2030 Water Resources Group

MONGOLIA | Ulaanbaatar

Hydro-economic Analysis on Cost-Effective Solutions to Close Ulaanbaatar's Future Water Gap

August 2016

Executive summary

The 2030 Water Resource Group Mongolia Partnership aims to enable sustainable water resource management in Mongolia. The partnership's Memorandum of Understanding was signed between the Government of Mongolia and 2030 WRG on 16 September, 2013.

This report focuses on Mongolia's capital and economic hub, Ulaanbaatar. Based on the water supply demand gap identified in the previous project phase, an inventory of implementable solutions to close the gap were identified and prioritised to allow for sustainable economic development.

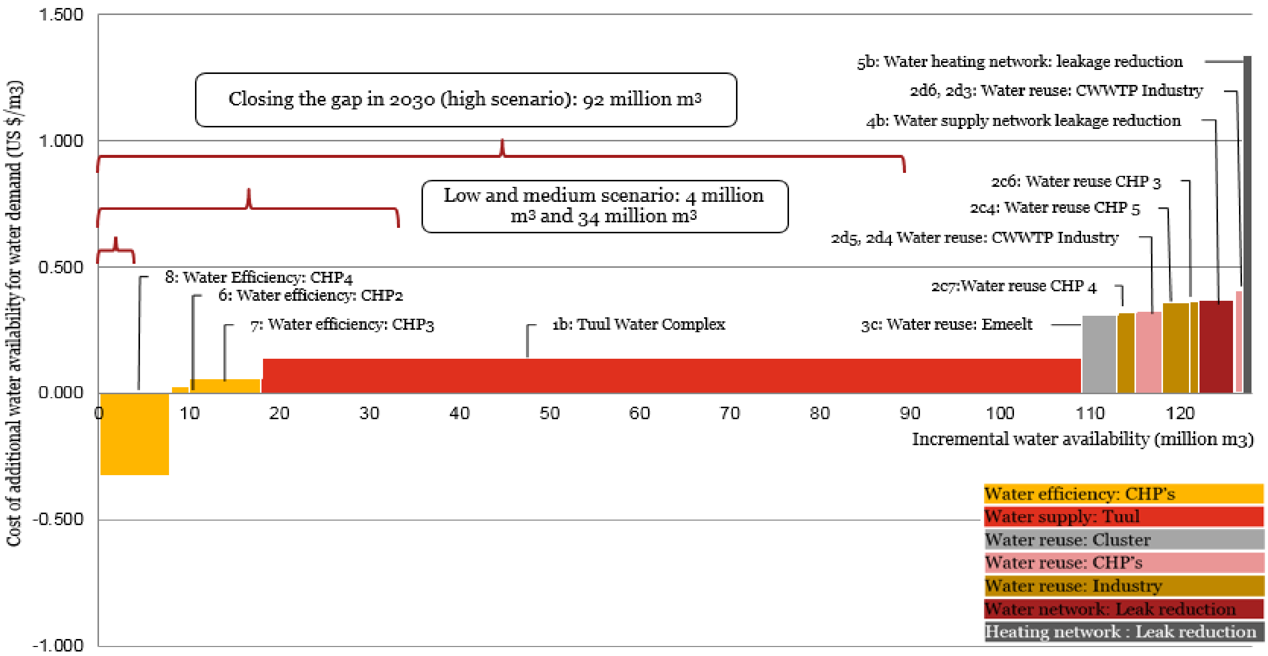
The water supply-demand situation

By 2021, water demand will not be met with the available water resources in the high and medium water demand scenarios. By 2030, a water demand supply gap is estimated in all scenarios. In concrete, it has been estimated that 3% (4 mn m3/yr) and 28% (34 mn m3/yr) of total water demand will not be met with the given water supplies by 2030 in the low and medium water demand scenarios respectively. In the high water demand scenario, 43% of the total water demand (92 mn m3/yr) is estimated to not be met with given supplies by 2030. It is assumed that all surface water resources will be utilised and that the current groundwater yield will remain until 2030. If this is not the case, the water supply demand gap is expected to occur earlier and higher across all scenarios.

Hydro-economic analysis on water supply augmentation and water demand reduction solutions

Solutions are focused around the key water users in Ulaanbaatar, which include the energy, domestic and industrial sectors. Analysed solutions include water demand reduction and water supply augmentation measures. These were selected from ongoing (governmental) initiatives, such as the Implementation Plan of Ulaanbaatar City Master Plan 2030, from stakeholder consultations and were customised from international best cases to Ulaanbaatar's context. The identified solutions were prioritised on the basis of an assessment framework which consists of financial, economic and environmental criteria (see Figure 10, Section 3.1.1 and Annex A.3).

Figure 1 Holistic cost curve prioritising solutions to close Ulaanbaatar's future water gap



Depending on the water demand scenario, solutions to close the gap were identified with the help of hydro-economic analysis[1] (see figure 1):

- In the **low water demand scenario,** there are two options to close the gap of 4 mn m3/yr. The most cost effective solution is to implement water efficiency measures in CHP4 which would result in cost savings of 10.2 mn USD/ yr. However, as USUG is already engaged in NRW reduction measures, which have the potential to close 95% of the low demand gap at 7.1 mn USD/yr this option may be preferred. The remaining 0.2 mn m3/yr could be closed by exploring the additionally identified solutions which are assessed in a qualitative manner (see below). , or by installing water efficiency measures in CHP4 in addition.
- In the **medium water demand scenario,** there are also two options to close the gap of 34 mn m3/yr. Following the cost curve, the most cost-effective solution (USD/m3) is the Tuul Water Complex. However, as the Tuul Water Complex cannot be constructed in segments, its construction would result in an excess of water available (57.3 mn m3/yr) and would result in high total costs (46.4 mn USD/yr). Alternatively, the remaining measures analysed in the cost curve could be chosen to close the gap at less than half the cost (21 mn USD/yr). These measures include the implementation of a combination of water efficiency measures at CHPs 2, 3 &4, reuse of treated Emeelt industrial wastewater, reuse of treated CWWTP water at CHPs 2, 3 &4, reuse treated wastewater from CWWTP at industrial clusters (Bayangol, Songinokhaikhan & Khan Uul) and USUG NRW leakage reduction measures (35.6 mn m3/yr).
- In the **high water demand scenario**, the only measures capable of closing the gap are the Tuul Water Complex in combination with water efficiency measures at CHP4 at 36.2 mn USD/yr.

Additional solutions which are expected to be able to contribute in closing the water gap were identified (see section 3.2). However, these solutions could not be included in the assessment framework due to a lack of data and were analysed in a qualitative manner. These include: grey water reuse in commercial and residential buildings, retrofitting appliances and behavioural change, on-site industrial wastewater treatment and reuse, industrial water efficiency measures and conveyance of treated wastewater to upstream water source locations.

Next Steps

The following next steps are recommended:

- The hydro-economic analysis showed that the size of the water gap requires very different sets of measures as response to close it. Thus greater certainty is required before decisions on next steps are be made. This certainty can be gained by a further validation of water demand; future yields of current water supply bore fields and usage of surface water which was beyond this project's scope.
- Currently, there is no regulatory provision to allow for reuse of treated wastewater, nor are there incentives for users to reuse treated wastewater. To enable treated wastewater reuse, a clear recycling and treated wastewater reuse policy, a legal and regulatory framework following a risk management approach, a sound and integrative strategy for reusing water and wastewater, good state of sewerage and wastewater treatment infrastructure as well as incentive and financing arrangements are required.
- Further assessments are required/ final outcomes of feasibility studies need to be awaited to gain a full picture of the potential of water efficiency measures at Combined Heat and Power Plants (CHPs), and Tuul Water Complex, reusing treated wastewater for CHPs and industrial water usage, grey water reuse at commercial and residential buildings and retrofitting of appliances.
- Even after all identified potential uses for treated wastewater, 81 mn m³/year would remain unused. Subject to downstream water requirements, options of conveying this water upstream for storage and reuse could be further explored and integrated into the relevant strategy documents, such as the Tuul Integrated Water Management Plan.
- With respect to mobilising finances, Public-Private-Partnerships (PPPs) are at a very nascent stage in Mongolia. Given the acceptance of the Mongolian government to use PPPs as a financing modality, the development, and with it the executing office UBDC, should be supported. Further, activities should be closely coordinated with active donor agencies, such as the Millennium Challenge Corporation which is currently developing a substantial donor programme in the area of water in Ulaanbaatar.

[1] All costs are indicated in Equivalent Annual Costs (EAC)

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AUTHORS

Ranen Banerjee (PwC India)
Jennifer Möller-Gulland (PwC India)
Chris Fawcett (Amec Foster Wheeler)
Graham Smith (Groundwater Solutions)
Gonzalo Delacámara (IMDEA/ Amec Foster Wheeler)
Baasandorj Lkhagvadorj (PwC Mongolia)
Enkhjin Bayarsaikhan (PwC Mongolia)
Ilona Kirhensteine (Amec Foster Wheeler)
Elena Gil Aunon (Amec Foster Wheeler)
Nithin Sreenivas (PwC India)

CONTRIBUTORS

Dr. Dorjsuren Dechinlkhundev (2030 Water Resources Group)
Christoph Jakob (2030 Water Resources Group)
Rochi Khemka (2030 Water Resources Group)
Contributors from stakeholder consultations

ACRONYMS

2030 WRG	The 2030 Water Resources Group
ADB	Asian Development Bank
AFW	Amec Foster Wheeler
AR	Artificial Recharge
ASR	Aquifer Storage and Recovery
AUSAID	Australian Agency for International Development
BAT	Best Available Technologies
BPCA	Battery Park City Authority
BT	Built Transfer
BWSSB	Bangalore Water Supply & Sewerage Board
CE ratio	Cost Effectiveness ratio
CFB	Circulating fluidised bed
Chalco	Aluminium Corporation of China
CHP	Combined Heat and Power Plants
CTB	Coal to Briquette
CTC	Community Transmission Centre
CTL	Coal to Liquid
CWWTP	Central Wastewater Treatment Plant
Deltares	Stichting Deltares
EAC	Equivalent Annual Cost
EBRD	European Bank of Reconstruction and Development
GWS	Groundwater Solutions
HoB	Heat Only Boiler
IBRD	The International Bank for Reconstruction and Development
IC	Incremental costs
IFC	International Finance Corporation
IWMP	Integrated Water Management Plan
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
KTNP	Khatan Tuul National Program
LEED	Leadership in Energy and Environmental Design
MAR	Managing Aquifer Recharge
MCUD	Ministry of Construction and Urban Development
MEGDT	Ministry of Environment, Green Development and Tourism
MINIS	Mining Infrastructure Investment Support Project
MoE	Ministry of Energy
MRAM	Mineral Resource Authority of Mongolia
MWRA	the Massachusetts Water Resource Authority
NRW	Non-Revenue Water

NWP	the National Water Program
OSNAAUG	Housing and Public Utilities Authority of Ulaanbaatar City
OTIA	Oyu Tolgoi Investment Agreement
PPP	Public-Private-Partnership
PwC	PricewaterhouseCoopers
SDC	Swiss Agency for Development and Cooperation
SEFIL	Strategic Entities Foreign Investment Law
SGR	Southern Gobi Region
STP	Sewage Treatment Plant
TC	Total Costs
TNC	the Nature Conservancy
TPP	Thermal Power Plants
UBDC	Ulaanbaatar City Development
UBDS	Ulaanbaatar City Heating Company
USUG	Ulaanbaatar Water Supply and Sewerage Authority
WWTP	Wastewater Treatment Plants

WEIGHTS AND MEASURES

◦C	Degree centigrade
km	kilometres
kWh	kilowatt hours
l	litre
lpcd	litre per capita per day
m	meter
m^3/day	meter cube per day
m^3/hr	meter cube per hour
m^3/yr	meter cube per year
mg/l	milligram per litre
mn	million
kW.hr	kilo watt hour
sqm	square meter
MNT	Mongolian Tugrik
MW	megawatt
MWh	megawatt hours
USD	United States Dollars

1. Setting the scene

The **2030 Water Resources Group** (2030 WRG) is a public-private-expert-civil society partnership and a platform for collaboration, helping governments to initiate and catalyse reforms designed to ensure sustainable water resources management in order to support long-term development and economic growth. The 2030 WRG supports sustainable water sector transformation by mobilising a wide range of key stakeholders, and providing comprehensive water resources analyses, understandable to both politicians and business leaders.

A memorandum of understanding was signed between the Government of Mongolia and 2030 WRG on 16 September, 2013. To gain more insight into Mongolia's water resource challenges, a consulting project for a '*Targeted Analysis on Water Resources Management Issues in Mongolia*' was commissioned to an international team of PricewaterhouseCoopers (PwC) India, Mongolia and Germany as well as Stichting Deltares (Deltares). Since then, a concrete work plan has been developed with the Ministry of Environment and Green Development.

Three regions – Tavan Tolgoi, Nyalga Shivee Ovoo and Ulaanbaatar – have been identified as hotspots in which targeted action is required to enable sustainable economic development, while considering social and environmental needs. To understand the extent of the local challenges, as well as to determine and prioritise solutions to close the water gap, this study was commissioned to the international team of PwC India, PwC Mongolia, Amec Foster Wheeler (AFW) and Groundwater Solutions (GWS).

1.1. Objective & approach

This analysis focusses on Ulaanbaatar. Building on the water supply demand gap identified in the previous 2030WRG PwC/Deltares study[2], the objective of this analysis is to identify and prioritise water demand and supply interventions as solutions to close this gap. A further objective is recommendations on implementation of the prioritised solutions.

The study area is the same as in the *Targeted Analysis on Mongolia's Water Challenges (*Phase 1 of the 2030 WRG work). Specifically, this implies that all upstream areas of the Tuul River Basin and partial midstream areas will be included in the analysis (see Table 1). Please see the Tuul Water Basin Integrated Water Management Plan for more details on area delineation of the sub-basins. [3]

Table 1 Overview of sub-basins included in the analysis

Sub-basin	Aimag	Soum
Upstream part	Tuv	Erdene | Tuv
Upstream part	Tuv	Bayandelger | Tuv
Upstream part	Ulaanbaatar	Nalaykh | Ulaanbaatar
Midstream part	Ulaanbaatar	Ulaanbaatar | Ulaanbaatar
Midstream part	Tuv	Erdene | Tuv

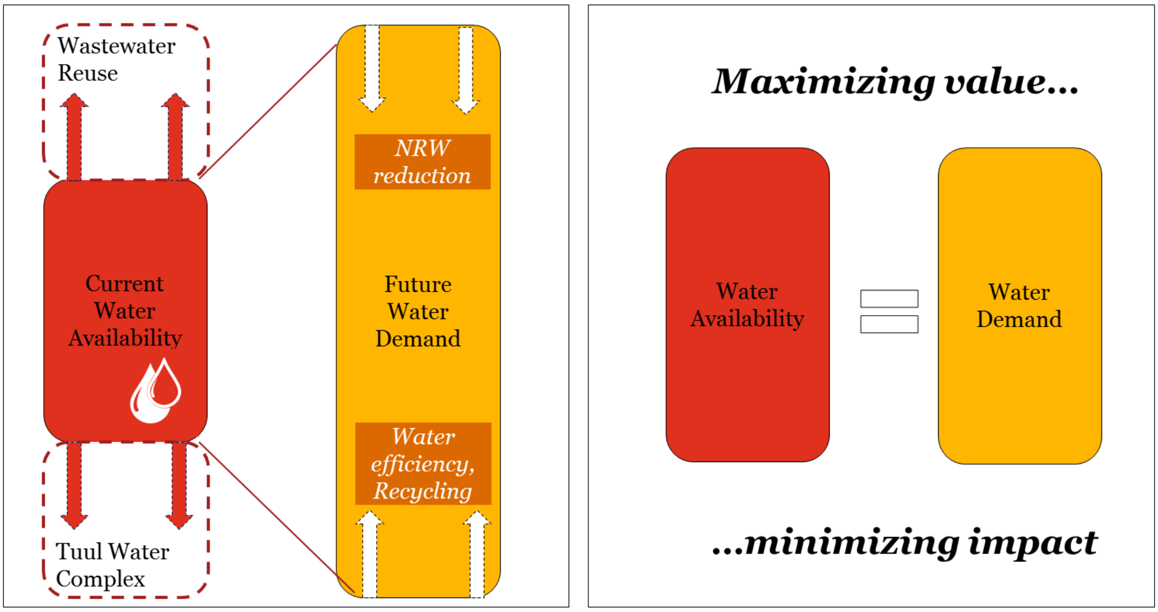
For this analysis, the following steps were followed:

1. **Understanding the future water supply-demand gap:** To allow for a more differentiated understanding on the future water supply-demand gap, water demand was estimated for three scenarios, namely low, medium and high demand until 2030 (see chapter 2).
2. **Identification of an inventory of solutions:** As Figure 2 shows, measures include water demand reduction and water supply augmentation solutions that were selected from the ongoing (governmental) programmes, plans and projects, such as the Implementation Plan of Ulaanbaatar City Master Plan 2030

[2] PwC/ Deltares (2014) Targeted Analysis of Mongolia's water challenges. 2030 Water Resources Group.
[3] MEGDT (2012) Integrated Water Management Plan of Tuul River Basin, accessible at http://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiN8bjb4-DNAhVJmZQKHVGDA5gQFggiMAA&url=http%3A%2F%2Fwww.tuulgol.mn%2Findex.php%2Fe-library%2Fdoc_download%2F41-tuul-river-basin-integrated-water-managemnet-plan&usg=AFQjCNG3czxtotG6qAXn6L6nVJwJYk_4Dg&sig2=nP0mrLJtYj0eJR-RWmmB8Q

(see section 1.2). In addition, challenges and areas of improvement were identified during targeted stakeholder consultations. Where required, international best cases were drawn upon to transfer potential solutions to the context in Ulaanbaatar (see Chapter 3.1 and Chapter 3.2).

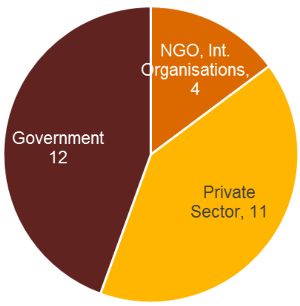
Figure 2 High level objective of the study



3. **Prioritisation of solutions based on comprehensive evaluation framework:** The identified solutions were analysed with respect to financial, economic and environmental criteria on the basis of which the solutions were prioritised (see chapter 3). Some solutions could not be included in the assessment framework due to a lack of data. Due to their deemed high potential to contribute to closing the water gap in future, these were detailed in a qualitative manner.
4. **Recommendations for implementing prioritised solutions:** Following the stakeholder consultations and secondary literature review, areas of action and required (institutional) changes are identified to allow for the implementation of the prioritised solutions (see chapters 5 and 4).

Stakeholder engagement was a key component of this project, including an interactive kick-off meeting; focus group discussions for private sector and NGOs as well 27 face-to-face interviews (see Figure 3 and Annex A.1).

Figure 3 Overview of stakeholders interviewed



1.2. Ongoing initiatives and programmes

Key documents with measures to address water challenges faced by Ulaanbaatar city, and approved by the Government of Mongolia include the following: Integrated Water Management Plan of Tuul River Basin (2012), Implementation Plan of National Water Program (2010), Implementation Plan of Khatan Tuul National Program (2012), Ulaanbaatar 2020 Master Plan and Development Approaches for 2030 (2013), and Implementation Plan of Master Plan 2030 (2016).

1.2.1. Tuul Integrated Water Management Plan

The Tuul river basin Integrated Water Management Plan (IWMP) was published within the framework of "Strengthening Integrated Water Resources Management in Mongolia" programme funded by the Government of the Kingdom of the Netherlands at Ministry of Environment and Green Development of Mongolia. The programme identified bottlenecks and barriers to achieving the water related ecosystems with a rich biodiversity that sustains the support of socio-economic developments in the country by the year 2025. The Tuul river basin IWMP document defined 55 measures to be implemented between 2012 – 2021 which cover water resource management, water accessibility and sanitation issues.

1.2.2. National Water Program (& Khatan Tuul National Program)

The National Water Program (NWP) and Khatan Tuul National Program (KTNP) were both initiated by the National Water Committee. The NWP and its implementation roadmap consists of 98 clusters of conceptual activities – regarding environmental protection, water quality monitoring, water supply and sanitation, and wastewater treatment technology improvements – to be implemented on a national level. The KTNP is focused on Tuul river basin, and is a sub-programme of NWP. The Implementation plan of KTNP includes 8 clusters of conceptual activities around water supply, environmental protection, water quality monitoring, wastewater treatment technology upgrade, and re-use of treated wastewater.

