On Adoption of State Policy of Energy").

Supply-Side Measures

To reliably and sustainably meet heating demand in Ulaanbaatar, investments are needed in production and transmission infrastructure, water management, and technical assistance. These measures, described below, will help to (i) reduce losses in the primary and secondary heating networks; (ii) increase transmission capacity so that more new customers can be connected to DH, which will prevent the expansion of small boilers; (iii) reduce heating-related air pollution as a result of implementing these measures; and (iv) optimize CHP operation by using heat accumulators and pooling of DH network operation, which will reduce overall fuel consumption and costs (photo 2.1).


Photo 2.1 Heat accumulator tank under construction. Credit: COWI

Increased Heat Production

Heat production capacity must be increased. Except for the Amgalan HOB plant, commissioned in 2016, no new heating sources have been built since 1983. Plans to construct the CHP5 plant (500 MW heat) in eastern Ulaanbaatar have been put on hold, and discussions have been held on rehabilitating and expanding existing CHPs. Other options for increasing production capacity are as follows:

- Extend the capacity of the Amgalan HOB plant from the current 230 MW (200 Gcal per hour) to 350 MW (300 Gcal per hour).
- Replace the existing CHP3 plant (290 MW heat and 250 Gcal per hour) with a new 370 MW plant (320 Gcal per hour) at an indicative investment cost of US$350 million.
- Generate more heat from CHP4 by means of direct connections from the boilers through pressure-reduction valves to the DH heat exchangers.[8] Since the connection was not originally designed for

[8] Stakeholders from UBDHC and CHP4 reported that excess heat production capacity is available at both CHP3 and CHP4. The limiting factor for system extension is the hydraulic capacity of the heat transmission network.

continuous use (i.e., only for boiler start-up and shut-down conditions), the pressure-reduction valves may need to be replaced with better ones designed for continuous use. The heat transmission network would need to be strengthened in order to supply the increased amount of heat to the city.

- Release some production capacity to connect new customers through pooled operation of all heat sources, demand-driven operation, and heat storage.
    - Introduce pooled operation incrementally: start in the summer, later extend into spring and autumn, and finally run year-round. After each extension, lessons learned should be converted into investments focused on phase-out of the identified bottlenecks.
    - Re-introduce demand-driven operation by fixing the temperature control systems in the substations. The water flow in the network would start to vary, creating more opportunities for heat storage in the network.

Ulaanbaatar has very limited agricultural or forest residues in its surroundings, making local coal the only currently available, large-scale fuel alternative to DH. In the future, heat pumps, solar power, and wind energy, together with heat storage, may offer options to at least partially substitute for coal.

Improved Heat Transmission

Improving heat transmission capacity by means of network reinforcement is vital for further development of efficient DH systems in Ulaanbaatar. The total replacement value of pipes that UBDHC considers as being in poor or fair condition amounts to US$244 million (approximately MNT 600 billion). The replacement cost of pipes in the poorest condition is US$125 million or about half of the total replacement cost (photo 2.2).[9]

Photo 2.2 Removal of corroded pipe. Credit: COWI

Establishment of Water Management Program

A Water Management Program—jointly launched by UBDHC and OSNAAUG—needs to be set up to identify and fix leaks, as well as improve water quality.[10] Good quality water is a precondition for ensuring the longevity of pipelines (i.e., 50-plus years), as well as appropriate operation of the DH system, particularly heat meters and control valves. Key components are as follows:

[9] The unit prices for estimating pipeline replacement cost are based on those of World Bank and Seureca (2015) and are adjusted to 2017 price levels.

[10] Water management must do two things in parallel. First, it must track water losses (water balance) and fix leakages across the system in order to reach an annual network replenishment rate close to 1 (equal to replenishment water consumption divided by network water volume). Second, it must improve water quality to meet international standards for best practices.

- Analysis of water quality—Installation of additional chemical analysis equipment for monitoring of make-up and return-water properties must be consistent with international best practices.
- Data collection—UBDHC and OSNAAUG should systematically collect data on replenishment water and meter readings from substations on water consumption.
- Data evaluation—Metered data should be evaluated relative to the size of the connected secondary systems. In cooperation with OSNAAUG and other stakeholders, information on consumption of replenishment water should be applied for identification of substations with high replenishment water needs and targeted location of leaking pipes.
- Leakage identification—Leaking HTW heat exchangers and identification of the cause of the measured increase in alkalinity should be identified. HTW heat exchangers should be tested for leakage (i.e., pressure tested to ensure that domestic cold water does not flow into the DH system).
- Testing building installation—Systematic testing of installations should be launched. As the task involves many buildings, priority should be assigned to buildings in areas selected for replacement of secondary side piping.
- DH water-quality testing—Water in the primary and secondary pipe systems should be tested to identify the source location of oxygen penetrating the pipe network (observed as increased alkalinity).
- Systematic review of operational parameters—For selected substations where it is suspected that oxygen is penetrating the DH network, such parameters as available pressure, differential pressure, and pressure coverage compared to height and elevation of connected buildings should be monitored.
- Standards review—Requirements for DH water quality should be revisited and updated, as necessary, to ensure compatibility with international best practices.

Provision of Technical Assistance

Technical assistance is needed in adjustment of substations and mixing loops. Such support is needed to get existing substations into working order (e.g., having automatic controls on heat exchangers, speed-controlled pumps, the pressure-holding system, and mixing loops). Special attention should be given to providing training and specialist advice on how to select, install, and adjust components, including items in the priority investment plan (PIP) (Section 4). Technical assistance should cover comprehensive training, twinning, study tours, and other activities that familiarize operational staff with modern, demand-driven DH systems and preventive maintenance practices. The program should be prepared in cooperation with key sector stakeholders (e.g., UBDHC, OSNAAUG, the PCHCs, and CHPs), and address all operational data and adjustment needs for operation of the modern equipment installed.

Demand-Side Measures

Transitioning to cost-reflective prices for heating energy and introducing consumption-based billing (CBB) practices for DH customers are key to improving the financial viability of demand-side energy efficiency investments. In the near term, specific demand-side options for Ulaanbaatar city include (i) introducing CBB in residential buildings, (ii) improving the energy efficiency of the building envelope (e.g., via insulation of walls, basements, and/or attics; and repair or replacement of external doors and windows) and (iii) improving operations and maintenance (O&M) practices. The proposed approach to energy efficiency financing for public and residential buildings is to focus initially on a selected segment in order to streamline limited resources.

Introducing Consumption-Based Billing

Introducing a facilitated transition to CBB will allow for introducing better-defined consumption blocks and tariffs for better demand-side management. Experience in other countries of Europe and Central Asia indicates that building-level heat metering and CBB can generate substantial energy savings (about 25–30 percent of the heat consumed). However, implementation requires careful planning and phasing and should be accompanied by extensive public outreach campaigns. Given Ulaanbaatar's low tariff levels and weak homeowners associations (HOAs) without financial and institutional power to take responsibility, it is recommended that a time-bound transition path toward CBB be developed.

Over the next five years, it is recommended that the installation of building-level heat meters and apartment-level hot water meters be prioritized. The preconditions for CBB should be introduced throughout the system. Energy meters and mixing loops should be installed at the building/staircase level throughout the existing high-rise buildings. All new buildings should be designed with double-string radiator systems with thermostatic radiator valves (or preferably with floor heating systems to achieve lower water temperatures). For new building/staircase level substations, strict requirements should be introduced to maximize the difference of supply and return temperature for improving energy efficiency of heat distribution.

Financing for implementing a pilot project for CBB at the apartment level should be considered. The CBB pilot should not be limited to procurement and physical implementation of heat meters and thermostatic radiator valves. It should also cover adequate arrangements for financing and implementation (e.g., direct-to-consumer subsidy and distribution programs through the heating utilities), follow-up technical assistance services, data collection and evaluation, and public outreach campaigns. In addition, data collection and comparison with similarly equipped buildings operated without CBB should be part and parcel of the pilot.

It is expected that the pilot would demonstrate how providing customers heating control options accompanied by CBB affects their energy consumption behavior and the resultant efficiency. The proposed pilot should include both retrofitting of heating installations in existing buildings and installing flat stations, double-string systems, and horizontal distribution at the apartment level and thermostatic radiator valves in new buildings. The performance of reference buildings for comparison of metered data should be monitored and compared with buildings of a similar size and condition. A more successful pilot would include higher heat tariffs, which would provide more energy-saving incentive.

Financing Building Energy Efficiency

Effective financing mechanisms should be made available to support implementation of an energy efficiency program targeted to public or residential buildings. For this to happen, a comprehensive market assessment would be needed to understand the technical, economic, and financial aspects of energy efficiency improvements for various types of buildings. Such an assessment would select and design an adequate implementation and financing scheme. It would also evaluate market capacity and quality of services and products; identify key policy, regulatory, financial, and institutional barriers to realizing the energy efficiency potential; and recommend specific ways to address them. Likewise, the financial costs and benefits of potential reduction in air pollution and greenhouse gas (GHG) emissions would need to be assessed.

Before turning to the multi-family residential buildings, the central focus of energy efficiency investments should be public-sector buildings and residential houses in ger areas. Most multi-family apartment buildings lack well-functioning collective decision-making structures, sufficient incentives for private investment, and household access to affordable financing. However, investments in public-sector buildings can anchor the promotion of energy efficiency across all economic sectors. Improved energy efficiency in public buildings that serve a large segment of Ulaanbaatar's population (e.g., schools, hospitals, and kindergartens) can have a demonstration effect and offer social benefits.

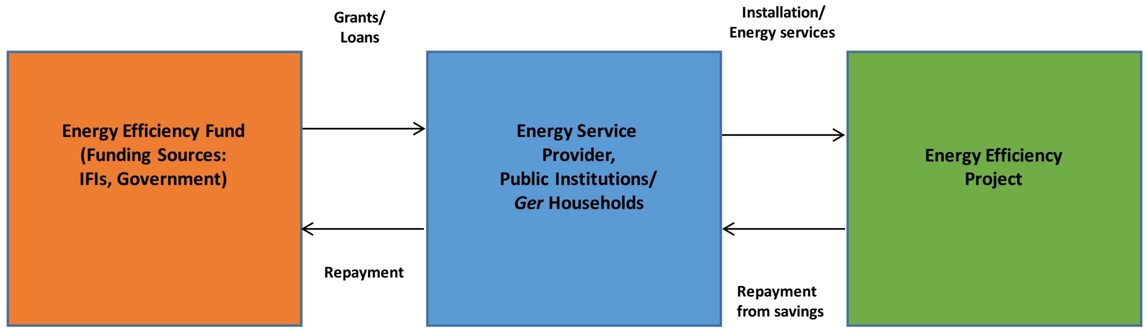
However, scaling up the successful implementation of public-sector projects requires that various challenges be addressed. Key among them are (i) strained public-sector budgets and limited access to financing, (ii) institutional and regulatory barriers (e.g., lack of benchmarking data, incomplete legislation, and weak enforcement of building codes), (iii) lack of awareness and incentives regarding the potential for economically and financially viable energy efficiency, and (iv) insufficient implementation capacity.