1.2.1. Ulaanbaatar 2020 Master Plan and Development Approaches for 2030/ Implementation Plan 2030[4]

The key measures suggested in Tuul river basin IWMP, NWP, and TNP documents were summarised in the Ulaanbaatar 2020 Master Plan and Development Approaches for 2030 (Master Plan 2030). The four volumes of the Master Plan 2030 were published by Capital City Master Planning Agency, and provide comprehensive coverage of the city's background and technical details, including engineering design of infrastructures such as water supply and sanitation networks. The Master Plan 2030 underwent a considerable update since 2013, and the Implementation Plan of Master Plan 2030 was approved by the State Great Khural in March 2016. Mentionable updates include cancellation of decentralised wastewater treatment plants (WWTP) planned in Selbe and Bayankhoshuu areas and include a new centralised wastewater treatment plant (CWWTP). The Implementation Plan reduced the 18 water supply, sanitation, and infrastructure measures down to 5 concrete plans to address water issues in Ulaanbaatar city; it acts as an umbrella across other initiatives for key activities.

[4] Ulaanbaatar 2020 Master Plan and Development Approaches for 2030 - Implementation Plan /Project 2016.03/ Capital city governor's office and approved by Government of Mongolia (2016)

The table below shows the full list of water (5 measures) and heat (2 measures) infrastructure related measures listed in the Implementation Plan of Master Plan 2030.

Project name	Implementing Agency	Investment cost (mn MNT)	Source of financing	Category	Description	Status (as enquired from UB City Governor's office)
Engineering design of Expansion of CWWTP	USUG with the Ministry of Construction and Urban Development (MCUD), UB city mayor's office	580,000	National budget, Capital city budget, other	water supply and sewerage	Current capacity is of CWWTP is 170,000 m³/day. Following are planned: 1. Technology upgrade 2. Construction of additional 250,000 m³/day module 3. Sludge processing plant	Feasibility study is complete. Engineering design in progress.
Expansion of CWWTP			loan, other			Searching for financing sources.
Tuul Water Complex	USUG with MCUD, MEGDT, UB governor's office	552,000	National budget, Capital city budget, other	water supply and sewerage	1. Fresh water reservoir: 405.4 mn m³ of volume 2. Hydro-power plant: 7.4 MW (total energy produced per year: 43.1 mn kW.hr)	Feasibility study is complete. Engineering design in progress.
Trenchless relining of aged pipelines	MCUD, UB city governor's office	15,200	Other, foreign loan	water supply and sewerage	43.7 km pipeline relining using Austrian technology. Goal is to improve water quality.	Contracts pending to be signed by the new Government. Work is expected to start in Sept. 2016.
Connecting freshwater reservoirs	MCUD, UB city governor's office	26,955	National budget	water supply and sewerage	1. Construction of 12 km pipeline that will connect West, 3-4 District, Tasgan, Northeast reservoirs. 2. Expansion of Northeast reservoir by additional 18,000 m3.	Engineering design is completed. Searching for financing sources.
Exploration of water supply resources in Bagakhangai District	MEGDT with UB city governor's office	650	Capital city budget	water supply and sewerage	Exploration of water supply source within 40 km radius from Bagakhangai district.	Project has not started yet, as of Jul 2016.
Central heating network upgrade	MoE with UB city Governor's office	36,016	National budget, Capital city budget, other	heat supply	Upgrade of main heating network lines, increase the diameters and construct new pump stations.	In progress.
Networks within apartment complexes	UB city Governor's office	15,045	Capital city budget	heat supply	Upgrade and replacement of network within apartment complexes.	In progress.

2. Ulaanbaatar's water resource management challenges

2.1. The water resources situation

2.1.1. Water supply

To date, Ulaanbaatar's water supply relies exclusively on groundwater. Surface water resources from Tuul River remain unused till date due to higher water treatment costs and lack of a distribution system. Groundwater is sourced from seven bore well fields across the city (see Table 31 in Annex A.2) and amounts to 104 mn m3/yr.[5] Surface water is considered after deducting required environmental flows (see Table 30 in Annex A.2). [6] As Table 2 below shows, total water resources amount to 120 mn m3/yr.

Table 2 Overview of available water resources in Ulaanbaatar

	mn m3/yr	% total
Groundwater	104	86%
Surface water	16	14%
Total	120	

Source: Water Reserve Committee Resolution No. 2015/4 approved by Munkh-Erdem, Head of Water reserve committee, MEGDT, 7 September 2015 & MEGD (2013) Integrated Water Management Plan of Mongolia for estimates for surface water
Note: Only groundwater reserves of category A, B and C were considered. A further reserve in Ganchuurt region of 1.43 mn m3/yr in category P has been excluded as further verification is required.

The water supply service for Ulaanbaatar city is the responsibility of Ulaanbaatar Water Supply and Sewerage Authority (USUG) and the Housing and Public Utilities Authority of Ulaanbaatar City (OSNAAUG) and comprises of both piped network and trucked services. Mostly all commercial buildings and apartments have piped water connections, Gher residents are supplied either through piped supply or trucked supply both through kiosks. USUG maintains the central water supply and wastewater network, with which it supplies OSNAAUG and some bulk users, such as selected industries, directly. OSNAAUG further maintains the water supply and wastewater network through more than 170 Community Transmission Centres (CTCs) to service apartments, industries and other water users. Virtually, all industries are connected to either the USUG or OSNAAUG network, while some industries abstract groundwater also via private wells. Between November and June, all industries are dependent on water from the distribution networks as groundwater levels fall to 7 m below surface (net fall of 4 m), which is out of reach for their wells.[7]

USUG is a public company owned by the Ulaanbaatar city, which was established based on the "Law on State and Local Property" with a mission to manage the operation and maintenance of water supply and wastewater, including the wastewater treatment plants in the city. This includes, identifying the sources of supply and extracting water, treating it to the desired quality levels, storing and pumping the water in the main water supply network of the city. USUG provides 150,000 m^3/ day of fresh water; 100% of the connections are metered. The water supply network is 540 km long, excluding branch pipelines[8]. The network will be extended by 200 km to increase access to un-serviced areas. USUG reduced its non-revenue water (NRW) from 21% in 2011 to 14% in 2015.[9] The underlying causes for USUG's NRW include:

- Leakage in the truck lines owing to very old pipelines

[5] In the first phase of this project, groundwater data was taken from MEGD (2012) Integrated Water Management Plan of Mongolia. The update of the groundwater estimates from the Water Reserve Committee Resolution No .2015/4 results decreased available groundwater from 138.3 mn m^3/yr to 103.62 mn m^3/yr
[6]
[7] Interview with Mr Batsukh (Chief Engineer, USUG) on 7 April 2016
[8] Interview with Mr Batsukh (Chief Engineer, USUG) on 7 April 2016
[9] As per interview with Mr Batsukh (Chief Engineer, USUG) on 7 April 2016. The NRW of 21% in 2011 is also quoted by the IB Network. However, the JICA report (2013) Strategic Planning of Water Supply and Sewerage Services in Ulaanbaatar quotes a NRW ratio of 39% for USUG in 2011. Further data verification is recommended.

- Leakage between USUG and OSNAAUG networks– there are meters installed at sub-stations which measure the quantum of water supplied to OSNAAUG
- Illegal connections from the main network
- Unpaid bills (while 99 % users are paying bills and it included industries and water kiosks)

OSNAAUG is a public company owned by the Ulaanbaatar City. Twenty entities comprising branches and outsourced contractors are in charge of providing services to customers and OSNAAUG is responsible for managing and supporting their service provision as a headquarter organisation. OSNAAUG further distributes heat, water (cold and hot) from USUG and receives wastewater from apartment buildings and industries. OSNAAUG has 143 pumping stations and 300 substations, serving 92,539 households and 8,000 businesses. It receives 60,000 m^3/d of water from USUG with which it supplies 70% of all households in Ulaanbaatar, the remaining are directly supplied by USUG. Of all connections, approximately 67% are metered. The remaining 33% of water users either choose not to have a meter, as the meter needs to be paid by the user itself and the water tariff changes from monthly lump sum payments to actual water usage, or the installation is technically too difficult due to old infrastructure. NRW is calculated based on billed water amounts and ranges between 6.5%-10%. No actual measurements have taken place. Since 1995/96 the network has been reportedly continuously improved reducing NRW from 50% to current rates of between 6.5%-10% by:

- Upgrading pumps
- Installation of variable (demand-based) stations (KOICA project)
- Increase in metered connections to 67.4%.
- Installation of pressure regulators

OSNAAUG's tariff collection rate amounts to 80%. The remaining 20% are understood to be too poor to pay. Average per capita water usage amounts to 100-120 lpcd for metered connections and to 160 lpcd on average for the entire network. The high discrepancy between the average water usages was explained by OSNAAUG that they assume that more people than registered at OSNAAUG per apartment use one water connection (to save the water tariff). [10]

In total 7.22 mn m^3/yr are not metered. As NRW is not measured but calculated based on billed water quantities and as the exact number of people in each household are unknown there is no certainty if high average per capita. Water consumption is due to physical system losses or water consumption. Abstracting the calculated NRW 1.4 -2.2 mn m^3/yr from the unmetered water volumes, the usage of a total of 5 mn m^3/yr is uncertain and could be lost via additional (unknown) leakages or caused by high per capita water usage.

Water and wastewater tariffs are charged by USUG and OSNAAUG (see Table 3 and Table 4 below). In addition to these tariffs, a monthly base tariff applies (see Annex A.1). If water is abstracted directly, other tariffs apply (see Annex A.1).

Table 3 Clean water tariffs charged by USUG and OSNAAUG

Provider	Service type	Unit	Price MNT (excl. VAT)	Price USD (excl. VAT)
USUG/ OSNAAUG	Household – Metered	1 m3	500	0.25
USUG	Household – Unmetered	1 person	6,500	3.26
OSNAAUG	Household – Unmetered	1 person	4,485	2.25
USUG/ OSNAAUG	Factory, business, offices	1 m^3	950	0.48
USUG/ OSNAAUG	Beverage factories	1 m^3	1250	0.63
USUG/ OSNAAUG	Wool, cashmere, tannery, gut processing	1 m^3	950	0.48

[10] Interview with Mr. Tsendendamba (Head of Technology Department, OSNAAUG) on 13 April 2016.

Source: Data provided by USUG and OSNAAUG

Table 4 Wastewater tariffs charged by USUG and OSNAAUG

Provider	Service type	Unit	Price MNT (excl. VAT)	Price USD (excl. VAT)
USUG/ OSNAAUG	Household – Metered	1 m^3	310	0.16
USUG	Household – Unmetered	1 person	350	0.18
OSNAAUG	Household – Unmetered	1 person	2,415	1.21
OSNAAUG	Factory, business, offices	1 m^3	720	0.36
USUG	Factory, business, offices	1 m^3	750	0.38
USUG/ OSNAAUG	Beverage factories	1 m^3	960	0.48
USUG/ OSNAAUG	Wool, cashmere, tannery, gut processing	1 m^3	1,500	0.75

Source: Data provided by USUG and OSNAAUG

2.1.2. Water pollution & wastewater treatment

Ulaanbaatar has one Central Wastewater Treatment Plant (CWWTP), with a design capacity of 230,000 m^3/day. Average daily inflow amounted to 159,000 m^3/day in 2014, with maximum daily flows of 180,000 m^3/day. While the exact share of industrial effluent of total influent to the CWWPT is unknown, total water sales can be used as a proxy. Approximately 7% of USUG's and OSNAAUG's combined water sales account for industrial water. [11]However, it needs to be considered that some industries also use water from private wells, and that certain amounts of water are embedded in the final product.

The CWWTP has been operating since 1964. Despite partial reconstruction and renewal, overall operation of the CWWTP has deteriorated. In addition, while incoming effluent quantity lies within design parameters, incoming effluent quality has surpassed what the CWWTP can effectively treat (see Table 5).

Table 5: CWWTP influent and effluent water quality (2014)

Pollution Parameters		2014				
		Design Parameters for existing CWWTP	Inlet		Outlet	National Standard (MNS 4043-2011)
			Industrial	Domestic		
SS	mg/l	250	976	851	132	50
COD	mg/l	600	1,390	1,562	406	50
BOD	mg/l	250	546	635	169	2
NH4	mg/l	-	44	52	34	6
TP	mg/l	-	4.0	7.2	3.0	1.5
Total Cr	mg/l	-	0.7	0.9	0.3	0.3

Source: Artelia (2015) Feasibility study Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG-14/0221

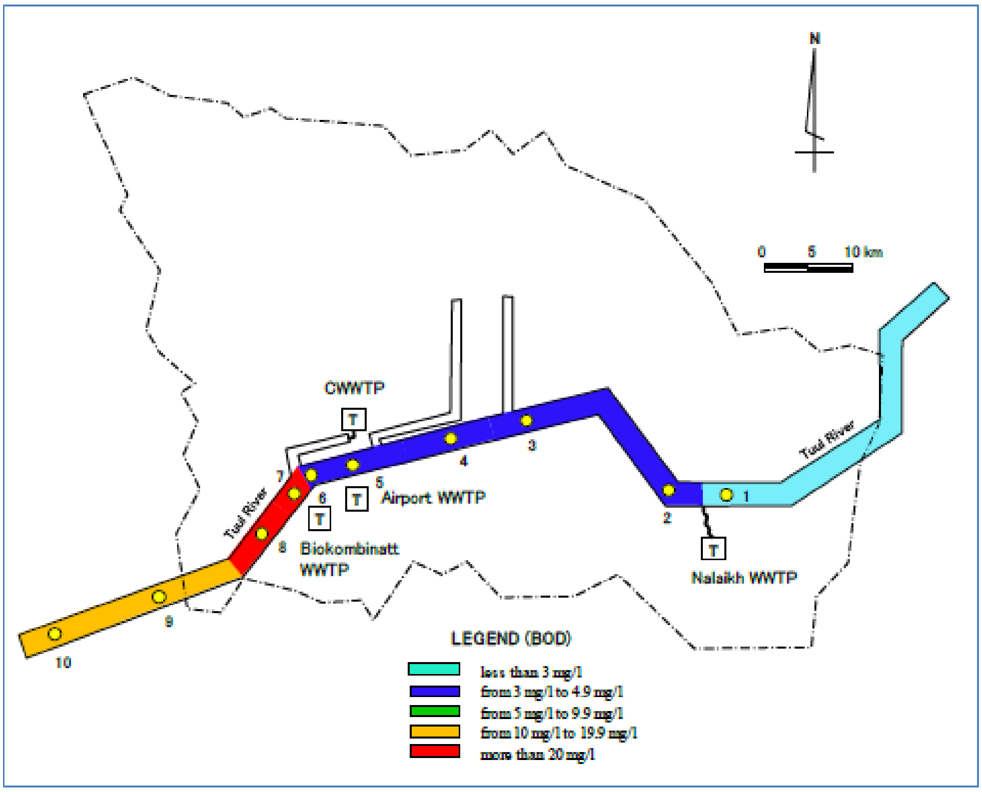
The pollutant concentrations between 2013 and 2015 have rapidly increased, and are assumed to come mostly from industrial wastewater. [12] As per regulation MNS-6561, polluting industries are mandated to pre-treat the effluent to comply with quality standards outlined in order /11/05/A/18 prior to connecting it to the central sewerage system. The key polluting industries in Ulaanbaatar include the leather, tanning and wool processing industries. Most of the tannery industry is concentrated in Khargia. An industrial wastewater pre-treatment plant, Khargia wastewater treatment plant, operates in this area with a design capacity of 13,000 m^3/day. Average effluent inflows, however, are approximately 2,000 m3/day, with maximum inflows of 9,000 m^3/day during a few days when raw hides are delivered to the tanneries. The effluent treatment efficiency is very poor at Khargia Wastewater Treatment Plant and thus the effluent discharged into the central sewerage system does

[11] Artelia (2015) Feasibility study Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG-14/0221
[12] Artelia (2015) Feasibility study Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG-14/0221

not comply with Mongolian effluent treatment standards. Polluting industries which are not connected to Khargia Wastewater Treatment Plant are required to pre-treat their effluent before discharging it into the central sewerage system. Compliance, however, is low. Both factors result in too high pollution concentrations at CWWTP, impacting the treatment efficiency and rendering reuse of treated wastewater and sludge as not feasible. [13]

The discharge of treated wastewater to the environment, which does not meet Mongolian effluent quality standards, namely MNS4943:2011, continues to severely impact the water quality of Tuul River. Figure 4 shows that water quality instantly declines to BOD levels of 20 mg/l and more right after the CWWTP outlet.[14] Tuul River water continues to be severely polluted, approximately 200 km downstream.

Figure 4 Pollution levels of Tuul River



Source: USUG (published in TEC International Co., Ltd (2015) Ulaanbaatar Expansion Programme Feasibility Study. Final Report. Submitted to EBRD)

The construction of a new CWWTP with a capacity of 250,000 m^3/ day, is underway, with the feasibility study currently being completed. The old CWWTP shall be rehabilitated if the demand for wastewater treatment exceeds the treatment capacity of the new CWWTP. [15] The new CWWTP will be designed to treat effluents, domestic and industrial, up to tertiary level. Table 6 illustrates the targeted effluent quality standard for the new CWWTP.

Table 6 New CWWTP effluent discharge objectives

Parameters	Unit	Permissible maximum concentration
Water temperature	C	20
pH	-	6-9
Suspended solids (SS)	mg/l	60
Biochemical Oxygen Demand (BOD)	mg/l	20

[13] Artelia (2015) Feasibility study Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG-14/0221
[14] TEC International Co., Ltd (2015) Ulaanbaatar Expansion Programme Feasibility Study. Final Report. Submitted to EBRD
[15] Interview with Chief Engineer Batsukh (USUG) on 7 April 2016

Chemical Oxygen Demand (COD)	mg/l	50
Ammonia Nitrogen (NH4-N)	mg/l	6
Total Nitrogen (TN)	mg/l	15
Total Phosphorous (TP)	mg/l	1.5
Organic Phosphorous (DOP	mg/l	0.2

Source: Artelia (2015) Feasibility study Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG-14/0221

However, the feasibility study states that without sufficient pre-treatment of industrial wastewater even the new CWWTP will not be able to operate at design treatment efficiency. To address this problem, the tannery industry and selected wool industries shall be relocated to Emeelt Light Industrial Park, which is currently under construction. In Emeelt industrial effluents will be pre-treated at the planned WWTP (capacity of 4.2 mn m^3/yr) before being discharged to the central sewerage network. However, a strict industrial pollution control is required to be implemented also for industries outside of Emeelt Light Industrial Park to allow for efficient wastewater treatment at CWWTP and the potential to reuse treated wastewater and sludge.

An overview of all WWTPs in Ulaanbaatar, including their level of functionality can be found in Annex A.2.3.

2.2. The water demand situation

2.2.1. Current and projected water demand

Ulaanbaatar's water demand has been estimated for the base year in 2010 and forecasted for the years 2021 and 2030. To provide a more differentiated picture of the water demand situation, three scenarios were applied, namely for low, medium and high water demand.

Currently, there are two key sources for water demand estimates and forecasts for Ulaanbaatar, namely:

1. Tuul Water Basin Management Plan, which builds on data derived as part of the IWRM project [16]
2. Ulaanbaatar City Master Plan 2030, which builds on data from the JICA study[17]

Building on the first phase of this project, the Targeted Analysis of Ulaanbaatar's Water Resource Challenges, water demand estimates and forecasts from the IWRM project were chosen as this data source provides a detailed geographic and sectoral break-down which was required for the hydro-economic analysis in this study. From this source, water demand forecasts are available between 2010 and 2021. The sectoral growth rates from the JICA report were applied to forecast water demand between 2021 and 2030 (see Annex A.2.4)). As both studies use the year 2010 as a base year, it is recommended to update the water demand estimates to reflect current changes.

Figure 5 and Table 7 show Ulaanbaatar's water demand in 2010, 2021 and 2030 in all three scenarios. It becomes obvious that key water users are the domestic and energy sector. In 2010, the domestic sector utilised 51% of total water demand, in 2030 (high scenario), 37%. The energy sector requires 30% and 40% in the years 2010 and 2030 (high scenario) respectively. Industrial water usage amounts to 9% and 13% in the years 2010 and 2030 (high scenario) respectively. A more detailed sectoral overview can be found in Annex A.2.