Enabling low-income consumers in ger areas to access heating appliances and improve energy efficiency is urgently needed. Many of the poorly-insulated public buildings in ger areas are heated by coal-fired boilers, while most ger households use simple stoves (fired by coal, wood, and waste products) to heat their tents or detached houses. Heating is expensive, accounting for an average of 16 percent of household income, thus also representing potentially large fuel savings from reducing heating demand through efficiency improvement. Considering the challenges and opportunities related to public buildings and residential houses in ger areas, several financing mechanisms can be considered, as elaborated on below.

Budget financing with piloting of more sustainable models. Under a budget/grant-financed energy efficiency program, the government provides funding (e.g., as part of a project financed by international financial institutions [IFIs] and/or other development partners) to public facilities/municipalities to cover the upfront costs of energy efficiency investments. Gradually, the program could include more sustainable financing features, such as budget-capture models, in which case future energy budgetary provisions for the benefit of public institutions and ger households are reduced until the loan has been (partially or fully) repaid. The government can then use some of the cash saved through the budget-capture system to finance additional projects. Another option is phasing in co-financing arrangements with the beneficiaries. Budget/grant-financed energy efficiency programs are typically implemented through a project implementation unit, which provides support for selecting buildings, conducts technical preparatory activities and related procurements (e.g., energy audits and designs), and supervises and implements the energy efficiency measures and monitoring of results.

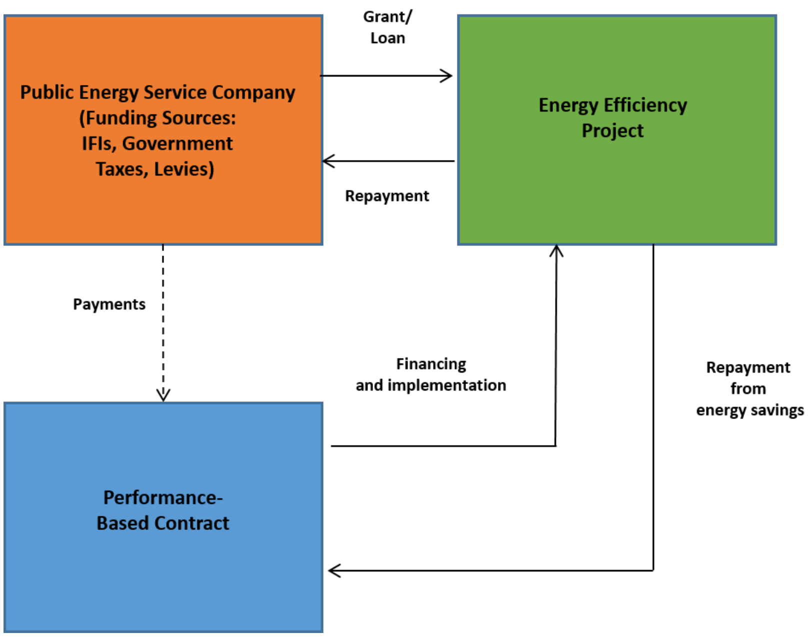
Revolving fund for energy efficiency. A variety of developing countries (e.g., Armenia, Bosnia and Herzegovina, Bulgaria, India, Kazakhstan, Macedonia, and Romania) are starting to use revolving funds to finance energy efficiency measures in public buildings and households. Such funds, typically set up by a government-established, independent entity, provide the upfront investments and technical assistance for preparing and implementing energy efficiency measures. Fund operators, who are supervised by a board of directors appointed by the government, can include both government and nongovernmental stakeholders. The public-institution beneficiary repays the investment costs based on the estimated or verified energy cost savings achieved. The fund is allowed to "revolve" by re-investing the repaid funds, while the public institution benefits through maintaining a positive cash flow (figure 2.1). Such a fund may offer financial products and technical assistance services to cover the varying needs and capacity of public institutions (e.g., loans, grants, guarantees for commercial bank loans, technical assistance for energy auditing, procurement, and supervision).

Figure 2.1: Revolving fund arrangements for financing energy efficiency investments



Public Energy Service Company (ESCO). A public ESCO is a government-owned corporation, established primarily to undertake energy efficiency projects. As a public enterprise, it often can sign contracts with other public agencies without undergoing a competitive process. This helps to overcome some of the unwieldy procurement and administrative challenges public agencies face when engaging private ESCOs. The public ESCO can better access public, donor, and other funds and thus can offer 100 percent project financing to its clients. Generally, clients repay the public ESCO based on the estimated energy costs savings, although sometimes a verification procedure is performed. The public ESCO will then subcontract all actual implementation to local contractors, thereby fostering a local ESCO industry. Various models have been used, depending on local conditions and capabilities of existing entities; common ones include "super ESCOs," internal ESCOs, and those that are utility-based or focused on demand-side management (figure 2.2).

Figure 2.2: Public ESCO model for energy efficiency investments



Implementing a CBB and energy efficiency improvement program should include a technical assistance component for capacity building,[11] along with educational or marking campaigns (if practical). Program administration would be required to support the program. Furthermore, additional funds would be needed to build capacity and provide technical assistance for Ulaanbaatar to administer the energy efficiency improvement program of public buildings and ger households. The municipal government would require substantial technical support from energy advisors to undertake walk-in energy audits, prioritize buildings and households, and conduct monitoring and reporting. Moreover, standardized information and technology (IT) systems and agreements for procurement would be required.

[11] Capacity building should be provided for government personnel, technical consultants, and service providers.

Section 3. Recommendations for Further Sector Development

In addition to the near-term actions proposed in Section 2, the roadmap identified a number of actions required to ensure ongoing, sustainable development of the heating sector. This section describes the interconnected institutional and policy/regulatory reforms and supply- and demand-side measures proposed for implementation over the medium and longer term.