[16] *"Strengthening Integrated Water Resources Management in Mongolia"* project which was implemented at the Water Authority with support from the Government of The Kingdom of the Netherlands (2008-2012). A key outcome of the project is the MEDGT (2012) Integrated water management assessment report.
[17] JICA report (2013) Strategic Planning of Water Supply and Sewerage Service in Ulaanbaatar

Figure 5 Water demand estimates 2010-2030 for low, medium and high water demand scenarios

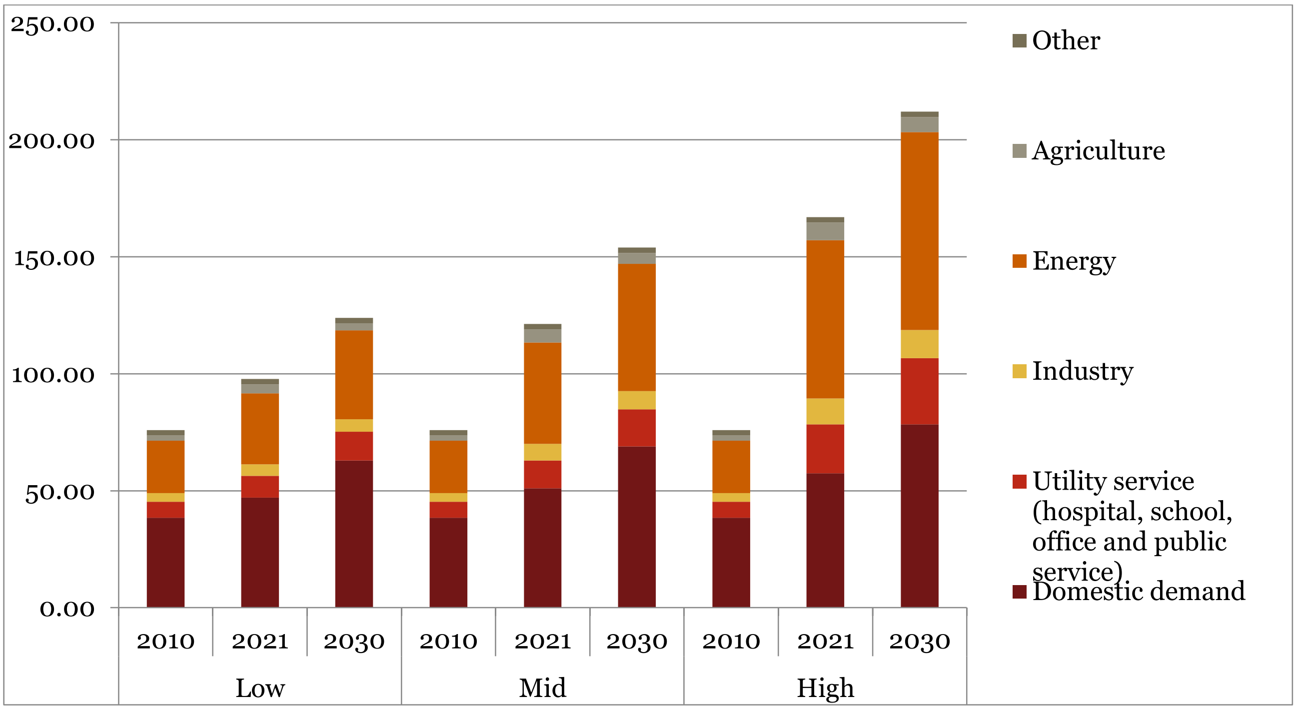


Table 7 Water demand estimates 2010-2030 for low, medium and high water demand scenarios

	Low			Mid			High		
mn m³/yr	2010	2021	2030	2010	2021	2030	2010	2021	2030
Domestic demand	38.40	47.04	62.90	38.40	51.08	68.97	38.40	57.40	78.37
Utility services	6.83	9.33	12.37	6.83	11.81	15.85	6.83	20.91	28.30
Industry	3.68	4.95	5.34	3.68	7.09	7.72	3.68	11.08	12.07
Energy	22.50	30.25	37.98	22.50	43.31	54.40	22.50	67.68	84.49
Agriculture	2.32	3.95	2.99	2.32	5.72	4.71	2.32	7.56	6.50
Other	2.20	2.25	2.25	2.20	2.25	2.25	2.20	2.25	2.25
Total	**75.93**	**97.77**	**123.84**	**75.93**	**121.27**	**153.90**	**75.93**	**166.90**	**211.99**

*Note: * Utility services include: hospital, school, office and public services*

For more details on the data underlying the gap, please see Annex A.2 and consult the report 2030WRG PwC/ Deltares (2014) "Targeted Analysis on Mongolia's water challenges".

2.2.2. Focus: Water demand in energy & heat generation

The energy sector requires 30% and 40% of total water demand in the years 2010 and 2030 (high scenario) respectively.

Energy, heat and hot water are currently supplied by three Combined Heat and Power Plants (CHPs), namely CHP2, CHP3 and CHP4. CHP2 and CHP3 have both been operating for approximately 40 years. The expected retirement periods of CHP2 and CHP3 were 2005 and 2011, respectively. However, due to lack of new heating sources, these two plants are still operating and the Ministry of Energy stated that there were no plans as of now to close these CHPs. [18] CHP4 is the biggest coal fired CHP plant in Mongolia and covers 70% of total electricity demand and 64% of total heat energy demand of the district heating system of Ulaanbaatar. The plant was built over 30 years ago and many upgrades and repairs have been done over recent years.

A new CHP, CHP5, is currently planned and estimated to be operational in November 2020. A 25 year concession agreement, under the Built-Own-Operate-Transfer scheme, was signed between the Government of Mongolia and the Consortium consisting of GDFSUEZ, Sojitz, POSCO Energy and Newcom. The technical feasibility study and conceptual design have been completed. With CHP5 located 16 km southeast of Ulaanbaatar, to date no definite, long-term water supply source has been identified. The Upper water source shall be used as interim solution, which is 50 km away from CHP5. [19]

Table 8 Overview of Combined Heat and Power Plants in Ulaanbaatar

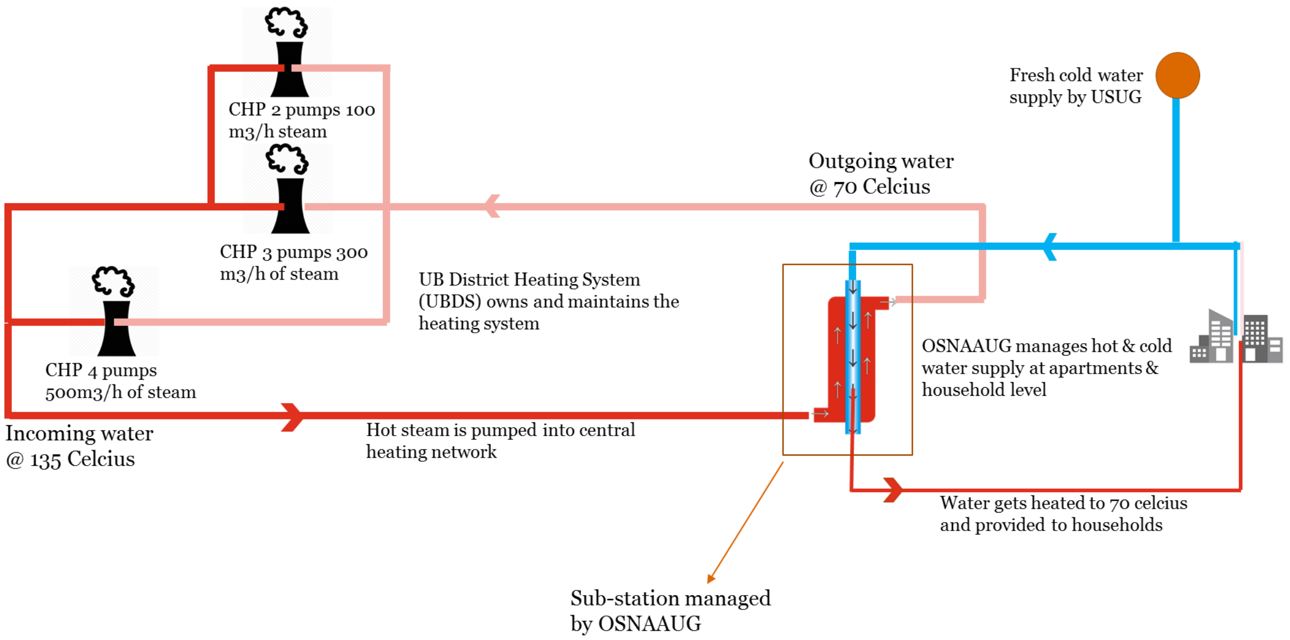
CHP Details	Ulaanbaatar V	Ulaanbaatar IV	Ulaanbaatar III	Ulaanbaatar II
Installed Capacity (MW)	450 MW	703 MW	186 MW	24 MW
Annual Power Generation (MWh)	3,055	3,550	1,000	148
Thermal Energy (Gcal)	3,000	3,517,204	2,168,878	178,145
Annual water demand (mn m³)	3	16,7	8.4	2.1
Water makeup for district heating (m³/day)	6,000	6,288	5,568	456
Hot water flow for district heating	8,200	12,000	8,000	740
Cooling System Type	Air/Dry Cooled	Wet Cooling	Wet Cooling	Wet Cooling

Addressing the increased need of heating in Ulaanbaatar, the Amalgan Heat Only Boiler (HoB) started operations in April 2015 and supplies heat to 50,000 households in the eastern and central part of Ulaanbaatar. Two more HoB plants are planned.[20]

The heating season lasts from 15th September to 15th May each year. Hot water is provided year round. Ulaanbaatar City Heating Company (UBDS) is responsible for the central heating grid and transfers heat from CHPs to OSNAAUG's pumping stations and sub-stations, as well as to other buildings (9,000 buildings). OSNAAUG has 143 stations across the city and has 300 sub-stations for receiving water and heat from USUG and UBDS. These sub-stations have heat exchanger at which the cold water will be heated to 70 °C and circulated to apartments. OSNAAUG supplies hot and cold water to 70% of residents of Ulaanbaatar. Heat is circulated in a closed loop system. Please see Figure 6 for more details.

[18] Interview with Ministry of Energy (11 April 2016)
[19] Tractebel Engineering GDF Suez (2015) CHP5 Project Technical Description
[20] ADB (2008) Mongolia Urban Development Sector – Evaluation Study.

Figure 6 Heat and hot water system in Ulaanbaatar



Source: PwC, Stakeholder interviews

UBDS owns 380 km long heating network, of which 280 km long is central heating. The total length of Ulaanbaatar's heating network is about 500 km long (including customers' own networks, such as OSNAAUG network). Within OSNAAUG, heat losses are estimated at around 20-25%, mostly owing to the older network lines. The losses, however, are calculated based on heat expenditure and are not measured, thus losses could be potentially higher.

To maintain the pressure in the distribution system, the amount of water re-circulating needs to remain constant. In winter 350-400 m^3/hr of make-up water is required, in summer 120-220 m^3/hr. The water loss is mainly due to:[21]

- Pipe leakage
- Illegal connections to heating network
- Improper use of heating pipes, e.g. some households without hot water supply withdraw hot water from the radiators to use for cleaning, some households with cool/warm radiators connect their radiator (central) to its sewage for hotter radiators. This is estimated to account for 5-10% of total make-up water required.

Ulaanbaatar City is implementing measure to reduce heat loss at household level, e.g. old apartments are being lined from outside. UBDS and Ulaanbaatar City are also performing annual improvement measures, replacing old and aging pipes, to reduce heat and water losses.

The water demand data for the energy sector requires an update. As of now, no information on water demand for the Amgalan HoB was available, nor for the two additionally planned HoB plants. The water demand estimates used in this study are expected to be too high, since publication of the water data provided in the Tuul Integrated Water Management Plan (MEGDT, 2012) changes impacting the water demand estimates have taken place. [22]In addition to CHPs, there is a Heat-only-boiler ("Amgalan HOB)) in operation since 2015. According to an ADB report, two more are planned. However, the Ministry of Energy has no information on these. The given uncertainties around additional water uses around energy prevented us from exchanging actual water demand data for CHPs with given data. However, this is an area which requires more insights in the future.

[21] Interview with UBDS (14 April 2016)

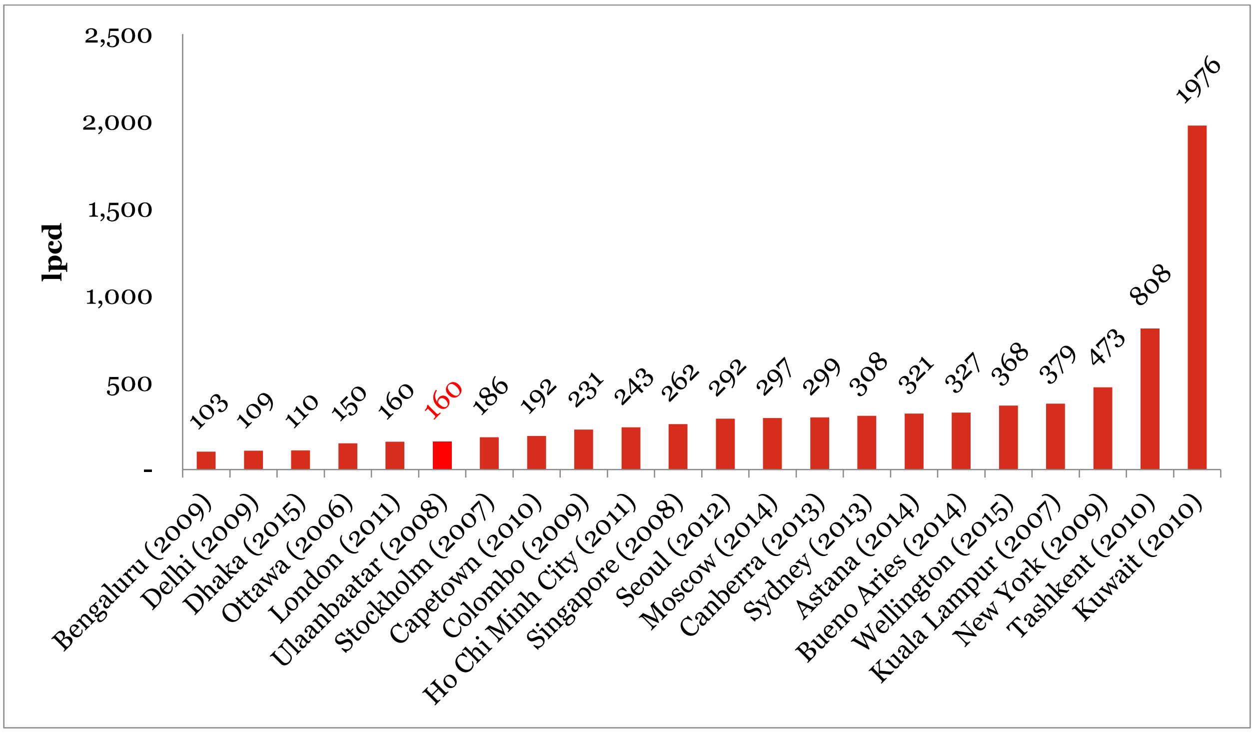
22 These include changes in CHP5 technologies from wet to air cooled and the expansion and renovation of CHP#4. The extent of the reduced water demand requires verification. The energy estimates in the MEGDT (2012) Tuul Integrated Water Management Plan seem too high. We assume this to be driven by changes occurring after publication, such as changes in CHP5 technologies from wet to air cooled and the expansion and renovation of CHP#4 (however, the impact on water resources is uncertain).

2.2.3. Focus: Domestic water usage

As described in chapter 2.1 of this report, USUG and OSNAAUG are responsible for the provision of public drinking water.

Per capita water usage across all apartments amounts to 160 lpcd, whereas metered apartments have a lower water usage per capita amounting to 100-120 lpcd. Figure 7 shows that the per capita daily water consumption in international comparison among other cities, is relatively low, with values for Moscow and Astana being roughly double that of Ulaanbaatar. The average water consumption of the Ger area[23] residents using water from kiosks is estimated at 5 to 10 litres per person per day, which is below the minimum consumption levels as recommended by the World Health Organisation.

Figure 7 Per capita daily water consumption for selected cities



The estimated and forecasted water demand for apartment and Ger areas is illustrated in Table 9 below.

Table 9 Estimated and forecasted domestic water demand

	Low			Medium			High		
Mn m3/yr	2010	2021	2030	2010	2021	2030	2010	2021	2030
Apartments	36.71	44.96	60.84	36.71	47.56	66.73	36.71	53.77	75.57
Ger areas	1.70	2.08	2.06	1.70	3.53	2.24	1.70	3.63	2.80
Domestic demand total	**38.40**	**47.04**	**62.90**	**38.40**	**51.08**	**68.97**	**38.40**	**57.40**	**78.37**

Note: the % allocation of water demand between apartments and gher areas as well as their growth rates between 2021 and 2030 is based on the JICA (2013) report, which provides the underlying data for the UB City Master Plan 2030.

2.2.4. Focus: Industrial water usage

Industries in Ulaanbaatar are mostly scattered around the city. There are some industrial areas in the districts of Khan-Uul, Bayanzurkh and Songinokhairkhan. Further, an industrial park is currently being planned, the Emeelt Light Industrial Park, which is intended mostly for the tanning, cashmere and wool industries.

[23] Ger is the traditional, tent-like dwelling of the nomads in Mongolia. Ger areas are peri-urban communities located in the outlying districts of major cities. These areas tend to be comprised of thousands of small, fenced-in plots of land, and remain isolated from the main commercial activity and public services.

Industrial water usage amounts to 9% and 13% of total water usage in the years 2010 and 2030 (high scenario) respectively.

Within industrial water demand, the light industry has the highest water consumption (81% in 2010). Light industry is composed of the food industry, as well as of leather, cashmere and wool processing factories. Heavy industry and construction and its materials industry amounted to 8% and 11% respectively in 2010.

71% of the total industrial water demand is estimated to come from non-food related industrial processes. The potential of substituting this amount with treated wastewater is explored in later sections of this report.

Table 10 Estimated and projected industrial water demand

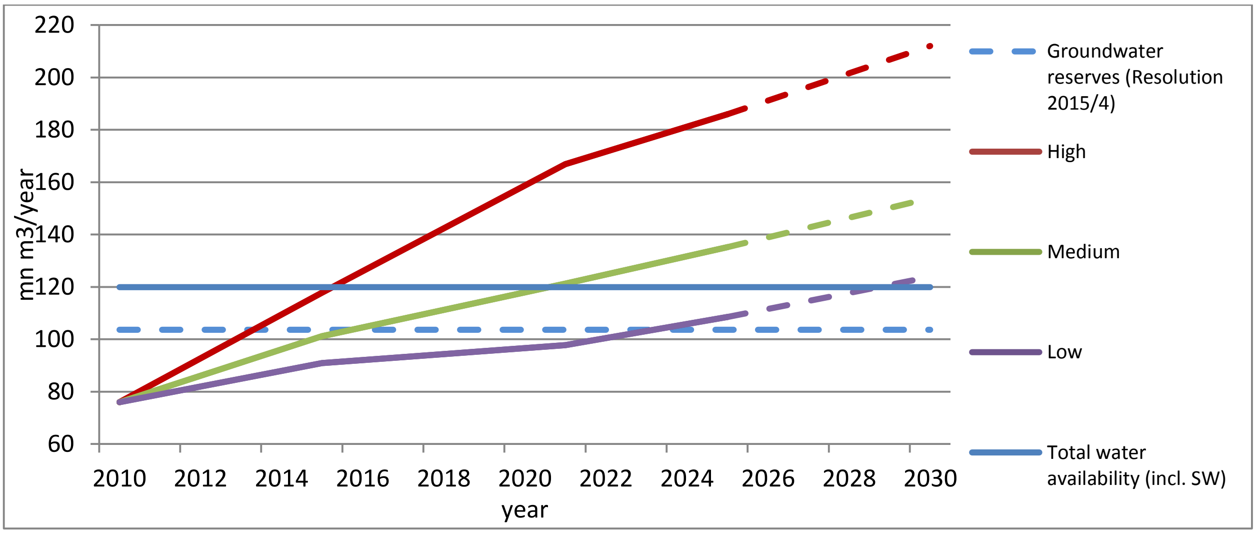
	Low			Mid			High		
Mn m3/yr	2010	2021	2030	2010	2021	2030	2010	2021	2030
Light industry	2.99	4.02	4.34	2.99	5.75	6.27	2.99	8.99	9.80
Heavy industry	0.30	0.40	0.44	0.30	0.58	0.63	0.30	0.90	0.98
Construction and its material industry	0.39	0.53	0.57	0.39	0.76	0.83	0.39	1.18	1.29
Industry total	***3.68***	***4.95***	***5.34***	***3.68***	***7.09***	***7.72***	***3.68***	***11.08***	***12.07***
Non-food industry subtotal	*2.63*	*3.59*	*3.62*	*2.63*	*5.41*	*5.59*	*2.63*	*8.76*	*9.13*

Note: Non-food industrial sub-total was derived from the %share of water demand from food industry over total water demand, as stated in the Ulaanbaatar Implementation Plan of UB Master Plan (see Table 40 *in Annex 2). The share of food industry over total water demand is estimated as 1.39% in 2030. Non-food industry comprises of non-food light industry, heavy industry and construction and its material industry. Water demand from energy is kept as a separate item.*

2.3. Water supply-demand gap

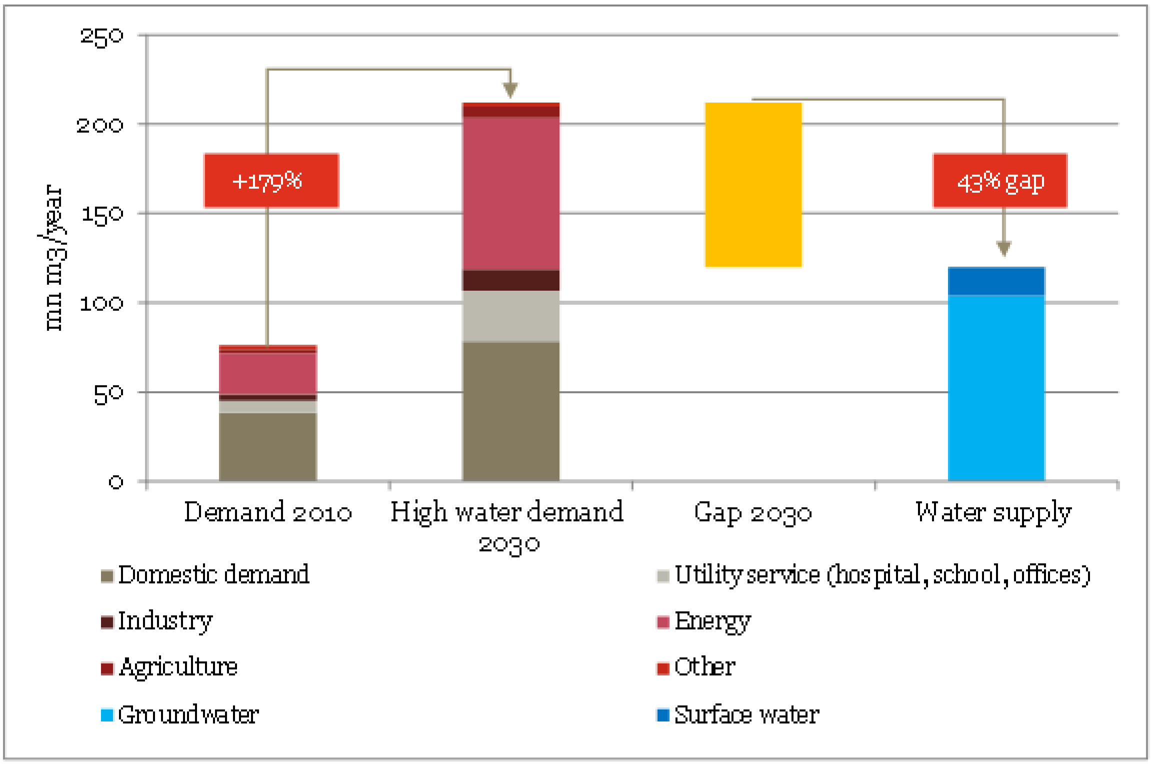
When contrasting the water demand estimates for the low, medium and high water demand scenarios with the available groundwater and surface water resources, it becomes apparent that a water gap is estimated in the high and medium water demand scenario as early as in 2021. However, it needs to be considered that, to date, surface water resources are not utilised. If groundwater remains the sole water resource, then the water gap will occur sooner (see Figure 8).