Institutional Reforms

Pooled operation among the four CHP plants should be adopted by revising existing contracts once technical pre-conditions (e.g., static pressure, booster pump connections, and substation automation) have been addressed. This would substantially reduce fuel costs and/or generate more electricity at an efficiency higher than today's. It would also increase supply reliability; plants could be used as back-up capacity for each other, improving the possibility of scheduling outage time for plants and parts of the pipe network. The economic benefits of pooled operation should be allocated between customers and the heat sources.

To enable pooled operation, changes in operation and management would be required of the transmission network, as well as CHP3 and CHP4. Priority should be given to the most efficient heat producer, with consideration of the technical possibilities and limitations set by the DH transmission network. The overall principle is that equipment essential to the operation of the DH transmission system that is geographically located within the fence of the CHP plant is owned and operated by that plant. Such equipment would include pipes, valves, instrumentation, meters, pumps, frequency converters, motors, heat exchangers, water treatment installations, and SCADA facilities. The CHP plant would provide pressurized DH water with the required supply temperature, static pressure, and replenishment water.

Once heat tariffs are on a sufficient cost-covering level, private-sector participation in heat production based on alternative energy resources will be more attractive from an economic perspective, making legal and regulatory measures clear, transparent, and stable. Private operators, whose heat source is not based on coal or fossil fuels, might be given the right to construct facilities for heat supply and delivery to UBDHC and/or secondary side companies. Third-party operators should be able to enter into long-term agreements on heat supply, conditional on supplying heat at a lower cost than those offered by the CHP and HOB plants. The offered (and agreed on) price should also reflect the availability of the heat source, which may depend on seasonality and the extent to which the heat source relies on other facilities (e.g., the CHP plants) for supply reliability.

Clear ownership of apartments and installations within buildings is critical to implementing heat metering and building energy efficiency (BEE) measures to reduce heat demand. The relevant legal framework should be changed to ensure that HOAs can obtain loans and enter into contracts with private companies (e.g., plumbers or contractors) and distribution companies.[12] The heating and HTW installations would become the common property of the apartment owners. Ownership would be transferred to the HOAs, who would become legal bodies with an elected chairman and board of directors, as well as defined formal rights and obligations. For individual houses, single-owner office buildings, apartment

[12] In this way, the HOAs themselves would not need to possess the technical skills required to operate, maintain, and adjust heating and HTW installations.

buildings with an owner, and rental apartments, no further measures would be needed as the building owner would already act as a legal body. For high-rise buildings with private ownership of apartments, the situation would be more complex since the strong single-owner representative (HOA) would have to be facilitated.

Policy and Regulatory Reforms

The cost-allocation procedures and mechanisms should be adjusted with the aim of establishing a sustainable system that reaches cost recovery. The billing principles and heat tariffs as part of the regulatory framework should achieve full or extensive cost recovery, ensuring that all operational expenditure and part of the capital expenditure (CAPEX) are covered and based on CBB that encourages energy efficiency.

Cross-subsidies between domestic and non-domestic customers would gradually be removed, while taking into consideration social protection measures. This would involve the following steps: (i) introducing a special tariff for the use of energy from DH return water; (ii) introducing a two-tier tariff system, consisting of a fixed fee (e.g., a capacity fee, depending on maximum capacity, measured in kilowatts or gigacalories per hour) and a variable tariff based on metered consumption; and (iii) gradually removing multiple cross-subsidies among various players across the whole chain of service provision by introducing further improvements to tariff-setting procedures. Potential tariff adjustments would need to be differentiated by income and consumption levels for domestic customers, with limited impact on the poorest households. This could be achieved through a reform of the tariff structure and/or new subsidy arrangements. In the meantime, a communication strategy and plan should be developed and implemented alongside the reforms.

Supply-Side Measures

Pooled operation should be used to extend the DH system into the new development areas and the existing ger areas. Activities should be launched to map future heating demand and plan system extension into ger areas. The mapping should be consistent with plans for end-user installations and pipe network reinforcements (primary and secondary side) and extension of heat production facilities. Such planning should include a thorough analysis and modeling of facilities required to fulfill the overall objectives of pooled operation and identification of needs for additional heat production capacity and full or partial replacement of aging facilities. The work would include development of technical concepts, preparation of budgets, obtaining financing, and further use of geographic information systems (GIS). It should be considered that pooled operation fulfills the requirement of supply reliability and efficiency optimization.

Photo 3.1 Aging piping suggested for replacement. Credit: COWI

Funds should be allocated for the ongoing improvement of system efficiency and optimization. In the mid and longer term, serious consideration should be given to implementing the following measures:

- Replacement of pipelines in the aging primary-side network. Dimensions of the new pipelines, justified by the hydraulic analysis and heat demand forecast, should be larger in order to increase transmission capacity.

- Identification and development of pilot areas for buildings suitable for low-temperature operation. A program should be launched to identify high return-line temperature consumers. Funds should be made available for the rectification, improvement, and change of installations with a too high return-line temperature, which results in high thermal losses and limited system capacity.
- Funding for a technical study to resolve operational constraints. Limited operational pressure is currently a problem; thus, a technical study would be needed to identify causes of the present limitation of 12 bar and raise the maximum operational pressure higher (closer to 16 bar).
- Launching of refurbishment program for heating and HTW installations in existing high-rise buildings. The high-rise buildings, which still have a substantial technical life, should be refurbished with completely new installations for heating and HTW, designed for low-temperature operation and possibly CBB at the apartment level.
- Phasing out of the 4-pipe central HTW heat exchangers. Over the long term, these heat exchangers should be replaced by building/staircase-level substations in which HTW is also heated.
- Further extension and development of SCADA for both primary and secondary side facilities. The aim would be for SCADA to manage the entire DH system (i.e., incorporating heat production facilities, substations, pumping facilities, valve facilities, end-user facilities, and heat accumulators).
- Possible integration of alternate heat sources. Solar, heat pumps, and use of heat-storage facilities should be identified and developed to operate jointly with the central DH system.

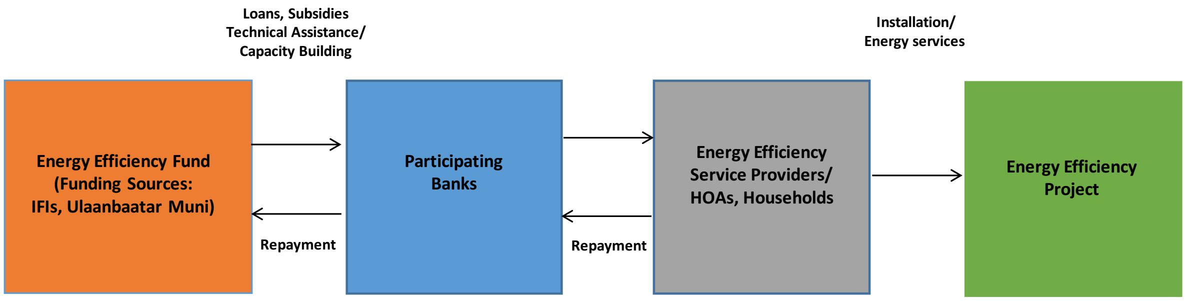
Demand-Side Measures

International experience demonstrates that investments to improve demand-side energy efficiency require strong policy/regulatory and legislative support. Decisive government actions and long-term commitment are required to enact and enforce legislation, adopt policy and regulatory enhancements, improve market conditions, build local capacity, and provide access to affordable financing.

Over the medium and longer term, CBB at the building/staircase level (and perhaps the apartment level) will be required. For a system with CBB, the tariff must be set at a level that, at a minimum, reflects the actual costs of operation. Furthermore, the tariff must be set at a sufficiently high level so that residents pay attention to the actual amount of energy and water they are using and begin to change their consumption behavior. Cost-reflective heat (and electricity) tariffs, a strengthened position of the HOAs, and upgraded national building codes that include mandatory preference for CBB are the main conditions that will make it possible to scale up CBB implementation and provide more energy-saving incentives for customers connected to the DH networks.

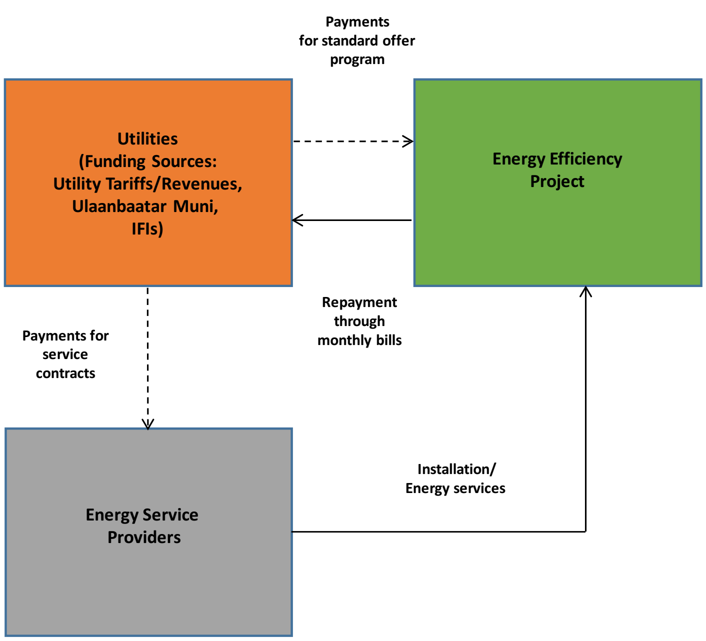
Financing mechanisms, including private-sector financing, should be considered for the larger residential buildings connected to the DH network. Decision-making structures for investments and mechanisms for financing more capital-intensive upgrades should be well-established, with higher tariffs and CBB in place to incentivize investing in energy efficiency generating energy savings. For residential energy-efficiency programs, international experience indicates four major financing options: (i) energy efficiency funds, (ii) commercial bank financing, (iii) partial credit guarantees, and (iv) utility-managed programs.

Figure 3.1: Proposed energy-efficiency financing options for larger residential buildings



Energy efficiency funds and commercial lines of credit, combined with grants-based incentive schemes, might be the most suitable financing options for larger residential buildings in Ulaanbaatar. At present, XacBank is providing US$2 million of its own funds for building energy efficiency loans. Ten households in Ulaanbaatar have already benefitted from XacBank loans, while 60 other households have taken out loans from the Savings Bank of Mongolia. Currently, the loan interest rate is low, the related risks are relatively high, terms are short, and banks tend to favor apartment lending. Since the government does not mandate energy efficiency improvements and the payback period is long, there is a concern of limited market demand. It is thus recommended that financial incentives in the form of subsidies and tax credits/deductions be considered to incentivize building owners to undertake thermal retrofits (figure 3.1). International experience shows that upfront subsidies that take household income levels into account are generally more effective than tax breaks for incentivizing such investments. Over the longer term, normal commercial interest rates and loan duration periods for this type of financing should be applied to ensure post-project sustainability and avoid undermining the development of a healthy commercial mortgage market and enhanced policy/program.

Figure 3.2: Potential model for a utility-managed energy efficiency program



Utility-managed energy efficiency programs may also be a viable option. Given their established relationship with customers and knowledge of local energy-use patterns, the utilities are well-positioned to support residential buildings in implementing energy efficiency programs. Because many heating companies are struggling to provide additional heat while making the necessary investments to sustain reliable services in Ulaanbaatar, they have a financial incentive to implement programs that reduce demand. In many countries, utilities have been required by their regulators to finance customers' investments in energy efficiency products, technologies, and equipment and use the utility billing mechanism to accept customers' repayment of the funds. The utility's monthly billing system provides a valuable mechanism through which customers can pay back utility-supported financing. In addition, an energy service provider could be contracted by the utility to implement the program (figure 3.2).