Figure 8 Water supply demand gap across three water demand scenarios (2010-2030)



By 2030, it is estimated that water supplies are insufficient to meet water demand across all water demand scenarios. In the low and medium water demand scenarios, 3% (4 mn m³/yr) and 28% (34 mn m³/yr) of total water demand respectively are estimated to not be met with given water supplies by 2030. In the high water demand scenario, even 43% of total water demand (92 mn m3/yr) is estimated to not be met with given supplies by 2030 (see Figure 9). Based on the water demand allocation, the key areas of intervention are energy, domestic and non-food industrial water demand. Energy water demand comprises 40% of total water demand (84 mn m3/yr), domestic water demand 37% (78 mn m3/yr) and non-food industrial water demand 4% (9.13 mn m3/yr).

Figure 9 Detailed water supply demand gap for high water demand scenario (2030)



3. Solutions to close the water supply demand gap

Section 3.1 provides an overview of the framework that has been used to assess a range of different project alternatives that could be implemented to close the water gap in the different water demand scenarios. The energy and industrial sector have been focused on as they hold the greatest quantifiable water demand reduction potential. Project alternatives that could be applied to these sectors have been selected for inclusion in the quantitative assessment where there is sufficient data available and where a substantive contribution to closing the gap can be made. Other solutions, which may also hold potential but information is lacking, will be discussed and analysed at a conceptual level in section 3.2.

3.1. Prioritised, concrete solutions

3.1.1. Assessment framework

As all analysed water demand reduction and water supply augmentation measures jointly result in more available water resources than required to close the gaps in the different scenarios, an assessment framework was designed to identify the most cost effective and best value alternatives to close the anticipated gap. An overview of the Assessment Framework with the criteria that have been used to prioritise the different project alternatives, is provided in Figure 10. The assessment framework includes financial, economic and environmental criteria, for which quantitative information was available or for which it was possible to estimate a value on the basis of benchmark figures. An overview of the criteria is shown in Table 11 below.

Figure 10 Assessment Framework to prioritise solutions to close the water gap

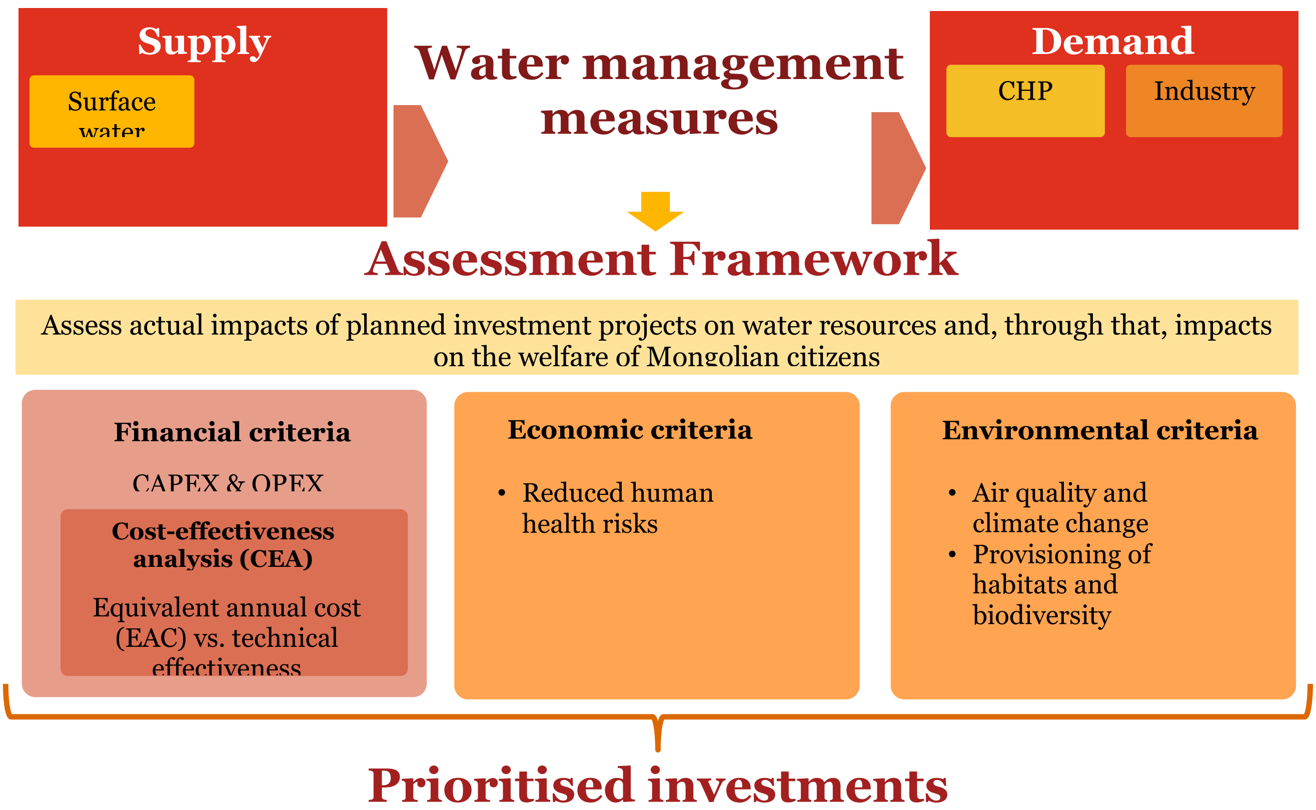


Table 11 Criteria used in the assessment framework

Criteria	Description
Financial costs of the project alternatives (capex and opex)	Information on capital investment costs (capex) and annual operational and maintenance costs (opex) for all different technological alternatives was sourced from project specific data or, estimated based on the installed capacity and unit investment factors available in the literature.
Technical effectiveness (water saving or water supply augmentation)	The total water withdrawal as a result of implementing the project alternative. This may provide water savings when water efficiency measures have been added, thus reducing the demand. Alternatively, the project alternative may augment supply. Estimates were based on benchmark figures for the same technologies applied elsewhere, discussed and validated for the Mongolian context (including discussion with stakeholders).
Cost- effectiveness ratio	The ratio is calculated using information on capex and opex expressed as an Equivalent Annual Cost (EAC) to allow for comparison of projects with different lifetimes.
Reduced human health risks	• Health damages associated with the energy consumed in order to provide water to each project alternative are monetised (i.e. expressed in terms of USD), using unit health damages per kWh of electricity produced (coal based) available in the literature (USD). • Such monetised health damages cover: carcinogens, public health burden of mining communities, fatalities in the public due to coal transport, emissions of air pollutants from combustion, lost productivity from mercury emissions, excess mental retardation cases from mercury emissions, and excess cardiovascular disease from mercury.
Air quality and climate change	Depending on the type of the project, emissions of air pollutants and GHG due to implementation of different project alternatives are calculated based on the information on energy used to provide water. Air quality and climate change damages from combustion are monetised (i.e. expressed in terms of USD), using unit emissions of CO_2 and N_2O per kWh of electricity produced and used to supply water to project alternatives.
Impacts on habitats and biodiversity	• Impacts of different project alternatives on habitats and biodiversity are calculated using the average air emissions per kWh of energy consumed to provide water to the project alternatives, and then monetised using a unit damage costs on biodiversity for air pollutants. • Damages on biodiversity (vegetation, fauna) are calculated using damage unit values for the following air pollutants: NH_3, Non-methane Hydrocarbons, including VOCs, NOX and SO_2.

To allow for a differentiated analysis, two sets of cost curves are presented:

1. Financial cost curves: Prioritisation of investment options is only based on financial criteria (see Annex A.6.1)

2. Holistic cost curves: Prioritisation of investment options is based on weighted financial criteria, economic and environmental criteria.

For holistic cost curves, a weighted sum of the above mentioned criteria was taken to prioritise different project alternatives. The weights are based on stakeholder consultations. The following weights were used to reflect the relative importance of different criteria (all summing up to 1):

- Financial & technical effectiveness – 0.2
- Economic – 0.3
- Environmental – 0.5

3.1.2. Introduction to cost curves

In general terms:

- Cost curves are a valuable decision-making tool that allow for a transparent presentation and comparison of alternative water supply augmentation and water demand reduction measures while not being prescriptive. In particular, cost curves show water supply augmentation and water saving potentials achievable through a wide range of technical measures and associated costs. They also allow comparing estimated additional water availability to the projected water supply and demand gap and identifying the most cost-effective range and sequence of measures.

- Cost curves reflect the benefits of implementing different water demand reduction and water supply augmentation measures as the amount of water being made available (the horizontal axis, mn m^3/yr). The vertical axis shows the cost per cubic meter of water saved or added per year (the vertical axis, USD/ m^3).

- It should be noted that cost curves do not reflect technical feasibility of proposed measures at a plant or site specific level. In particular, the curves do not distinguish between (a) new potential projects that have a higher degree of flexibility in choosing and implementing the most cost-effective technological alternative and (b) existing, operational sites that are less able to carry out technological upgrades or changes to processes.

- Furthermore, the cost curves analyse technical measures only, such as the implementation of wastewater reuse in industry or dry/air cooled systems at CHP Plants; they do not consider policies that might be required in order to enable or incentivise implementation of such measures.

- The costs and water availability depicted on the cost curves are not directly additive. The curves identify technological alternatives that have high water saving or augmenting potential per unit of cost in comparison to other alternatives available for each site or plant. Technological alternatives aiming to increase water efficiency, in particular, can be frequently inter-connected or mutually exclusive and hence not additive.

- The analysis distinguishes between two different costs: **Total Costs (TC)** and **Incremental costs (IC)**. Both costs are illustrated as **Equivalent Annual Costs (EAC). EAC** reflect the annual capital, operation and maintenance costs over the assets' lifetime. TC reflects the total cost of the investment, irrespective of the existing technologies (baseline). IC, on the other hand, reflects the costs required when considering existing or planned investments. Taking CHP Plants as an example, the analysed measure may only require an upgrade of the existing technology rather than the complete investment for the measure. For projects with multiple technological alternatives, such as water efficiency measures at CHPs, two sets of IC are derived – IC against the baseline and IC against the previous alternative. IC against previous alternative (e.g. comparing installation of dry/air cooled cooling system to hybrid one at a CHP) is used to construct cost curves. In some cases, multiple measures are suggested for the same (planned) project, e.g. cooling measures for CHP plants. In cases in which these measures are mutually exclusive, the most advanced measure is taken to calculate IC and TC. For example, if measures to close the gap include upgrades of the hybrid CHP plant but would also require a switch to a dry cooled CHP to ultimately close the gap, only the construction of the dry cooled thermal power plant will considered to avoid double counting of costs. In case measures suggest technologies which – besides saving water – are cheaper than those originally planned, IC can result being negative, i.e. savings are made, despite positive TC.

Parameters for the cost curves:

- **Financial costs** (USD/ yr) of different project alternatives included **capital investment**, i.e. fixed, one-off costs of projects such as costs of building, construction and technical equipment and **annual operational and maintenance costs** such as the energy cost of water pumping, air cooling and equipment maintenance among others. When comparing groundwater abstraction with cooling technology changes, capital and annual operational and maintenance costs were expressed as Equivalent Annual Cost (EAC) in USD to allow for comparison of projects with different lifetimes. To derive holistic cost curves, **economic** (reduced human health risks) **and environmental** (air quality and climate change, impacts on habitats and biodiversity) costs are also taken into consideration and weighted with financial costs (see section 3.1.1). For each technological alternative, IC against previous alternative were used to develop cost curves.

- **Technical effectiveness** (mn m3/ year) of different project alternatives reflect how much water would either be supplied or saved through different water augmentation and water demand measures considered. It should be noted that there are two possible ways of expressing incremental costs against increased water availability for different project alternatives. Conceptually, each measure can be assessed against baseline or against each second-best option. Cost curves were developed using incremental water availability against previous, i.e. second-best technological alternative.

- **Cost effectiveness ratio:** (USD/ mn m3 per year) were calculated for different project alternatives by dividing their calculated IC against previous alternative expressed as Equivalent Annual Costs (EAC) over their annual volume of water supplied or saved also measured against their second-best alternative. Based on the cost-effectiveness ratio, each project alternative shown on the curve is assessed against the previous one. For instance, changing a cooling technology at a CHP from wet closed cycle recirculating to hybrid (dry/wet) would result in reducing water demand from 1.1 m3/MWh to 0.78 m3/MWh. Furthermore, installing a dry/air cooled cooling system would result in 0 m3/MWh water demand. Calculating incremental water availability against baseline would result in a 0.32 m3/MWh reduction for installing hybrid cooling system and a 1.1 m3/MWh reduction for installing dry/air cooled cooling system. However, when calculating incremental water availability against the second-best alternative, anticipated water savings would be 0.32 m3/MWh reduction for installing hybrid cooling system and 0.78 m3/MWh reduction for installing dry/air cooled cooling system as this technological alternative is viewed against installing a hybrid cooling system and not the baseline option, wet closed cycle recirculating system.

Figure 11 How to interpret a cost curve

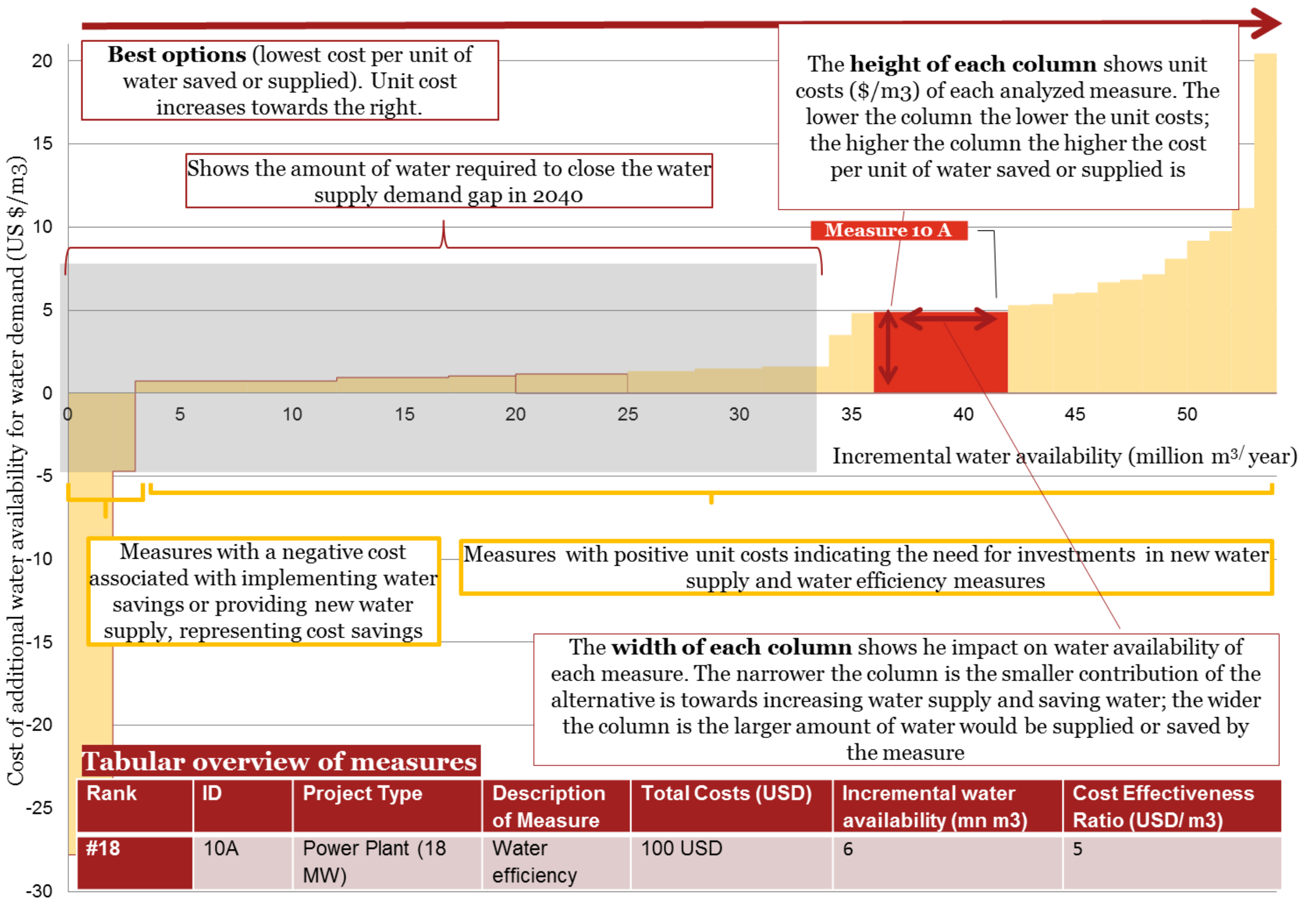


Figure 11 provides an example on how to read a cost curve. As mentioned above, the horizontal axis reflects incremental water availability (in this assessment, each project alternative, i.e. each column shows additional water availability in comparison to the previous technological alternative). The width of each column shows the relative increase in water availability; in other words, the larger the width of the column, the higher the incremental water availability.

The vertical axis shows the costs (in USD) to provide a cubic meter of water either through water supply augmentation measures or through water demand reduction measures such as dry cooling of CHP plants. The cost per cubic meter of water can also be negative that reflects a situation where a measure is increasing water availability and saving money. Similar to the width of the columns, their height reflects the costs per cubic meter. The lower the column, the cheaper it is to secure an additional cubic meter of water. The reverse holds true for negative costs; the taller the column, the higher the savings.

In the cost curve above, project alternatives located to the left are relatively more cost-effective in comparison to the much steeper part of the curve on the right. The example above shows that water supply demand gap can be closed by implementing measures in the grey box.

3.1.3. Cost curves

Financial as well as holistic cost curves were derived for Ulaanbaatar. The financial cost curves can be seen in Annex A.6.1, while the holistic cost curves are illustrated in the following section.

All eligible project alternatives in Ulaanbaatar were ranked by their cost-effectiveness ratios starting from the lowest score and moving up to the highest one to build the cost curves. It should be noted that there were several types of project alternatives that were not included in the cost curves. These were, in particular:

- Baseline technological options for all projects as these constitute the benchmark against which different project alternatives were assessed (in terms of costs and water augmentation potential)
- Project alternatives where the baseline already constituted the best technological option (e.g. dry/air cooled cooling system at CHP 5)
- Project alternatives resulting in negative water savings, in other words relatively more water intensive options in comparison to the previous alternative

Figure 12 shows the holistic cost curve, i.e. including financial, economic and environmental criteria, for Ulaanbaatar. Details on the analysed measures are available in the following section 3.1.4.