Section 4. Priority Investment Plan

Based on the list of near-term supply- and demand-side measures recommended for improving the reliability and efficiency of Ulaanbaatar's heating sector, a priority investment plan (PIP) was developed (Section 2). The process of selecting the priority investments began by screening the comprehensive list of measures for their economic and technical viability. This screening exercise resulted in a short list,[13] for which a cost-benefit analysis was conducted. Those investment items evaluated as having highest economic return or critical importance to DH operations were selected for the PIP. Meanwhile, a broad array of institutional and policy reforms as previously recommended are needed to accompany these priority investments in order to put the heating sector on a more sustainable path.

Cost Summary

At a total estimated cost of about US$50.3 million, the PIP would reduce Ulaanbaatar's annual coal consumption and pollutant emissions, while providing households better DH services and access to the network. By implementing the proposed PIP, the system would be expected to generate fuel-energy savings totaling 296 Tcal (344 GWh_{th}) per year and reduce network losses from approximately 144,000 to 53,000 Gcal per year for the pipes included in the proposed PIP. The reduction in carbon dioxide (CO_2) emissions would amount to 117,058 tons per year, with significant emissions reductions for other pollutants (e.g., 591 tons per year for sulfur dioxide [SO_2], 418 tons per year for dust, 153 tons per year for nitrogen oxides [NO_x], and 105 tons per year for carbon monoxide [CO]). In addition, some 88,000 households (23 percent of all households in Ulaanbaatar) and businesses would enjoy improved DH services, while about 2,000 ger households would gain access to the DH network. Table 4.1 breaks down the estimated costs for each of the investment items, as well as supporting program costs.

Table 4.1: Results of Cost-Benefit Analysis for Priority Investment Program

Investment item	*Description*	*Cost (US$)*	*Energy savings (Gcal/ year)*[a]	*IRR (%)*[b]	*NPV (US$)*
Pipeline replacement and extensions to eliminate small HOBs by CHP heat: $15.64 million					
UBDHC-101	Replacement of existing 2 x DN 800 pipeline from TK-501 to TK-521 with new 2 x DN 1000 pipeline	12,612,222	169,671	35[c]	40,405,412
UBDHC-102	Replacement of existing 2 x DN 400 + 1 x DN 600 from TK-521 with new 2 x DN 800 pipeline	2,023,559			
UBDHC-103	Primary side piping for expansion into Mongolian radio, TV area	645,407			

[13] The short list excluded measures found to have very high investment costs, low potential for improving DH efficiency, or limited technical feasibility.

UBDHC-104	Primary side piping for expansion into Denjiin 1000 area, West	250,374			
UBDHC-105	Primary side piping for expansion into Denjiin 1000 area, East	111,277			
UBDHC-106	Substations for expansion into Mongolian radio, TV area, equipment (no building)	0			
UBDHC-107	Substations for expansion into Denjiin 1000 area, West, equipment (no building)	0			
UBDHC-107A	HTW heat exchangers, building basement at staircase level	0			
Heat accumulator to supply more heat from CHP4 to downtown: $4.04 million					
UBDHC-108	Secondary side heat accumulator tanks, including auxiliary equipment	1,268,808			
UBDHC-109	Reinforcement of heat transfer capacity at substations	2,570,736	129,084	47	32,956,043
UBDHC-110	Secondary side water treatment equipment	200,000			
OSNAAUG-202	Expansion of primary side network	0			
OSNAAUG-203	Expansion of secondary side network, heating	0			
OSNAAUG-204	Expansion of secondary side network, drinking water supply	0	242,387	149[d]	69,930,443
OSNAAUG-201	New substations, including buildings	0			
OSNAAUG-205	HTW heat exchangers for building basements	0			
Heat and HTW balancing in buildings: $1.28 million					
OSNAAUG-207	Balancing valves for vertical risers in buildings, including installation works and trimming, heating	991,216	6,636	20	1,259,065
OSNAAUG-212	Balancing valves for HTW risers in buildings, including installation works and trimming, HTW circulation	285,848	3,586	30	815,430
Replacement of selected secondary networks: $5.19 million					
OSNAAUG-209a	Replacement of existing pipe network, heating (supply + return)	2,516,592	143,542	26	31,046,023
OSNAAUG-209b	Replacement of existing pipe network, HTW (supply + circulation) unit cost 66% of heat piping	2,678,259			
Mixing loops: $6.01 million					
OSNAAUG-208	Mixing loops	6,014,452	44,456	7	3,254,310
Separation of buildings currently with direct connection: $0.44 million					
OSNAAUG-206	Separation of small buildings today directly connected	444,102	401	-8	-305,160
SCADA: $0.20 million					
OSNAAUG-210	Substations to be connected to existing dispatch center with SCADA	203,335			-2,134,109
Critical substation components: $4.47 million					
OSNAAUG-211	Components critical for substations (e.g., instruments, control valves, heat meters)	1,220,008	6,141	0	0
	Energy meters for existing mixing loops	800,000			
	Technical assistance to water management program: leakage reduction and water-quality improvement, fixing alkalinity problem	1,000,000			
	Technical assistance for adjustment of substations and mixing loops	500,000			
	Pilot projects for CBB and low-temperature operation	950,000			
Subtotal:		**37,286,195**	**745,815**		
	Engineering preparation of bidding documents and tendering (10% of items value)	3,728,620			
	Site supervision and follow-up (15% of items value)	5,592,929			
	Contingency (10% of items value)	3,728,620			
Total Cost:		**50,336,363**			

Note: IRR = internal rate of return; NPV = net present value.
a. Primary fuel consumed.
b. Per year.
c. The 35 percent IRR is derived from eliminating the small HOBs and connecting the HOB customers to the main network.
d. The high IRR value of 149 percent assumes that, without the PIP, the small HOBs, with an efficiency of just 60 percent, would be expanded.