Figure 12 Holistic cost curve to close the water gap in Ulaanbaatar.

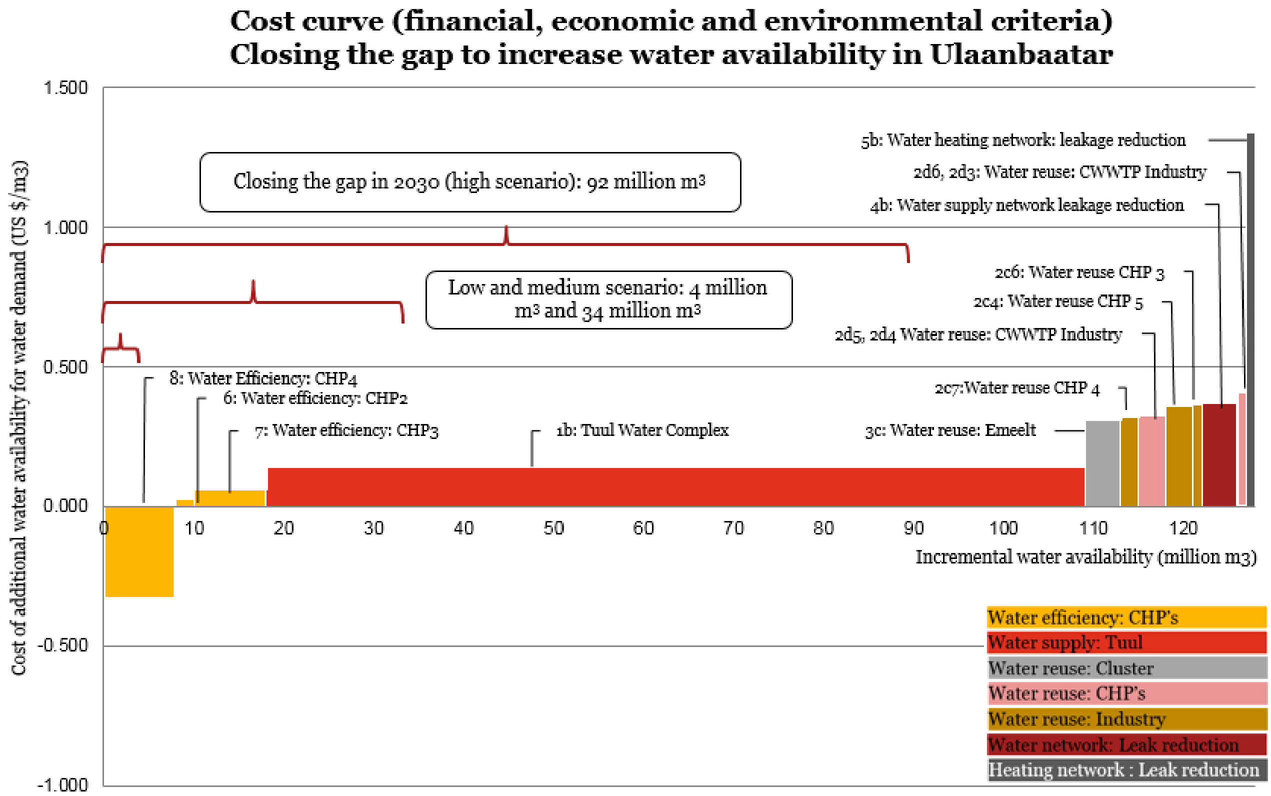


Table 12 enlists prioritised solutions accounting for a *step change* in technologies (e.g. 8i to 8n) and presents incremental costs and incremental water availability for each technological alternative considered in comparison to baseline (i.e. the starting point) required to close the gap. Annex A.5 illustrates all measures considered in the cost curve. Further, a tabular overview of the measures ranked as per cost curve, i.e. without considering step changes, is available in Annex A.6.1.

In addition to considering incremental costs of implementing these technological alternatives (i.e. in comparison to their baseline technologies), one may also wish to consider the total costs of implementing these measures assuming that there was no existing technology to build on (which will be higher than incremental costs).

In particular, total costs of implementing of these measures in Ulaanbaatar (i.e. disregarding the costs of baseline project alternatives) are about 14.2 mn USD/ year for low water demand scenarios and 65 mn USD/ year for medium and high water demand scenarios (see Annex A.6.2)

Considering the results of holistic cost-effectiveness analysis in the Ulaanbaatar region, key highlights include:

- Alternatives related to installation of **dry/air cooled cooling systems** for CHPs demonstrate negative cost-effectiveness ratios ranging from -0.33 USD/m³ to 0.21 USD/m³. Cumulatively, these measures add 18.4 mn m³ of water in Ulaanbaatar (in comparison to baseline technologies installed at each affected CHP).

- Development of **Tuul Water complex** has significant water augmenting potential of 91.25 mn m³ per year with cost-effectiveness ratio of 0.14 USD/m³.

Table 12 Ulaanbaatar - Prioritised list of solutions (holistic criteria)[24]

Rank	ID	Name - Project title	Baseline technology	Complete technology description	Capex (capital investment costs), USD	Opex (annual operational costs), USD	EAC (Equivalent Annual Cost), Capex, USD	Total cost (USD, EAC)	Incremental costs (USD, EAC against baseline)	Incremental water availability (mn m³/year, against baseline)	Cost effectiveness ratio (USD/ m³)
1-16	8 i,j,k,l, m,n	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	123,210,000	1,387,500	12,775,609	14,163,109	-10,202,653	8.55	From - 0.33 to - 0.21
Sub-total – low demand gap (3.99 mn m³)								**14,163,109**	**-10,202,653**	**8.55**	
2-17	6 f,g,h j,k,l,m ,n	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler	3,785,684	42,632	392,536	435,168	268,003	1.99	From 0.03 to 0.07
3-15	7 i,j,k,l, m,n	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, CFD Boiler, Boiler Blowdown reuse	32,598,947	367,105	3,380,175	3,747,281	2,307,806	7.88	From 0.06 to 0.10
21	1b	Tuul Water Complex (Dam #3)	NA	Tuul Water Complex (Dam #3 with reservoirs; water treatment plant and conveyance pipeline)	353,988,654	10,605,060	35,819,274	46,424,334	46,424,334	91.25	0.14
Total medium (34.05 mn m³) and high (92.14 mn m³) demand gaps								**64,769,892**	**38,797,490**	**109.7**	

[24] The complete table, including all measures listed in the cost curve is illustrated in Annex A.5.

However, there are additional options to close Ulaanbaatar's water supply demand gap when not following the sequence of the cost curve strictly. The options for each scenario are illustrated in Table 13 below. Details on each measure can be found in section 3.1.4 in Annex A.5 and A.1.

Table 13 shows that there are two options to close the water supply demand gap in the low and medium scenario.

- In the low demand scenario, the implementation of water efficiency measures in CHP4 would result in cost savings, besides closing the gap. However, USUG is already engaged in NRW reduction measures. These NRW reduction measures have the potential to close 95% of the low demand gap. The remaining 0.2 mn m3/yr could be closed by exploring solutions described in the following chapter[25], or by installing water efficiency measures in CHP4 in addition.

- In the medium demand scenario, 34 mn m3/yr need to be made available to close the gap. Following the cost curve, the most cost-effective solution per m3 of water is the Tuul Water Complex. However, as the Tuul Water Complex cannot be constructed in segments, its construction would result in an excess of water available (an additional 57.3 mn m3) and would result in high total costs (EAC 46.4 mn USD/yr). Alternatively, the remaining measures analysed in the cost curve could be chosen to close the gap at less than half the cost (21 mn USD/yr). These measures include the implementation of a combination of water efficiency measures at CHPs 2, 3 &4, reuse of treated Emeelt industrial wastewater, reuse of treated CWWTP water at CHPs 2, 3 &4, reuse treated wastewater from CWWTP at industrial clusters (Bayangol, Songinokhaikhan & Khan Uul) and USUG NRW leakage reduction measures (35.6 mn m^3 vs the gap of 34 mn m^3). Thus, the construction of the Tuul Water Complex results in 25.4 mn USD/yr in excess to the alternative solution.

- In the high water demand scenario, the only measure capable of closing the gap is the Tuul Water Complex in combination with the water efficiency measures at CHP4.

Table 13 Overview of options to close the water gap in low, medium and high water demand scenario (2030)[26]

Scenario	Gap (mn m^3/year)	Measures	Incremental water availability (mn m^3/year)	EAC (mn $/year)
Low water demand	4	**Option 1** • Water efficiency measures at CHP4	8.6	- 10.2
		Option 2 (currently implemented) • USUG NRW reduction	3.8	7.1
Medium water demand	34	**Option 1** • Tuul Water Complex	91.3	46.4

[25] These solutions include: grey water reuse in commercial and residential buildings, retrofitting appliances and behavioural change, on-site industrial wastewater treatment and reuse, industrial water efficiency measures and conveyance of treated wastewater to upstream water source locations

[26] Total capital and operational expenditures over the entire project lifetime can be found in Annex A.5.

		Option 2 • Water efficiency measures at CHP 2, 3 &4 • Emeelt cluster WWTP reuse • Reuse treated wastewater at CHP 3, 4 &5 • Reuse treated wastewater from CWWTP at industrial clusters (Bayangol, Songinokhaikhan & Khan Uul) • USUG NRW reduction	35.6	21
High water demand	92	• Water efficiency measures at CHP4 • Tuul Water Complex	99.8	36.2

3.1.4. Most cost effective solutions

The following sections briefly outline the analysed measures, sorted by their relative cost-effectiveness as shown in the holistic cost curve above. More information on these measures, including data sources and assumptions made for the analysis, as well as total capital and operational expenditure, can be found in Annex A.1.

3.1.4.1. Water efficiency measures at CHPs

Heating and hot water for the city of Ulaanbaatar, in addition to electricity generation, is supplied from three Combined Heat and Power (CHP) plants, with a further new plant about to be constructed. CHP plants require reliable access to large volumes of water and typically, the largest single demand for water is associated with the cooling system for the steam turbine, followed by district heating makeup, boiler make-up, for the removal of SO_2 from flue gases and for ash handling. The combined water demand for the four CHP's will be 21Mm³/year by 2030 which is/will be supplied from groundwater sources.

Figure 13 outlines the general technical options for water demand reduction which could be applied to the three existing plants. Each box illustrates technological options, which can be further improved by the measures to the right of each box. The existing baseline for CHP plants will determine the additional options that can be potentially added. Dry/ air cooling (with circulating fluidised bed boilers and boiler blowdown reuse) on the far right illustrate the best case, with respect to water usage. As CHP5 is in planning and about to be developed no additional measures are being proposed as it is assumed that the implementation of best practice will be a precondition of project funding.

Figure 13 Technical options to decrease water demand at CHP plants

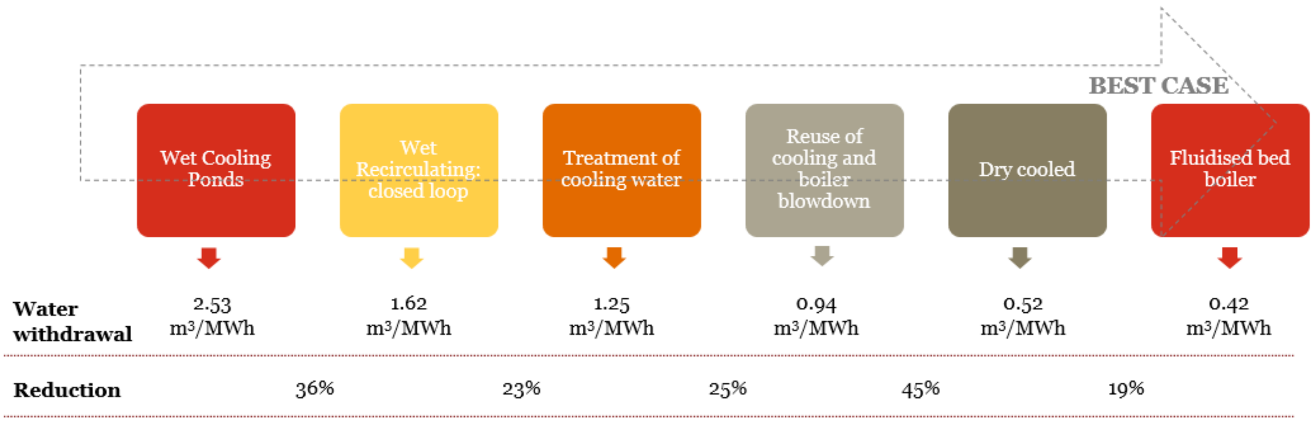


Table 14 provides a description of the baseline and best case prioritised technical option to be implemented to reduce water demand at each of the CHP plants. The water savings, total and incremental EAC, cost-effectiveness ratio and contribution to closing the gap is shown.

Table 14 Summary of water savings, costs and cost effectiveness ratio of prioritised technical options at CHP plants.

#	ID	CHP Plant	Baseline	Option Description	Water Saving (mn m^3/year)	Total Capital Costs (Mn US$)	EAC Total (Mn US$)	EAC Incremental (M$)	CE Ratio (Holistic)
1	8 i,j,k,l,m ,n	CHP4	Wet CL cooling, PC boiler, Boiler blowdown reuse	Dry cooled, fluidised bed boiler, Boiler blow down reuse	8.55	123.21	14.16	-10.2	-0.33-0.21
2	6f,g,h,j, k,l,m,n	CHP2	Cooling ponds, PC boiler	Dry cooled, fluidised bed boiler, Boiler blowdown reuse	1.99	3.79	0.44	0.27	0.03-0.07
3	7i, j,k,l,m, n	CHP3	Wet CL & pond cooling, PC boiler	Dry cooled, fluidised bed Boiler, Boiler blowdown reuse	7.88	32.6	3.75	2.31	0.06-0.10
-	-	CHP5	Dry cooled, fluidised bed boiler, Boiler blowdown reuse	No change	-		-	-	-
	Total				18.42	159.6			

3.1.4.2. Tuul Water Complex (Dam #3)

The Tuul Water Complex is a proposed project, currently at feasibility stage, providing a significant new source of water supply from the Tuul River into Ulaanbaatar. The outline proposal comprises the development of three new multi-purpose reservoirs behind dams that would provide hydro-power, water treatment works and pipelines into Ulaanbaatar. The feasibility report[27] recommends the choice of Dam #3 as a first phase, which will supply 250,000 m^3/day (91 Mm^3/year) with water treatment works and pipeline but not to include hydropower. A summary of the water augmentation potential, total EAC and cost effective ratio and contribution to closing the gap is provided in Table 15.

Table 15 Summary of water augmentation potential, costs and cost effectiveness ratio at Tuul Water Complex

#	ID	Description	Water Augmentation (mn m^3/year)	Total Capital Costs (Mn US$)	EAC Total (M$)	CE Ratio (Holistic)	Closing the Gap %
21	1b	Tuul Water Complex (Dam #3)	91.3	353.99	46.4	0.14	99%

3.1.4.3. Reuse of treated wastewater from CWWTP for CHPs

The Central Wastewater Treatment Plant (CWWTP), located in the south west of the Ulaanbaatar, is the largest wastewater treatment plant in the City with a capacity of 230,000 m^3/day (approximately 85% of total treatment). Domestic wastewater from apartments, companies and public facilities is received via the public sewage network for treatment before being discharged into the Tuul River. Pre-treated industrial wastewater from the Khargia wastewater treatment plant and wastewater from industries is also received directly by the

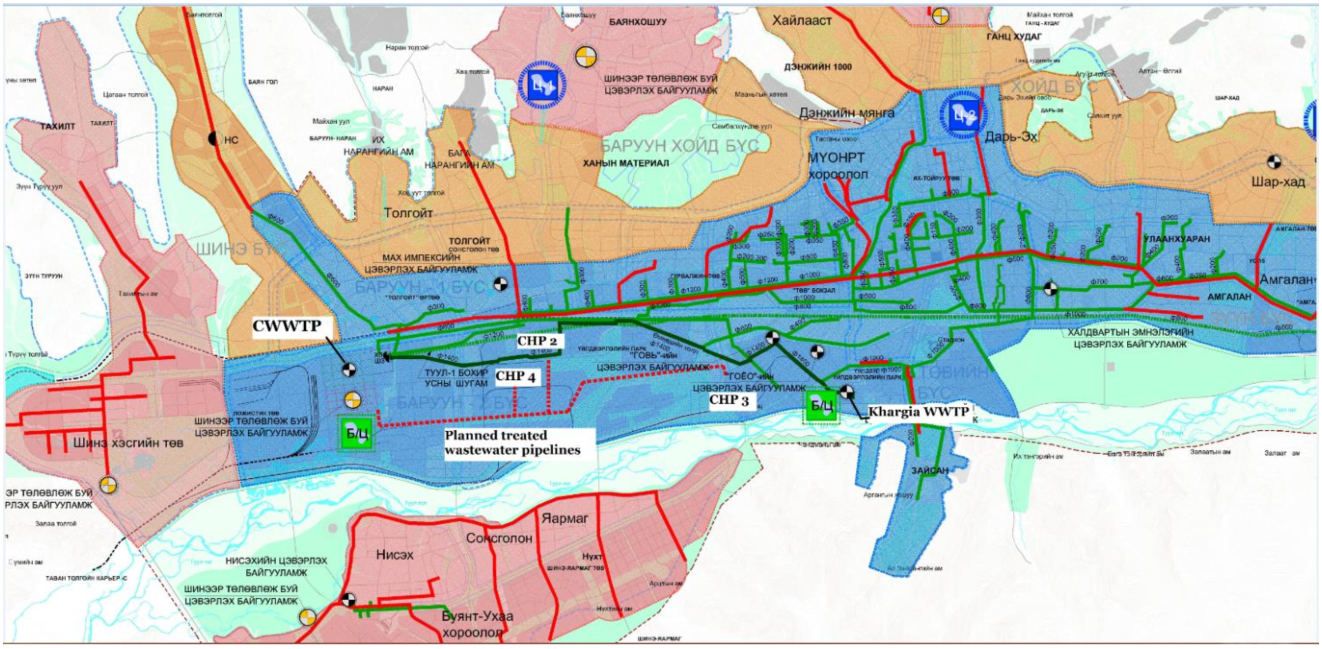
[27] Yooshin Engineering Corp (2016) Feasibility Study and Basic Engineering Design Development of Tuul Water Complex Project 2nd Consultation Workshop

CWWTP. The existing infrastructure at the CWWTP is not sufficient to treat the mixed wastewater and as a result the discharge into the Tuul is not meeting the required standards.

A planned project, currently at feasibility stage[28], proposes to establish a new tertiary treatment facility with a capacity of 250,000 m3/day (91Mm3/year) and to establish how the existing facility could be rehabilitated to provide additional capacity.

As highlighted above, the four CHP's have a total water demand of 21Mm3/year. An option exists to substitute a large component of the existing groundwater supply for the CHP's with treated wastewater from the new CWWTP, rather than this water being discharged back into the Tuul. This option would require new pipelines and pumping stations from the CWWTP to each CHP. The quality of water that will result from the planned treatment processes would be sufficient to substitute the water required for 'plant[29]' requirements. However, additional treatment[30] to meet the water quality needs would be required to provide for the 'process[31]' elements at the CHPs. If reuse is adopted the existing groundwater supply to the CHP's could then be used for other purposes.

Figure 14 Map showing location of CHP's in relation to the CWWTP.



A summary of the water augmentation potential, total EAC and cost effective ratio and contribution to closing the gap from the reuse of treated wastewater at each CHP, once the water efficiency measures outline in Section 3.1.4.1 have been implemented, is provided in Table 16.

Please note that the cost estimates do not include the capital and operational expenditure of the CWWTP itself, as this will be constructed regardless of whether treated wastewater will be reused or not and can thus be considered as sunk costs.

Table 16 Summary of water augmentation potential, costs and cost effectiveness ratio from implementing the reuse of treated wastewater at the CHPs.

#	ID	CHP Plant	Description	Water Saving (mn m3/year)	Total Capital Costs (Mn US$)	EAC Total (M$)	CE Ratio (Holistic)	Closing the Gap %
23	2c7	CHP4	CWWTP water reuse – additional wastewater treatment conveyance	1.72	6.32	2.70	0.32	1.9%

[28] Artelia (2015) Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG14/0221 Consultancy Services for Design Work: Feasibility Study
[29] Plant water would include: cooling, washing, ash handling, fire-fighting, dust suppression etc.
[30] Sand filter and cartridge filter treatment if added would provide water of adequate quality for process water requirements.
[31] Process water: makeup water for heating networks and boilers, chemical dilution.

27	2c4	CHP5	CWWTP water reuse – additional wastewater treatment conveyance	2.82	14.08	4.88	0.36	3.1%
28	2c6	CHP3	CWWTP water reuse – additional wastewater treatment conveyance	0.52	2.81	0.92	0.37	0.6%
33	2c5	CHP2	CWWTP water reuse – additional wastewater treatment conveyance	0.11	1.07	0.24	0.47	0.1%
		Total		5.17	24.28			

3.1.4.4. Cluster-based industrial WWTPs and reuse of treated wastewater (Emeelt)

International experience has shown that multiple benefits can be obtained from establishing smaller wastewater treatment plants at the centre of industry clusters (Emeelt, Bayangol, Songinokhairkhan Khan Uul, Bayanzurkh, Bayangol (near airport)) rather than at a central location. The treated wastewater from these plants could then be put back into supply through new pipes for the industries to use. An example of this option could be developed at the Emeelt Industrial Park where a new industrial wastewater treatment plant is being proposed as part of an EBRD programme[32]. Following a slight adjustment[33] and addition to the proposed treatment processes, wastewater from the industrial wastewater treatment plant could be reused for all non-potable water requirements.

A summary of the water augmentation potential, total EAC and cost effective ratio and contribution to closing the gap from the reuse of treated wastewater from the proposed Emeelt industrial wastewater treatment plant is provided in Table 17.

Table 17 Summary of water augmentation potential, costs and cost effectiveness ratio from implementing of cluster based reuse of treated wastewater at the Emeelt Industrial Park.

#	ID	Description	Water Saving (mn m³/year)	Total Capital Costs (Mn US$)	EAC Total (M$)	CE Ratio (Holistic)	Closing the Gap
22	3c	Emeelt Industrial Wastewater Reuse	4.2	14.72	6.3	0.31	4.3%

3.1.4.5. Reuse of treated wastewater from CWWTP for industrial uses

Treated wastewater from the CWWTP could be reused to supply industry around Ulaanbaatar, replacing the existing sources. The treated water could be piped to the centre of industrial clusters (Emeelt, Bayangol, Songinokhairkhan Khan Uul, Bayanzurkh, Bayangol (nr airport)) and then connected to specific industry sites. Being precautionary, additional treatment[34] would provide water for sufficient quality for all non-potable water requirements. It should be noted, for certain uses, a lower output water quality of the CWWTP would be sufficient and would reduce costs.

A summary of the water augmentation potential, total EAC and cost effective ratio and contribution to closing the gap from the reuse of treated wastewater from the proposed Emeelt industrial wastewater treatment plant is provided in Table 18.

Table 18 Summary of water augmentation potential, costs and cost effectiveness ratio from implementing the reuse of treated wastewater at the industry cluster locations.

[32] EBRD (2015) Ulaanbaatar Wastewater Expansion Programme Feasibility Study, Final Report
[33] Replace the proposed Treatment Process 4, activated carbon adsorption with advanced oxidation (AOP) to remove recalcitrant COD. This would have a comparable cost to that already proposed.
[34] Sand filter and cartridge filter treatment if added would provide water of adequate quality for process water requirements.

#	ID	Industry Cluster	Description	Water Saving (mn m3/ year)	Total Capital Costs (Mn US$)	EAC Total (M$)	CE Ratio (Holistic)	Closing the Gap %
24	2d5	Bayangol	CWWTP water reuse - additional treatment & conveyance	2.56	9.9	4.07	0.33	2.8%
26	2d4	Songinokhairkhan	CWWTP water reuse - additional treatment & conveyance	0.77	3.18	1.25	0.34	0.8%
29	2d2	Khan Uul	CWWTP water reuse - additional treatment & conveyance	0.77	4.22	1.37	0.37	0.8%
31	2d3	Bayanzurkh	CWWTP water reuse - additional treatment & conveyance	0.77	5.4	1.50	0.41	0.8%
32	2d6	Bayangol (nr airport)	CWWTP water reuse - additional treatment & conveyance	0.26	1.93	0.52	0.42	0.3%
		Total		**5.12**	24.63			

Note: Emeelt has not been included in the analysis as the cluster based approach reuse of treated wastewater has assumed to be applied.

3.1.4.6. Leak detection and non-revenue water reduction in central water supply network (USUG)

USUG maintains the central water and wastewater supply network in Ulaanbaatar supplying 150,000 m3/d to OSNAAG and additional supply direct to some industries. It is estimated that the current losses from the network from leaks and non-revenue water are 14%[35] which has been reduced from levels of 21% in 2011.

Further improvements are planned by using a trenchless technology applied by Sekisuis to rehabilitate part of the pipe network using spiral wound relining. This project is already ongoing and is managed by USUG. An option exists to further deploy this trenchless technology to reline a proportion of the pipe network and reduce NRW to 7%[36], which is approximately 3.8 Mm3/year.

Table 19 Summary of water savings, costs and cost effectiveness ratio from the rehabilitation of the central water and wastewater supply network

#	ID	Description	Water Saving (mn m^3/year)	Total Capital Costs (Mn US$)	EAC Total (M$)	CE Ratio (Holistic)	Closin the Ga %
30	4b	Leakage Reduction- central water supply network	3.8	61.36	7.1	0.37	4.

3.1.4.7. Water and energy leakage reduction in central heating supply system

The three existing CHP plants pump hot steam at 135° to the 280km long central heating network which is maintained by the Ulaanbaatar City Heating Company (UBDS). The hot steam is pumped in a closed circuit to heat exchangers operated by OSNAAG which heats up cold water which gets distributed in a separate closed circuit to apartments, business and public buildings.

There is currently approximately 2.36-2.93 Mm3/year of makeup required to replace water due to leaks in the system. There is a planned investment to rehabilitate 11.7km of heating network which will replace the pipes and reduce the makeup water required.

A summary of the water savings achieved, total EAC and cost effective ratio and contribution to closing the gap from the rehabilitation of 11.7km of heating network is provided in Table 20.

Table 20 Summary of water savings, costs and cost effectiveness ratio from the rehabilitation of 11.7km of heating network.

[35] Interview with Chief Engineer Batsukh (7 April 2016).
[36] NRW of 7% is considered in this study as a best achievable and economically viable level.

#	ID	Description	Water Saving (mn m^3/year)	Total Capital Costs (Mn US$)	EAC Total (M$)	CE Ratio (Holistic)	Closin the Ga %
36	5b	Leakage Reduction- central heating supply system	0.28	18	1.87	1.34	<1

3.2. Additional solutions

Besides the solutions which were quantified and prioritised in the cost curve, additional solutions were identified which were considered of importance to address Ulaanbaatar's water challenges, but could not be included in the cost curves due to a lack of data. These solutions were identified during stakeholder consultations and are based on international best practices which were set into Ulaanbaatar's context.

3.2.1. Grey water usage in commercial and apartment buildings

Commercial and apartment buildings have multiple uses of water – some water uses can be replaced with grey water or treated wastewater.

Over the past decades, more and more solutions to reuse water and treated wastewater have been found. Solutions can vary from simple capturing of water from washbasins which is then directly used for toilet flushing to a complex way of treating the grey water generated and recirculating it through a dual piping system for flushing and other non-potable purposes. Selected case studies show that water savings can amount to 37%-66%

***Box 1:* Reusing treated greywater in commercial & office parks - A case from Cyber City, Gurgaon, India**

Cyber City in Gurgaon in the outskirts of National Capital of Delhi is a mixed use development with over 15 million[37] square feet of space planned as Integrated Business District. The development was undertaken by DLF (a private real estate company) which developed an ecosystem in cyber city for work, live and play. The development started in the year 2000 and by 2004, DLF realized the importance of conserving and recycling water in the largest office spaces of DLF Cyber City. One of the key initiatives of the company has been its investment on the necessary infrastructure for its Sewage Treatment Plant (STP) to ensure that used water from offices and other amenities could be easily recycled and reused. During peak summer DLF Cyber City consumes about 9500 m3/day of water. The local utility supplies only about 3000-3200 m3/day of water which is used for the purposed of drinking, pantry, wash basins and other uses. To mitigate the risk of water scarcity, DLF's STP facility with a capacity of 7000 m3/day recycles 100% of waste water and ensures that people in DLF Cyber City do not have to face water crunch. This planning at the early stage has now helped the **Cyber City to meet 60% of the current demand from recycling & reuse.** Most of the treated water is being used in cooling towers and horticulture. 100% sludge from STP is used as manure in horticulture.

Now the utility bills for the DLF tenants is lower than it would have been without reusing greywater and has become a key selling point for this complex. Additional water supply would cost almost Rs. 40/m3 (supplied through tankers). The quality of treatment is higher than the prescribed standards by Central Pollution Control Board (CPCB).

[37] DLF EDGE (2014)– Newsletter of DLF Cyber City

of total water usage, if adequate solutions are applied[38]. illustrates the successful case study in India in which a mixed use building complex has invested in STPs and a dual piping system and thus achieved fresh water savings up to 60%.

International experience suggests that it is cost effective to install community/ decentralised STPs for water users exceeding 20,000 m^3/year[39]. Thus, buildings in which treatment of grey water and reuse could be economically and technically feasible include large apartment complexes (>100 apartment units), high end hotels, as well as large office buildings and governmental buildings.

The water usage in 2030 by water users who could potentially apply reuse of water and wastewater solutions is listed in the table below.

Table 21: Water demand by category

Category	Usage in 2030 (m3/year)
Hotels	0.72
Utility services (offices, businesses and schools)	27.60
Apartments	75.57
Total	**103.89**

Data on bulk users exceeding water usage of 20,000 m^3/year was not available at time of research for all water user categories. For hotels, however, detailed water usage data exists from USUG. Seven hotels in Ulaanbaatar use more than 20,000 m^3/year, the cumulative usage of these hotels account for 0.48 mn m3/year. Assuming water savings of 37%, based on international experience[40] , total potential water savings of 0.18 mn m^3/year can be achieved (see Box 2).

Box 2: Closed Loop Water Reuse in new buildings – Case of New York City[41]

Battery Park City, New York, serves as a very recent urban water reuse model which ultimately provides benefits of water reuse as a means of achieving growth with less impact on natural resources. Battery Park City is a redevelopment area located at the southwestern tip of Manhattan which consists of 0.37 mn sqm under the control of the Hugh L. Carey Battery Park City Authority (BPCA). This land was created from landfill and demolition of old, deteriorating piers which existed along the Hudson River waterfront, the full build out of which would include 14,000 residential units 0.56 mn sqm of commercial space and more than 0.11 mn sqm of parks, plazas and waterfront walkway.

Begun initially in the 1970's, the BPCA adopted a mission to demonstrate sustainable urban development for the redevelopment of this land and in 2000 issued its Environmental Residential Guidelines, which set forth goals and standards for environmentally responsible building. This was at the same time that the United States Green Buildings Council launched LEED® (Leadership in Energy and Environmental Design) Version 1. The two programs were closely aligned and both included water conservation objectives. The BPCA Environmental Residential Guidelines also included a water reuse component which was more advanced than the LEED requirements.

Figure 15: MBR module in the basement of Solaire

In order to win the rights for land lease development in Battery Park City, developers had to submit competitive bids which illustrated how the objectives of the guidelines would be fulfilled while offering their best bid price. The BPCA rated the developer proposals based on price and compliance with the guidelines. The first winning proposal was awarded to Albanese Development for a 27 story residential building to be named The Solaire which included water reuse as a component of a long list of other environmental features. The Solaire was completed in

[38] Case Studies – Article published in American Society of Heating (2008), - "The Solaire – NYC's Living Lesson"; "Water Reuse: An International Survey of Current Practices, Issues & Needs – Japan" and " DLF Cyber City – Case of water reuse in commercial buildings"
[39] Olivia Jensen, (2016) Wastewater reuse in Beijing an evolving hybrid system, International Journal of Water Resources Development
[40] Considering minimum water savings based on cases from Solaire US (refer Box 2), DLF Cyber City, India (refer Box 1)
[41] Kyra Epstein (2008), NYC's Living Lesson

2003 and it became the first residential project in the US to incorporate direct closed loop water reuse. The project went on to be awarded a LEED Gold certification for new construction and later a LEED Platinum for operation and maintenance.

Solaire has consistently **achieved a 48% water consumption reduction by comparison to a comparable base residential building in NYC** and a **56% reduction in wastewater discharge**. **37% of fresh water demand for Solaire is being met from treating greywater.** In cumulative terms, **there is a 43% reduction in total potable water demand** due to reuse and other water efficient systems**.** This water and wastewater reduction is achieved by a combination of wastewater reuse and water conservation where non-potable water is distributed in closed loop systems for uses that include toilet flushing, cooling tower make-up, laundry and irrigation. The typical configuration for a closed loop direct water reuse system consists of holding tanks for wastewater and rainwater. In some buildings, greywater is used in place of wastewater as a source of supply for the water reuse system. Wastewater and rainwater are treated and placed into storage in a non-potable water reservoir prior to distribution back to the non-potable water uses in the building. The percentage of non-potable water varies with the use of the building and can be as high as 95% in office uses[42].

3.2.2. Retrofitting appliances & behavioural change

Improving the water use efficiency by reducing avoidable losses has been one of the key strategies of cities across the world. This is mostly being done through large campaigns to mobilise residents, private sector and public buildings to install advanced water fittings to avoid leakages and to reduce water consumption (low flow modules). A successful case of implementation of retrofitting in Massachusetts is provided in **Box 3** below.

***Box 3:* Water Conservation through retrofitting – A Case from Massachusetts**

The Massachusetts Water Resource Authority (MWRA) is a wholesale water provider for 2.2 million people in 46 cities, towns, and municipal water districts in Massachusetts. From 1969 to 1988, MWRA withdrawals exceeded the safe yield level of 1.36 mn m³/day by more than 10 percent annually. Consequently, MWRA was under pressure to make plans to increase supply capacity. One of the plans it developed was to divert the Connecticut River, which would cost $120 million to $240 million (in 1983 dollars) and have an annual operation and maintenance cost of $3 million. MWRA also developed a plan for a new water treatment facility that complied with the Safe Drinking Water Act. The plant was originally designed with a 690 mn m3/ annum demand maximum. Ultimately, the Commonwealth of Massachusetts determined that a water conservation plan would be the best initial solution for its supply needs, with other plans to follow as needed.

Although adequate precipitation helped avoid a major water-supply crisis during the 20 year period of exceeding the safe yield, MWRA began a water conservation programme in 1986 to help address the supply problem. The conservation programme included the following:

- Vigorously detecting and repairing leaks in MWRA pipes (270 miles) and community pipes (6,000 miles).
- Retrofitting 370,000 homes with low-flow plumbing devices.
- Developing a water management programme for area businesses, municipal buildings, and non-profit organisations.
- Conducting extensive public information and school education programmes.
- Changing the state plumbing code urging new toilets to use no more than 0.007 m3 of water per flush.
- Improving meters to help track and analyse community water use.
- Using conservation-minded water/sewer rate structures on the community level.

[42] Water Sustainability & International Innovation

MWRA's conservation efforts reduced average daily demand from 1.52 mn m3/day in 1987 to 1.16 mn m3/day in 1997. The decrease in demand allowed for a reduction in the size of MWRA's planned treatment plant, as well as a 20-year deferral of the need for an additional supply source.

The present-value (July 2002) cost savings of deferring the water supply expansion are estimated to be $75 million to $117 million, depending on the initial capital investment. The capacity of the treatment plant has been reduced from 2.27 mn m^3/day to 1.84 mn m^3/day—an estimated $36 million cost reduction. Together, the deferral of the water-supply expansion project and the reduction in the capacity of the treatment plant amount to a total savings of $111 million to $153 million. The estimated cost of the conservation programme is $20 million.

Source: EPA Water Resources Centre's Publication on Cases in Water Conservation (2002)

The current water consumption in Ulaanbaatar is between 160 and 165 litres per capita per day, which is considered to be reasonable compared to international standards. Experiences show that water consumption increases with growing income levels. Considering that Mongolia is a growing economy, it is recommended to adopt water efficiency measures.

The targeted users for the retrofitting programme would be residential apartments, utility services including offices, businesses, schools and commercial buildings like hotels. The total water consumption by these user categories is over 100 mn m^3/year. The breakup of the usage can be seen in Table 21.

Based on the information provided by OSNAAUG[43], around 67.4% of the apartments managed by OSNAAUG are metered, which accounts for water consumption of 14.68 mn m3/year and the unmetered connections account for water consumption of 7.22 mn m^3/year. Abstracting estimated (calculated) non-revenue water (6.5%-10%, or 1.4-2.2. mn m^3/yr of total water distributed), but could be related to high water usage in apartments or physical system losses. Average water consumption amounts to 0.1-0.12 m^3/day for metered apartments, whereas total average water consumption amounts to 0.16 m^3/day. A water audit needs to be done to identify the actual consumption and losses within buildings to draw up a plan for solutions. If it is found that water can be saved by the user, appliances should be retrofitted and public awareness campaigns should be started to reduce water consumption. To address the future predicted increase in water consumption, the installation of water efficient appliances in all new buildings could be made mandatory.

Water saving potential through retrofitting can range between 0-40% depending on the existing infrastructure, pipelines, and bathroom fittings in the buildings of Ulaanbaatar. Installation of higher efficiency toilets and replacement of showerheads has been one of the most common interventions in the many cities in the world which has resulted in reasonable extent of water savings. For a higher per capita base consumption, the amount of water savings could be as high as 50% of per capita usage. An example of toilet and showerhead replacement programme is provided in Box 4 below.

***Box 4:* High efficiency toilets and showerheads to reduce water consumption – A Case from Goleta, California**

The Goleta, California, Water District serves approximately 75,000 customers spanning an area of about 117.3 mn sqm. Goleta's water supply comes primarily from Lake Cachuma (11.47 mn m^3/year) and the state Water Project (5.55 mn m^3/year). The district can also produce approximately 2.5 mn m^3/year from groundwater wells. In 1972, analysts predicted future water shortages in Goleta, so the district began seeking additional water sources and established a water efficiency program.

Goleta's water efficiency program cost approximately $1.5 million and emphasised plumbing retrofits, including the installation of high-efficiency toilets (0.006 m3 per flush) and showerheads. The programme also included free onsite water surveys, public education, and changes in metering and rate structure. A mandatory rationing plan was imposed on May 1, 1989 to reduce use by 15 percent.

Between 1987 and 1991, Goleta issued 15,000 rebates for high-efficiency toilets and installed 35,000 low-flow showerheads. Between 1983 and 1991, 2,000 new high-efficiency toilets were installed in new construction and remodels. Onsite surveys and public education efforts helped consumers improve outdoor water efficiency, and increased water rates provided extra incentive for consumers to reduce water use. The conservation and rationing programmes, as well as the rate increases, contributed to a 50-percent drop in per capita residential water use in 1 year—between May 1989 and April 1990. Total district water use fell from 0.47 to 0.34 m^3 per

[43] Discussion with OSNAAUG (13th April 2016)

capita per day—twice the original target of 15 percent. The water-efficiency programme also reduced sewage flow from 0.025 million m3 per day to 0.015 m³ per day. As a result, Goleta Sanitary was able to delay a multimillion-dollar treatment plant expansion.

Source:

If a water audit reveals that physical losses, rather than unbilled high per capita water consumption, are the cause for the high unaccounted for water, then measures to reduce water losses in pipelines leading to apartments from OSNAAUG lines should be adopted. This could be clubbed with the installation of low flow devices that require less water than regular appliances. A successful example of such intervention is seen in Massachusetts wherein the water savings were as high as 24% of the per capita consumption. The details of the case are provided in Box 3 below.

The extent of investments required for these kind of interventions will be minimal compared to the cost savings from postponement of large investment required to source water through construction of new dams or in terms of savings with purchase of water. Ulaanbaatar should seriously consider retrofitting as an option and should take a programmatic approach in implementing the same. An example from Ashland is more suitable to look at potential saving for a city by adopting retrofitting measures. The details of the case are provided in **Box 5** below.

Box 5: **Postponement of dam construction by saving water consumption: A Case from Ashland, Oregon**

Ashland, Oregon, is a small city of approximately 20,000 people. The Water Division treats and transports an average of 0.03 million m3 daily in the summer and 0.01 million m3 daily in the winter. Annual usage is approximately 0.68 m3 per capita per day. Ashland experienced an accelerated population growth rate in the late 1980s. At the same time, it faced the imminent expiration of a critical water right. Initially, the city had two options available to increase water supplies. The first was to create a reservoir by damming Ashland Creek at a cost of approximately $11 million. The second was to lay 13 miles of pipeline to the Rogue River at a cost of approximately $7.7 million. The city decided, however, that neither option was fiscally or politically feasible. Furthermore, the proposed dam site disturbed habitat for the endangered spotted owl. Ashland therefore decided to implement a four-point water efficiency program to address its water supply problem.