Priority Investment Descriptions

Pipeline Replacement and Extensions to Eliminate Small HOBs by CHP3 Heat

It is expected that increased heat transmission from CHP3 will eliminate small coal-fired HOBs in ger areas, Denjiin district, and the combined radio-TV area, thereby reducing coal and carbon emissions substantially. Pipe reinforcement in the CHP3 area will extend into the Mongolian radio-TV and Denjiin 1000 areas. To the extent possible, the construction of new substations and end-user installations will focus on CBB and heating of HTW at the building and staircase level. The closer the heating control is to the building and apartment, the better it works. Therefore, building- and staircase-level substations and mixing loops control heat demand according to customers' needs much better than traditional, large group substations serving several buildings. In this case, however, customers are expected to invest in their substations.

Installation of new piping would support reduction of leakage and improved water quality. The components are as follows:

- UBDHC-101: Replacement of 5.5 km of DN800 trench with a new DN 1000 to help CHP3 to transmit more heat to new customers.
- UBDHC-102: Replacement of existing 2 x DN 400 + 1 x DN 600 pipes (3 pipes together) in the CHP3 area with a new 2 x DN 800 piping with 1.1 km trench length to improve energy efficiency and increase CHP transmission capacity.
- UBDHC-103: Extension of primary side piping (approximately 0.6 km trench) to Mongolian radio-TV area (15 Gcal per hour peak demand, 3,000 full load hours).
- UBDHC-104: Extension of primary side piping to Denjiin West district (10 Gcal per hour peak demand, 3000 full load hours).
- UBDHC-105: Extension of primary side piping to Denjiin East district (10 Gcal per hour peak demand, 3000 full load hours).

One focus of the PIP is to eliminate existing HoBs and prevent new HoBs to be built in the outskirts of the ger area, located near to the DH network. In such way, high economic and environmental return can be achieved. The incremental investment cost of the items UBDHC 101-107, for instance, is US$10.1 million ($15.6 million in new investments minus the alternative [HOB, HTW] of $5.3 million). The business as usual (BAU) scenario (i.e., without IFI support) assumes that small HOBs with 60 percent efficiency are constructed, entailing annual coal consumption of 248 Tcal and 98,000 tons of CO_2 emissions per year. The project case assumes 200 percent heat production efficiency at the CHP, requiring 81 Tcal, and 32,000 tons of annual CO_2 emissions (table 4.2). Such a high heat production efficiency is based on incremental fuel consumption caused by extracting heat from the steam turbines to DH.. Therefore, the benefits of the project components would amount to 167 Tcal of coal saved, and 66,000 ton of CO_2 emissions reduced. The coal cost level is based on the lower heating value of 4,000 kcal per kg and a price of US$88.4 per ton and the CO_2 emissions are valued at US$5 per ton. Moreover, CHP is equipped with effective electrostatic precipitators to capture particulate matter emissions and tall chimneys, comparing with the HoBs that are equipped with cyclones and lower chimneys.

Table 4.2: Summary of Fuel and CO_2 Emissions (UBDHC 101-107)

Item	*BAU*	*Project*	*Reduction*
End-user heat demand (Tcal)	149	149	0
Production efficiency (%)	60	200	n.a.
Network efficiency (%)	100	92	n.a.
Coal consumption (Tcal)	248	81	167
CO_2 emissions (thousand tons)	98	32	66
Investment cost (million US$)	10.3	15.6	−5.3

Note: n.a. = not applicable.

The high internal rate of return (IRR) of 35 percent assumes increasing the pipeline diameter in the main network in order to supply heat to those new customers resulting from HoB elimination (table 4.1).

The total coal savings of 745,815 Gcal p. a. (Table 4.1) represent some 15% of the heat energy delivered by UBDHC. Therefore, the expected fuel and emission savings are substantial.

Heat Accumulator to Supply More Heat from CHP4 to Downtown

It is proposed that 1–2 pilot heat accumulators be installed to the secondary side of the group substation to charge heat from the primary network at nighttime, when idle capacity is available, and discharge heat to customers during the day. Thus, daytime heat would be released to other customers downtown.

The components are as follows:

- UBDHC-108: 1-2 secondary side accumulator tanks, including auxiliary equipment to unidentified locations.
- UBDHC-109: Reinforcement of heat transfer capacity at substations to be able to charge the accumulator.
- UBDHC-110: Secondary side water treatment equipment to protect the new accumulator heat exchanger and extend the lifetime of pipelines and armatures.

The accumulator tanks would amount to US$1.57 million in investment cost. Reinforcement of heat transfer capacity at substations, at a cost of US$2.57 million, would comprise new substations, HTW heat exchangers, and piping for expansion into the Bayangol area. In practice, replacement of heat piping would reduce leakage and help improve water quality owing to reduced water consumption. Because cold water pipes lie in the same ducts as the heating pipes, it would make sense to replace cold water pipes in ducts at the same time that heating pipes are replaced. New substations and end-user installations should be constructed with a focus on CBB and heating of HTW at the building level/staircase level. Secondary side water quality is vital to the lifetime of pipelines and heat metering and control devices. The cost of secondary side water treatment equipment would amount to US$0.20 million.