Ashland's water conservation programme became a natural addition to the city's existing resource conservation strategy, which addresses energy efficiency, regional air quality, recycling, composting, and land use. In 1991, the city council adopted a water efficiency programme with four major components: system leak detection and repair, conservation-based water rates, a high-efficiency showerhead replacement programme, and toilet retrofits and replacement. The city estimated that these programmes would save 0.0023 million m3 of water per day at a cost of $825,875—approximately one-twelfth the cost of the proposed dam—and would delay the need for additional water-supply sources until 2021.

Implementation of the programme began with a series of customer water audits, which in turn led to high-efficiency showerhead and toilet replacements and a $75 rebate programme (later reduced to $60). Ashland also instituted an inverted block rate structure to encourage water conservation. Recently, Ashland began offering rebates for efficient clothes washers and dishwashers (including an energy rebate for customers with electric water heaters). The town provides a free review of irrigation and landscaping, as well.

Implementation of Ashland's Water Conservation Program began in July 1992. By 2001, almost 1,900 residences had received a water audit. Almost 85 percent of the audited homes participated in the showerhead and/or toilet replacement programs. Ashland has been able to reduce its water demand by 0.0018 million m3 per day (16 percent of winter use) and its wastewater flow by 0.0007 million m3 per day. An additional benefit of the programme has been an estimated annual savings of 514,000 kilowatt-hours of electricity, primarily due to the use of efficient showerheads.

3.2.3. On-site industrial wastewater treatment and reuse

A few selected companies in Ulaanbaatar already treat their wastewater on-site (see Table 22). However, wastewater is not always re-used. Treated wastewater can be reused for toilet flushing, car washing, greeneries, and construction and for certain processes in non-food industries etc. However, currently there are no incentives to treat or reuse treated wastewater. This potential can be explored.

Premium Concrete uses approximately 52,000 m^3/yr, of which the significant majority of the water is used to make concrete (final product) and thus is not discharged. However, the remaining wastewater is treated, and of which 50% are re-used in the production process. Premium Concrete stated that if wastewater were treated to 99%, i.e. by tertiary treatment, then 100% of Premium Concrete's water demand could potentially be met by treated wastewater (instead of water from private wells). Incentives to explore this option, however, are insufficient, as the costs to source and procure treated wastewater is estimated to be higher than their current water tariff of 188.8 MNT/m^3.

MCS Coca Cola treats all its industrial wastewater to tertiary treatment. Besides, some water usage for greeneries, MCS Coca Cola cannot reuse this water as it requires drinking water quality for its production. However, MCS Coca Cola does give part of the treated wastewater away for free to cleaning companies, which collect the treated wastewater in trucks, and have made a contract with the municipality allowing fire fighters to collect the treated wastewater in case of emergency. However, only 6% (9,394 m3/yr) are reused during spring and summer (4 months), leaving a further 165,000 m^3/yr available for other uses (currently it is being discharged into the central sewerage system). While water/ wastewater reuse is considered within the water tariff scheme, the incentive is said to be minimal and insufficient to make wastewater treatment and reuse of economic interest. MCS Coca Cola engages in these initiatives as part of their global corporate responsibility scheme.

Makh Impex, a large meat producing company, currently pre-treats its industrial wastewater according to regulatory requirements before discharging it to the central sewerage system. While they could not re-use treated wastewater, they are currently speaking to neighbouring companies in their industrial cluster on investing in a centralized cluster effluent treatment plant.[44] Total wastewater amounts to approximately 240,000 m^3/yr. The companies within this cluster are all part of the food industry and thus could only use the treated wastewater for toilet flushing and for greeneries. The balance could be used in other industries close to this cluster. As in the previous cases, these companies do not have an incentive, besides goodwill, to invest in the effluent treatment plant. They did express that they would appreciate recognition and support from the government to make these plans a reality.

Table 22 Selected case studies of companies engaging in wastewater treatment and reuse

Company name	Total water usage (m^3/year)	Treated wastewater (m^3/year)	Re-used wastewater (m^3/year)	Treatment level	Water tariff (MNT/m^3)
Premium Concrete	51,853	238	119	Mechanical	188.8
MCS Coca Cola	312,0529	174,514	9,394 (not by CC)	Tertiary	1250
Makh Impex	80,400	56,280	None	Mechanical	990

Thus, it becomes apparent that while there is potential for re-using treated wastewater within industries, there is a lack of incentives to do so. With a revision of the incentive system, this solution has potential to reduce industrial fresh water withdrawal substantially. Solutions need to be factory specific and can be further explored

[44] The companies in the cluster are the following: TESO (dairy products, noodles, others), Altan Taria (flour), Talkh Chikher (large scale bakery), Suu (dairy products), Arvain undes (beverages, vodka), Khatan Suikh (meat products), Mill House (flour, noodles), Ulaanbaatar spirt (beverage), Monsuu (dairy products) and Tushiglen (pharmaceuticals).

3.2.4. Industrial water efficiency measures

As international case studies demonstrate, industrial water efficiency measures can lead to substantial water savings.

In Ulaanbaatar, key industrial water demand comes from the light (46%) and food industries (35%). Within the food industry, 28% of water use is required for the beverage industry (see Chapter 2.2.4). describes how Coca Cola's achievement improved their water efficiency between 2004 and 2012 by 21.4%, illustrating the potential efficiency gains which are achievable in the beverage industry.

However, water efficiency measures are highly sector and factory specific. Thus, no quantification on overall water savings could be made. However, it is recommended to understand the potential of industrial water efficiency measures, especially in the tannery, wool and cashmere, construction and its material industries and beverage industries.

Box 6 Water efficiency measures in the beverage industry

Globally , Coca-Cola has improved their water efficiency by 21.4% between 2004 and 2012. One key component of this achievement was the reduction or removal of water usage in the manufacturing processes.
In 2004, 2.7 L of water were required to produce 1 L of product. In 2014, only 2.03 L were required. Coca-Cola's goal is to reduce the water use ratio to 1.7 L of water per 1 L of product by 2020. The achievement of this goal would result in a 37% reduction in the water use ratio between 2004 and 2020.
Coca-Cola Mongolia currently uses 2.2L of water to produce 1 L of product.

Source: MCS Coca Cola, http://www.coca-colacompany.com/stories/setting-a-new-goal-for-water-efficiency/

3.2.5. Conveyance of Treated Wastewater to Upstream Water Source Locations

UB's primary water supplies are currently sourced from groundwater held within the alluvial aquifers associated with the Tuul River catchment; this is a renewable resource with recharge mostly provided through infiltration of perennial surface water flows. In the future, this scheme may be augmented by an off-take from a surface water reservoir created by the construction of a dam in the upper reaches of the Tuul River. It is currently envisaged that 90% of mean annual surface flow will be released from the dam to maintain downstream environmental/ecosystem services. It is anticipated that such flows will also maintain those components of the groundwater supply scheme that are located downstream.

Subject to the scale of adoption of initiatives to utilise wastewater treated at the proposed new CWWTP, for power plants and industry, a significant volume of surplus treated wastewater will become available in the near-future. Where all initiatives discussed above are pursued, this volume would be in the order of 80.91 mn m3/yr.

Table 23 Overview of supply and uses of treated wastewater from CWWTP

Supply/use of treated wastewater	mn m3/yr
Treated wastewater from CWWTP	**91.2**
Suggested usage for CHPs	**5.17**
Suggested usage for industry	**5.12**
Total remaining treated wastewater	**80.91**

Historically, wastewater has been discharged into the lower reaches of the Tuul River and consequently lost from the UB water supply cycle. Opportunities may exist, however, to retain this water within the supply cycle with diversion to the upstream water source area. Conceptually, one could consider injecting treated wastewater to replenish groundwater within, or upstream of, the existing supply bore-field areas and/or direct discharge along the upper reaches of the Tuul River or reservoir that would be created with construction of the Tuul Water Complex.

There is a significant body of experience on the use of a variety of sources of water - natural waters, urban storm water and recycled water derived from sewage treatment plants - for managing aquifer recharge (MAR). Numerous schemes, involving artificial recharge (AR) and/or aquifer storage and recovery (ASR), have been established throughout the world especially in areas of water shortage. Schemes have been developed, variously, for drinking water supplies, irrigation and ecosystem restoration projects.[45] Recent scientific knowledge of aquifer processes can support policy and management decisions and inform practical applications.[46]

Guidelines for the use of recycled water for drinking water supplies have been developed[47] and Codes of Practice established.[48]

The objectives of ASR projects are to store water when it is readily available and recover water during dry or high demand periods. The sole objective of AR wells is to replenish the water in an aquifer.

ASR can be a low cost alternative to store water compared to surface storages and can minimise losses due to evaporation. Recharge can be through infiltration basins, bank filtration, direct injection (i.e. pumping) or gravity feed into a well. Injection wells are used for AR and ASR in areas where surface infiltration is impractical. Construction of AR and ASR wells varies depending upon site-specific conditions and project objectives. Wells may either be a deep pit draining into porous layers above an underground source of drinking water or use multiple layers of casing and tubing to inject water under pressure directly into an aquifer. Potential benefits of ASR over traditional surface water storage (such as reservoirs) include:

- larger storage volumes with minimal surface footprint
- no evaporation losses
- typically lower infrastructure costs

An example of a wastewater reuse scheme being used to replenish groundwater is that found in Australia where its first full-scale Groundwater Replenishment Scheme is being built in Perth, Western Australia following the successful completion of a 3-year trial. [1]The scheme will have a capacity to recharge 14 mn m³/yr of water into groundwater supplies and can be expanded to ultimately deliver 28 mn m³/yr of water when needed. The injected water is sourced from a Wastewater Treatment Plant where rigorous treatment removes chemicals and micro-organisms (bacteria, nutrients, detergents, oils, pesticides and heavy metals). At the site, the treated wastewater is subjected to further treatment at an advanced water recycling plant; this process includes ultra-filtration, reverse osmosis and ultraviolet disinfection which removes chemicals and micro-organisms to meet Australian guidelines for drinking water. The treated water is injected into the underlying aquifer (depths >200m) through a series of bores spaced up to 750 m apart. The water is essentially stored in the aquifer and taken out some time later for further treatment and supply to the drinking water system.

- minimal environmental impact
- natural underground filtration

Box 7 Wastewater Reuse Scheme in Perth, Australia

- projects are scale-able, allowing staged implementation

Box 7 illustrates a best practice example on reusing wastewater in Perth, Australia. The potential for establishment of any large-scale groundwater replenishment scheme for UB will be constrained by relatively shallow water levels and limited thickness of the alluvial aquifers from which supplies are currently being developed. This will be exacerbated by depth of freezing during winter.

Notwithstanding these constraints, relatively small schemes operating only on a seasonal basis may – as a minimum - be sufficient to maintain water levels and provide water security in the established bore-field areas and will additionally mitigate any adverse impacts of upstream dam construction and/or reduced natural flows that may result in the future from land use changes and/or climate change. Such mitigation could also be provided by the direct discharge of treated wastewater into the upper reaches of the Tuul River tributaries and/or within the Tuul Complex dam reservoir. For the latter, such practice would additionally provide additional

[45] https://www.epa.gov/uic/aquifer-recharge-and-aquifer-storage-and-recovery

[46] Dillon, P 2016: Managing Aquifer Recharge in Integrated Solutions to Groundwater Challenges*: chapter in "Solving the Groundwater Challenges of the 21st Century", Ryan Vogwill:* ISBN 9781138027473 - CAT# K25534. Series: IAH - Selected Papers on Hydrogeology. April 21, 2016 by CRC Press.

[47] Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies, May 2008. A publication of the Environment Protection and Heritage Council, the National Health and Medical Research Council and the Natural Resource Management Ministerial Council.

[48] http://www.recycledwater.com.au

confidence in the maintenance of prescribed environmental flows and the option to release 100%, as opposed to 90%, for downstream use.

Whilst climatic conditions will present challenges and constraints, the potential benefits that would accrue from the conveyance of treated wastewater to upstream sources are significant. Concept Level assessment is considered warranted and should be undertaken within the framework of the existing, or an updated, integrated catchment management plan.

Box 7 – Wastewater reuse for replenishment of groundwater (Perth, Australia)

4. Conclusions and recommendations

The current water supply demand analysis estimates that Ulaanbaatar will fail to meet 4 mn m^3/yr (3%), 34 mn m^3/yr (28%) and 92 mn m^3/yr (43%) of total water demand in 2030 in the low, medium and high water demand scenario respectively, with given supplies. The analysis assumes that all available surface water will be used (currently water supply only includes groundwater) and that the existing bore wells will continue supplying groundwater at the current yield and quality. If these assumptions fail to hold, the water gap is expected to be even higher.

This analysis has identified and prioritised a number of concrete measures to close the gap in each scenario:

- In the low demand scenario, the implementation of water efficiency measures in CHP4 would result in cost savings (- 10.2 mn USD/ yr (EAC)), besides closing the gap. However, USUG is already engaged in NRW reduction measures. These NRW reduction measures have the potential to close 95% of the low demand gap at 7.1 mn USD/yr (EAC). The remaining 0.2 mn m3/yr could be closed by exploring solutions described in Section 3.2, or by installing water efficiency measures in CHP4 in addition.

- In the medium demand scenario, 34 mn m3/yr need to be made available to close the gap. Following the cost curve, the most cost-effective solution per m3 of water is the Tuul Water Complex. However, as the Tuul Water Complex cannot be constructed in segments, its construction would result in an excess of water available (an additional 57.3 mn m3) and would result in high total costs (EAC 46.4 mn USD/yr). Alternatively, the remaining measures analysed in the cost curve could be chosen to close the gap at less than half the cost (21 mn USD/yr). These measures include the implementation of a combination of water efficiency measures at CHPs 2, 3 &4, reuse of treated Emeelt industrial wastewater, reuse of treated CWWTP water at CHPs 2, 3 &4, reuse treated wastewater from CWWTP at industrial clusters (Bayangol, Songinokhaikhan & Khan Uul) and USUG NRW leakage reduction measures (35.6 mn m^3 vs the gap of 34 mn m^3).

- In the high water demand scenario, the only measure capable of closing the gap is the Tuul Water Complex in combination with water efficiency measures at CHP4 at 36.2 mn USD/yr (EAC).

In addition, this analysis has identified a number of measures, which have shown great success in reducing water demand/ augmenting water supply internationally, and which following a series of stakeholder engagements were found to be suitable for Ulaanbaatar's context. However, due to data constraints, no concrete technical effectiveness or costs could be assessed. These measures include: 1) Grey water reuse in commercial and residential buildings, 2) Retrofitting of appliances in commercial and residential buildings and behavioural change, 3) Industrial water efficiency measures, onsite industrial wastewater treatment and reuse and 4) Conveyance of treated wastewater to upstream source locations.

The following actions are recommended to be undertaken before identified measures are implemented:

- **Water demand validation:** The wide range of options, depending on the extent of the water gap demonstrates the necessity to gain greater clarity on current and future water demand. While an update of the current water demand data and forecast was not part of the project scope, it is strongly recommended to do so before any decisions are made on implementing identified measures.

- **Water supply validation:** To ensure the correct understanding of current and future water supplies, an audit of existing water supply sources, such as key bore wells, should be undertaken.

- **Quantification of water demand reduction/ water supply augmentation potential from additional solutions:** As mentioned above, a number of additional measures were found to be adequate for Ulaanbaatar to address the water gap. Particularly for the low and medium water demand scenarios, these options could have potential to complement the quantified options in the cost curve at a lower cost.

- **Implementation of a framework to allow for reuse of water and treated wastewater:** While regulatory and institutional structures are in place which govern the discharge of wastewater from industries and wastewater treatment plants to the central sewerage network or to nature, Mongolia is yet to define these to enable the reuse of water and treated wastewater. Further, incentives need to be put in place to make these measures attractive for water users. Close cooperation with 2030 WRG's work stream#2 on water valuation and incentives is suggested.

- **Identification of uses for excess treated wastewater:** Even after deducting treated wastewater from CWWTP being used for CHPs and industries, 81 mn m^3/year remain unused. Compared to the high water demand scenario gap of 92 mn m^3/yr, this can be considered a significant resource. Subject to downstream water requirements, options of conveying this water upstream, as was suggested in this report, could be explored further with concept level studies and integrated into the relevant strategy documents, such as the Tuul Integrated Water Management Plan.
- **Mobilization of finances:** Public-Private-Partnerships (PPPs) are at a very nascent stage in Mongolia. Given the acceptance of the Mongolian government to use PPPs as a financing modality, the development should be supported. Further, activities should be closely coordinated with active donor agencies, such as the Millennium Challenge Corporation (MCC) which is currently developing a substantial donor program in the area of water in Ulaanbaatar. Financing instruments need to be blended to reduce risks or increase returns for the investors and thus catalyse private capital.
- **Ensuring policy coherence:** While the planning cycle of the central government differs from the investment phases of the Ulaanbaatar City Master Plan 2030 which is governed by Ulaanbaatar City, it is crucial that the objectives and interests are aligned between both plans. With elections occurring in June 2016, the new government needs to ensure policy coherence and continued cooperation with Ulaanbaatar City to enable the implementation of the Ulaanbaatar City Master Plan and other ongoing projects.

Concrete implementation ideas and next steps are briefly mentioned below and outlined in more detail in Chapter 5.

- **Water efficiency measures at Combined Heat and Power Plants (CHPs):** While the political will ensures that the aged CHP# 2 and #3 remain on the grid, an overall business case needs to assert advantages of rehabilitation over construction of new CHPs.
- **Tuul Water Complex:** Further planning is subject to the results of the final feasibility report, with particular attention to environmental flows, impact on downstream water supply bore fields, Tuul river flows under different climate scenarios, evaporation rates of the dam, safeguarding measures from identified natural hazards and capital and operational costs. In addition, an environmental impact assessment is required.
- **Reusing treated wastewater for industrial/ CHP water demand:** Once the regulatory framework is implemented, exact water quality requirements as well as peak and average flow requirements for different CHPs and industries (companies) need to be ascertained. Building on this, it can be identified whether it is more cost effective to transfer lower quality effluent which will be treated at demand by receiving companies or to transfer high quality effluent which does not require any further treatment for the majority of industries. Capacity building may be required to ensure technical capability exists at Governmental level, USUG and in receiving companies.
- **Grey water reuse in commercial and residential buildings:** In cooperation with USUG and OSNAAUG suitable buildings/ clusters of buildings will be identified in which grey water reuse is found to be cost-effective. Grey water reuse could be mandated for buildings exceeding a certain size/ water usage.
- **Retrofitting buildings and behavioural change:** In cooperation with OSNAAUG and the Government of Mongolia, the current scope for water savings via retrofitting appliances can be assessed. More importantly, however, programs should be designed to address the typical increase in water consumption with increasing incomes, e.g. with various incentive schemes.

Once clarity is gained on the extent of the future water gap and on which solutions are prioritized, it is imperative to create an integrated and action plan, which takes current and future activities of other stakeholders, such as development agencies like MCC, into consideration, and maximizes synergies between all undertakings.

5. Implementation and next steps

The chapter offers some suggestions and preconditions required for the implementation of the identified measures.

5.1. Water efficiency measures at CHPs

Approach: Water efficiency measures provide a key mechanism for reducing water demand in Ulaanbaatar. It is recognized that two of three existing CHP plants are on average40 years old and thus can be considered at the end of their lifetime (CHP#2 and CHP#3). There needs to be political will and a clear business case to lead their rehabilitation over the construction of new CHPs.

Technical preconditions: The starting point for this would be to work in very close collaboration with the existing engineers at the CHP plants to gain a full understanding of the existing processes and technologies at each CHP plant. This is crucial to be able to determine the applicability of the technology options highlighted and how these could be implemented. Detailed feasibility studies and costings for each of the CHP plants should be completed.

Financing: This program could be financed with support from external funding agencies.

Stakeholders involved: Ministry of Energy, Ministry of Environment, Green Development and Tourism, UB City Governor's Office and CHP operators,

5.2. Tuul Water Complex

Approach: There is already a very well advanced programme of work that is assessing the feasibility of options for the three different dam locations. It is important that this programme of work is continued and remaining steps as has been set out for the recommended Dam #3 location to ensure that the Mongolian Government is fully satisfied with the chosen location and approach.

Technical preconditions:

There are a number of existing studies, such as the feasibility study, that have been identified and need to be completed. Focus lies on the outcome of the following assessments:

- **Environmental flows**: To fully understand the quantity, timing, and quality of water flows required to ensure a broader set of values and benefits from river and what the impacts will be from the dam and diversion. The impacts of climate change on the flows is of particular importance.
- **Sustainability of existing bore fields**: To understand the current sustainability of the existing water supply bore fields under different climate scenarios and also how this might be impacted by the dam and diversion.
- **Evaporation rates**: To fully quantify the evaporation rates that can be expected from the dam and how this might be affected by climate change.
- **Earthquake hazard**: To fully assess the earth quake risk at the dam site, the likelihood of dam collapse, the impact from flooding as a result and potential mitigation measures that could be put in place.
- **Capital and operating expenditures:** This study has used the cost estimates from the interim report of the feasibility study. In case these cost should be revised, the assessment with respect to the cost effectiveness of the Tuul Water Complex needs to be revised as well.