An additional peak demand of about 37 Gcal per hour could be served by means of accumulation and 111.6 Gcal delivered per year. As a project alternative, small HoBs at 50 Gcal per hour (50 percent spare capacity) would need to be installed to deliver the same 111.6 Tcal per year. CO_2 emissions for the project would amount to 22,500 tons per year, compared to 73,700 tons per year under the BAU scenario. A high indicative IRR of 47 percent is expected (table 4.1).

Heating and HTW Balancing in Buildings

Balancing of heating and HTW pipe systems inside buildings would be needed to improve service quality and achieve comfortable and stable room temperatures in all apartments.

There are two components:

- OSNAAUG-207: Balancing valves for vertical risers in buildings, including installation works and adjustment (heating for 20.3 Gcal per hour peak load and 66.9 Tcal per year). After balancing is completed, the new heat demand would be 60.8 Tcal per year with a 9 percent savings (6.1 Tcal). The investment cost would be US$0.99 million, and the indicative IRR would amount to 20 percent.
- OSNAAUG-212: Balancing valves to HTW risers in buildings, including installation works and adjustment with 44 Gcal per hour at the staircase level and 90.5 Tcal per year hot water delivery. It is assumed that each valve would cover a circulation loop in a 9-floor building with 18 apartments, each with a designed peak load of 0.03 Gcal per hour and a coincidence factor of 0.62 at basement level. After balancing is completed, the new heat demand would be 84.4 Tcal per year with a 7 percent savings (6.1 Tcal). The investments cost would be US$0.29 million, and the indicative IRR would amount to 30 percent.

The balancing valves for heating pipes, HTW circulation loops, and mixing loops are critical. For heating pipes, the balancing valves contribute to correct flow distribution internally in buildings, while adjusting the flows per each riser pipe. For HTW circulation loops, they adjust water flow in the circulation pipe. The mixing loops in staircase/building basements adjust the supply water temperature to the radiator circuits automatically according to the actual outdoor temperature. In this way, the heat released from the radiators to rooms match the heat demand in the apartments at the actual outdoor temperature. The mixing loops would also include energy meters, which are necessary for building/staircase-level CBB.

Replacement of Selected Secondary Networks

Targeted replacement of existing secondary side piping (and possibly reinforcement) would support the Water Management Program, while reducing leakage and helping to improve water quality. The proposed quantity (136,800 m of single piping) is quite large and has been adjusted due to the high cost implications.

The two subprojects are as follows:

- OSNAAUG-209a: Replacement of existing pipe network, heating (supply + return), at an investment cost of US$5.0 million. The benefits are based on 1.4 Gcal per hour and 8 Tcal per year heat losses abatement.
- OSNAAUG-209b: Replacement of existing pipe network, HTW (supply + circulation), at an assumed unit cost of 66 percent of heating piping at US$5.4 million investment cost. The benefits are based on 1.8 Gcal per hour and 15.8 Tcal per year heat losses abatement.

The combined quantitative savings for the subprojects are 143,000 tons in coal and 56,700 tons in CO_2 emissions. The indicative IRR is 26 percent.

Mixing Loops

Replacing old, outdated hydro-elevators with mixing loops would improve the energy efficiency of heat distribution inside buildings.

The component is described below:

- OSNAAUG-208: Mixing loops to 90.5 Gcal per hour peak load and 271 Tcal per year (299 Tcal without project) heat demand. The heat energy savings would be 10 percent at an investment cost of US$12.0 million. It is assumed that one mixing loop covers a load of 9 x 2 x 80 m² x 50 W per m² = 72 kW (i.e., for replacement of one hydro-elevator in one entrance in a 9-floor building).

The estimated savings for coal and CO_2 emissions are 16 Tcal and 6,300 tons, respectively. A negative IRR of -5 percent is indicated at 10 percent heat energy savings. With 16 percent heat savings, which is possible, the IRR would be zero. Fuel price increases are needed to make the mixing loops economically viable.

Separation of Buildings Currently with Direct Connection

Separation of primary and secondary networks in buildings is required to ensure the safety and efficiency of the DH operation. OSNAAUG has suggested a package for separating buildings directly connected to the primary system by installing heat exchangers. When all buildings are indirectly connected, various possibilities will open. For example, the primary network can operate without being limited by the pressure rating for directly connected building installations.

The component is described below:

- OSNAAUG-106: 1.6 Gcal per hour and 6.8 Tcal per year heat delivery, covering both space heating and HTW, based on the assumption that each consumer has a design thermal load of 0.05 Gcal per hour.

Owing to the new mixing loops, a 10 percent savings is expected in space heating. Thus, savings of 0.4 Tcal of coal (about 200 percent efficiency) and 200 tons of CO_2 emission are expected. The IRR remains negative, at -8 percent, as the CHP heat production efficiency is 200 percent and fuel prices are low. Though the current coal and emissions savings remain too low to gain a positive IRR, this investment is necessary for safe operation of the DH system.

SCADA

The development of SCADA should be coordinated between UBDHC and OSNAAUG so that one system would be monitoring, possibly from two locations. The SCADA of UBDHC should be extended to cover more substations, and side monitoring should be facilitated for the OSNAAUG control room.

Critical Substation Components

In the transition toward building/staircase-level CBB, it is suggested that billing principle be reformed so that heating bills can be charged by the staircase, rather than the apartment, level. The metered energy for heating at the staircase level would be distributed among the apartments based on square meters of heated floor area for each apartment. Implementation of this billing principle should be supported by reinstalling energy meters for the existing mixing loops.

In addition, other critical components in the substations should be rehabilitated, replaced, or added. These include temperature controllers (e.g., temperature sensors and control valves). Such components would be crucial for converting DH system production to a demand-driven mode, starting from the primary network and extending to the secondary ones.

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