Following the completed feasibility study, an Environmental Impact study needs to be conducted.

Financing: This program could be financed with support from external funding agencies or via Public Private Partnership modalities.

Stakeholders involved: Ministry of Environment, Green Development and Tourism, UB City Governor's Office, USUG, Consultants undertaking current feasibility study (Yooshin Engineering Corporation, Kyunghwa Engineering Co Ltd, EcoBase and Prestige Company).

5.3. Reuse of water and treated wastewater

Recycling water/ re-using treated wastewater have several advantages: 1) can be used to reduce pressure on water supplies and 2) reduces discharge of wastewater and storm water thus reducing pressure on receiving environments.

5.3.1. Policies, regulatory framework and overall preconditions

The analysis of various recycling and reuse schemes worldwide suggests that the implementation of recycling water/ re-using treated wastewater requires certain preconditions[49]:

- **Political will and commitment to promote wastewater reuse:** Wastewater reuse was included as a measure in the Ulaanbaatar City Master Plan 2030. However, this measure was excluded in the recently published Implementation Plan of Ulaanbaatar City Master Plan 2030. Stakeholder consultations across public and private sector, as well as civil society, nonetheless, showed a strong preference for recycling water/ re-using treated wastewater as key measure.
- **A clear recycling and treated wastewater reuse policy:** The policy should be aligned to existing relevant policies, such as the National Water Program. Given the importance of reuses of water/ treated wastewater to CHPs and industries in Ulaanbaatar, a policy dialogue should be initiated between relevant ministries and stakeholders to pave the way for strong support of the new policy. Objectives of wastewater reuse need to be clearly stated, including wastewater reuse for certain purposes in CHPs and industries, as well as reusing water in commercial buildings. Roles and responsibilities of stakeholders need to be clearly defined. Some cities mandate wastewater treatment and reuse for certain water users (see Box 7). Depending on political will, it is recommended to mandate wastewater treatment and reuse for large apartment complexes as well as for large commercial buildings, including hotels, offices etc., and institutions.

Box 8: Greywater reuse in existing buildings - Case from Japan

Japan is situated in an area of the world that receives an abundant amount of rainfall. Japan's per capita rainfall is actually one-fifth of the world average due to the country's dense population (Japan for Sustainability, 2009). As a result, Japan is strained by rising freshwater demand. Compared to agriculture and industry, where the total volumes of water use have either stayed the same or are decreasing, the residential sector uses a greater share of water. From 1975 to 2002, total household water use increased by 5.0 billion cubic meters. In addition, approximately 40 percent of Japanese have experienced cuts in the supply of water. Fortunately, however, 70 percent of Japanese also support the utilization of rainwater or recycled water. The government of Japan is highly aware of the need to conserve water, so greywater technology is already a popular choice for household water needs.[50]

The Japanese government does not provide incentives for household residents to implement greywater systems in their own living spaces. Nevertheless, many people choose to implement them in urban areas because water costs are very high. Residents typically limit the use of greywater systems to simple system revolving around the bathroom toilet. Hand washing basins are placed above toilets and are connected to the same water pipes that deliver water to the urinal. When new water is delivered to the urinal, water comes out of the hand-washing basin. The water from hand washing is then used to fill the urinal as greywater. While this system is very simple, it nevertheless promotes the conservation of water for residential use.

On the other hand, the Japanese government is making an effort to implement greywater technology in more extensive urban commercial uses. In the capital city of Tokyo**, greywater recycling is mandatory for buildings with an area greater than 30,000 sum** or with a potential non-potable demand of more than 100 cubic meters per day. In order to offset the costs associated with construction,

[49] ACWUA Working Group on Wastewater Reuse, (2010), Wastewater Reuse in Arab Countries: Comparative Compilation of Information and Reference List.
[50] Kevin Chung and Meredith White, Grey Water Reuse – "Green Cities"
Grey Water for Domestic uses – Environmental Agency (2011), Govt. of UK

the Japanese Ministry of Construction provides subsidies of up to 50 percent of the capital costs. The government also assists in connecting commercial greywater systems to the public sewerage system. Therefore, while residential greywater use is minor in Japan, commercial greywater use is very extensive.

Source:

- **A legal and regulatory framework, following a risk management approach:** While regulations and standards exist on the discharge quality of treated wastewater to the environment by wastewater treatment plants and other users (MNS4943:2011) and on the discharge quality of industrial effluents to the municipal sewerage system (discharge requirements order a /11/05/A/18), there are no regulations on recycling water/ re-using treated waste water. The usage (intended or unintended) of recycled water/ treated wastewater may lead to risks related to human and environmental health. Thus it is paramount that regulations and procedures, such as National Guidelines, exist to safeguard from these risks. Effective implementation of national guidelines paramount, as errors can lead to loss of public and institutional confidence. For example, in the Netherlands a dual water scheme was mismanaged which led to lower quality river water being supplied for non-drinking residential purposes and consequently to an outbreak of illness. Future water recycling schemes were abandoned. Guidelines on how to design a legal and regulatory framework exist, which can be used as basis to create those applicable to the Mongolian context. As such, extensive guidelines have been developed and adopted in the Australian National Water Quality Management Strategy (NWQMS)[51]. The guidelines follow a risk management approach, in which risks are identified and managed in a proactive way, rather only than reacting once problems arise. Thus, the quality assurance occurs <u>before</u> usage, addressing key risks around reusing water and treated wastewater. Further, ISO standards are currently being developed for centralized and decentralized (waste-) water reuse in urban areas and for risk performance evaluation of water reuse systems (ISO/TC 282).[52]
- **A sound and integrative strategy for recycling water and wastewater reuse:** It is highly recommended to create a Master Plan on recycling and reusing treated wastewater. The Master Plan needs to be aligned with the integrated water resource management approach, i.e. with the Tuul River Basin Management Plan and additional planning documents, such as the Implementation Plan of Ulaanbaatar City Master Plan. The Master Plan should identify concrete projects – potentially building on this study – and should cover technical, institutional, legislative, social, economic, and financial and O&M aspects.
- **Good state of sewerage and wastewater treatment infrastructure:** With the imminent construction of the new Centralised Wastewater Treatment Plant (CWWTP), significant potential exists to pave the way towards re-using treated wastewater. CWWTP is planned to have tertiary treatment, providing a source of high quality effluent. While the new CWWTP is better equipped to cope with industrial effluents, it is still estimated to operate below standard if (untreated) industrial effluents continue to mix with sewage water. This problem prevails even if tanneries move to Emeelt Industrial Park and jeopardizes the attempt to significantly improve wastewater treatment in Ulaanbaatar.[53] Thus, to be able to re-use treated wastewater, the discharge requirements order on industrial discharge quality to the municipal sewers (a /11/05/A/18) needs to be strictly enforced.
- **Incentives and financing arrangements:** If not mandated by law, water users need to be incentivised to choose for reusing water/ treated wastewater. Ideally the cost of reusing water/ treated wastewater should be lower for water users than that of freshwater.
    - ***The profitability of water and wastewater reuse schemes needs to be assessed.*** If the schemes are deemed to be profitable and exceed a certain size, the option of financing the scheme via Public-Private-Partnerships can be explored. One PPP has been formed between the Tuul Songino Water Resource JSC and the Mongolian Government to treat the discharge from

51 Natural Resource Management Ministerial Council, Environment Protection and Heritage Council and Australian Health Ministers Conference (2006) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1). National Water Quality Management Strategy.

52 ISO guidelines for water reuse in irrigation have already been completed. The remaining guidelines will be completed in May 2018. More information can be found following this link: http://www.iso.org/iso/iso_technical_committee?commid=4856734

53 Artelia (2015) Feasibility study Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG-14/0221.

the current WWTP to the required quality and supply this to the CHPs. The discharge from the current WWTP would be provided by USUG free of charge. The tariff for treated wastewater for the CHPs, however, is still under discussion and it seems uncertain how this project will move on. [54] Generally, there needs to be an understanding on the share of costs which can be covered by tariffs and the share of costs which may require an upfront capital expenditure from USUG/ Government of Mongolia/ Aid organisation.

- ***The water and wastewater tariffs should be set such as to create incentives to re-use water/ wastewater.*** Currently, reclaimed wastewater reuse in Mongolia is very limited. In article 20.2 of the Law on the Natural Resources Use Fee (item 20.2.3), there is a provision on water reuse, accepting that a discount in the *water use fee* can be guaranteed if water reuse happens. An additional provision was included in Annex 2 of the Government resolution 326 from 2013, referring to potential rebates in the water resources use fee on the basis of the volume of reused water. The actual, practical procedure is very unclear though, since the regulation has not established a clear methodology to calculate the amount of water for which the water resources use fee should not be paid. Further, it was stated that as the *wastewater tariff* is based on the water usage volumes, rather than on actual wastewater discharge and quality, there is no incentive for water users to treat and/ or reuse the wastewater, as the tariff remains the same. A *polluter pays pollution tax* law was promulgated in May 2012, which introduces a tax on all water users discharging wastewater. This tax has the potential to significantly incentivize the pre-treatment and treatment and reuse of wastewater. However, to date it is still under discussion, as its application would result in unaffordable taxes for some companies, threatening their very existence. Adjustments will have to be made to create the incentive function, while allowing water users to adjust to the new situation and avoiding mass bankruptcies. It is understood that this process may most likely extend until after the elections in 2016.

Stakeholders involved: Ministry of Environment, Green Development and Tourism, Ministry of Industry, Ministry of Construction and Urban Development, UB City Govenor's Office, Industrial and Housing Associations, International Experts.

5.3.2. Reusing treated wastewater for industrial/CHP water demand

Approach: The use of treated waste water from the WWTP for CHP and industrial could provide a significant alternative water source to groundwater. The use of treated waste water would require the development of a comprehensive water reuse policy and strategy as outlined above and would necessitate political will to address perception issues with the use of this alternative sources.

Technical preconditions:

- The starting point for this would be to work in very close collaboration with the existing engineers at the CHP plants and industrial sites. It would be important to ascertain the exact water quality, average and peak flow requirements for the processes at each different site location and to determine what existing water treatment plants might be already in place (e.g. particularly for the CHP plants). Based on this additional treatment at the WWTP can be optimised to match the requirements and multiple treatment options can be considered to minimise costs. New pipelines will be required to convey the treated waste water back to each site so an optimised route should be planned to minimise total pipeline length and the associated feasibility studies undertaken. The provision of technical guidance should be provided to support this process should this be required.
- Further, required water quality differs for all water uses. While some water users require water in drinking water quality, such as uses with human contact, other water users require only lower water quality, such as construction industries. In some cities, such as in Bangalore (India), treated wastewater is distributed at a lower water quality to meet main demand, while other companies connected to the system have installed an additional water treatment plant to treat the water to their required quality. Currently it is planned to treat the effluents from the CWWTP to tertiary level. The option of re-using the treated wastewater even at a lower quality can be assessed. This may result in considerable cost savings; even below currently estimated wastewater treatment costs for the CWWTP **(see Box 8).**

Financing: This program could be financed by the budgetary provisions of the city or with support from external funding agencies. Pipeline costs could be borne by individual industries. An alternative could be a financing scheme via Public Private Partnership modalities in which the private entity provides and distributes treated wastewater. The latter approach is currently being tested by Tuul Songino Water Resources JSC, which

[54] Stakeholder interview with USUG (7th April 2016)

is attempting to form a PPP to provide treated wastewater to CHPs in Ulaanbaatar. While it is said that there has been an agreement already to supply Tuul Songino Water Resources JSC with effluent from the current CWWTP free of cost, there are disagreements on future pricing of this new water resources (see section 5.5). [55]

Stakeholders involved: Ministry of Energy, Ministry of Environment, Green Development and Tourism, Ministry of Industry, UB City Governor's Office, Industry Associations, key industrial water users and CHP operators,

Box 9: Customized treated wastewater reuse - A Case from Bengaluru, India[56]

Project location: Bengaluru

Project overview: Bangalore International Airport which was being planned in the city was located towards North of the city which had severe water scarcity challenges and the cost of fresh water from the utility was higher. There were many industrial units in the surrounding areas which also faced similar challenges. The Government came up with an option of providing treated wastewater for industries and to the Airport at lesser cost.

The recycled water from the STP is supplied to

- International airport at Devanahalli
- Bharat Electronic Limited factory
- Indian Tobacco Company
- Rail Wheel Factory
- Indian Air Force

The challenge: There was an ever increasing demand for water due to the growth of the Bengaluru city. The cost of fresh water was increased to industrial consumers to cross subsidize the domestic consumers. Some of the large industrial units in the city installed their own STPs to use treated water for non-potable industrial purposes. However the smaller/medium industries & industries in the northern part of Bangalore were deprived of low cost water options. Further, a new airport was under construction and was located far from the city and has water scarcity and requested government to provide both water. The cost of water for Airport was higher and the Airport company was also looking for a cheaper option.

The solution: Bangalore Water Supply & Sewerage Board (BWSSB - water utility of Bangalore City) decided to construct 10 MLD STP (Tertiary treatment) in the north part of Bangalore to provide one standard quality of water for industries to buy at lesser cost. The quality needs of some of the industries were not matching the output quality of the STP and the industries decided to have a Water Treatment facility to treat the water to desired levels. In this option, the treated water from STP was at least 50% the cost of fresh water. BWSSB decided to lay pipeline up to the airport providing treated water and enroute it provided access to the industries which were interested in using treated water at an agreed price.

Implementation: The STP was designed, constructed and commissioned by Subhash Projects and Marketing Ltd (SPML). It had partnered with OTV, a French company dealing in water, sewage and waste water engineering .The concession authority was BWSSB.

Costs of measure:

Capital cost: USD 5.8 million for construction of Sewerage Treatment Plant (STP) of capacity 3.65 mn m3/year

Operational and maintenance cost –

- Power charges- USD 0.13 million per year
- Cost of manpower utilized- USD 0.06 million per year
- Chemical charges- USD 0.05 million per year
- Total O&M charges- USD 0.2 million per year

Who bears the costs: The STP was designed and constructed by SPML with 52% loan support from French Government Funding. The remaining funds required for this project have been sourced through Karnataka Urban Infrastructure Development and Finance Corporation Ltd (KUIDFC)/Housing and Urban Development Corporation (HUDCO) under Megacity Scheme.

Results: Monthly revenue generated by BWSSB through sale of treated water is USD 0.04 million per month. The supply rates are as follows:

[55] Presentation by Tuul Songino Water Resources JSC (2009) at the 3rd Annual China Water Congress. Tianjin. China & Interview with Chief Engineer Batsukh (USUG) on 7 April 2016.

[56] Wastewater recycling for non-potable uses- Bangalore experience- Chief Engineer, BWSSB, Bangalore bwssb.gov.in, spml.co.in, Potential of Sewerage Treatment Plants in Bangalore- Executive Engineer, BWSSB , Recycle and reuse of wastewater initiatives in Bengaluru- Chief Engineer, BWSSB

- USD 0.23 per m3- supplied at the plant site
- USD 0.38 per m3- supplied through pipeline laid by BWSSB

Source: Wastewater recycling for non-potable uses- Bangalore experience- Chief Engineer, BWSSB, Bangalore; bwssb.gov.in, spml.co.in, Potential of Sewerage Treatment Plants in Bangalore- Executive Engineer, BWSSB , Recycle and reuse of wastewater initiatives in Bengaluru- Chief Engineer, BWSSB

5.3.3. Grey water reuse in residential & commercial buildings

Approach: Use of grey water within buildings and apartments could be driven through policy interventions that can mandate buildings/apartments generating more than specific quantities of wastewater (60 m3/day) to install community STPs that would generate reusable quality water. This would be also driven by the potential savings in water tariff with reduction of fresh water demand. Also, such buildings should be mandated to have twin piping system that would allow for use of treated wastewater for specific purposes such as flushing, gardening etc.

Technical Pre-conditions: The starting point of this intervention is to identify the optimal size of community level STPs suitable for UB conditions and identifying such buildings/cluster of buildings that could install community level STPs. Cooperation with OSNAAUG/USUG would be critical to assess the implementability of this solution. It also requires defining the technology of STPs to be installed by apartments and buildings in Ulaanbaatar. The technology has to be carefully chosen considering the capital cost, operating cost, ease of operations, availability of technology, availability of spares, ease of maintenance etc. Accordingly, such technology should be made available extensively in the city for users to install and operate STPs. The Government of UB City should also define the standards of treated water that would be fit for re-use and should keep in place a mechanism to monitor the operations of community STPs.

Financing: The individual apartment level investments on STPs could be borne by households and investments required to attract technology players for supplying STP technologies and manpower for operations could be initiated by City Government of Ulaanbaatar or Government of Mongolia.

Stakeholders involved: OSNAAUG, USUG, Ministry of Environment, Green Development and Tourism, Ministry of Construction and Urban Development, UB City Governor's Office, Housing Associations, Owners/ Managers of residential and commercial buildings, International Experts.

Regulatory Enforcement of Community level STPs – Case of Bangalore City

The Karnataka State Pollution Control Board (KSPCB) is the state authority for prevention and mitigation of pollution. It is a state authority that operates under the guidance of Central Pollution Control Board and Ministry of Environment and Forests (MoEF), Government of India. Community scale STPs (CSTPs) (small scale STPs built within residential apartments) were made mandatory by KSPCB through various notifications that are listed below:

- In 2006, the MoEF issued the Environment Impact Assessment Notification[57] that brought large residential complexes that have over 5,000 sq. ft. built up area under the purview of Karnataka State Pollution Control Board. Such apartment complexes had to obtain the consent of KSPCB to discharge and continue to discharge sewage Invalid source specified..
- The Bruhat Bangalore Mahanagara Pallike classified residential complexes with more than 50 houses as domestic bulk generators of waste.
- In 2007, the state government decided to relax the norm by exempting units with less than 20,000 sq. ft. built up space in areas with sewers from consent for discharge of sewage (GoK 2010)[58]. Thus the rule applicable to projects with,
  - more than 50 units/flats/apartments
  - more than 20,000 sq. ft. built space in sewered area, and
  - more than 5000 sq. ft. built space in non sewered area
- The Karnataka Water Rules section 25,26 mandates residential complexes to obtain Consent for Establishment and Consent for Operation of discharge of sewage at standards specified by the KSPCB, necessitating construction and operation of STPs within campus.
- The quality standard for reuse of treated water as per KSPCB's official memorandum[59] is as follows
  - pH : 6 to 9
  - BOD : <= 10 mg/L
  - Turbidity : <= 2 NTU

[57] http://envfor.nic.in/legis/eia/so1533.pdf
[58] http://bbmp.gov.in/documents/10180/2094243/Town+Planning.pdf/3724a6d9-f074-4ebe-8865-b38c293790bd
[59] KSPCB 2012

- E-Coli : NONE

With the above regulations, any new building while submitting its plan for approval has to make provision for STP (if the building falls under the such category) without which the city authorities will not give permission to construct the building. Further, for the existing complexes and buildings, a team of engineers from KSPCB randomly inspect the apartments and check if they have installed STPs. If an apartment is found in violation, KSPCB will issue notices, after which the owners can be booked under the Water (Prevention and Control of Pollution) Act, 1974 and electricity supply may be cut for non-compliance.

Source:

5.4. Retrofitting buildings and behavioural change

Approach: First, a water audit of OSNAAUG's network and identification of potential for retrofitting and behavioural change initiatives is required. Following this, programmatic approach is recommended for the entire city to adopt retrofitting to reduce water consumption. This programme should be driven by the Governor's Office of Ulaanbaatar City. The programme could cover the following components:

- Replacement of existing lesser efficient appliances with higher efficiency, low flow units - This program is to be supported with availability of higher efficient units/appliances in the market. UB City could come up with a technical team to assess and the technicalities of low flow, high efficiency units and could identify the models & brands providing such units and can provide rebate to the users who come forward for the replacement of toilet seats. The rebate could be provided at the point of sale or a mechanism is to be arrived at to appropriate rebate (voucher system).
- Water audits at apartments – There could be provision for free water audits at household level. This audit could identify the extent of leaks from the mains to the household level and can recommend water efficient fittings to reduce consumption.

Technical pre-conditions: Implementing this solution would require defining technical specifications that could be categorised as efficient systems. Further, it requires identifying the brands, models that comply with the defined specifications of water consumption and fall under the category of high efficient system. The water auditing needs to be backed up with availability of technical skills in Mongolia to carry out apartment level water audits. This capacity could be enhanced with international tie-ups on technology.

Financing: This programme could be financed by the budgetary provisions of the city or with support from external funding agencies.

Stakeholders involved: OSNAAUG, Ministry of Environment, Green Development and Tourism, Ministry of Construction and Urban Development, UB City Governor's Office, Housing Associations, International Experts.

Box 10 Water saving initiative in New York City

Since the mid-1970s, New York City's (NYC) water facilities were exceeding safe yields, and by 1990 three of the city's wastewater treatment plants were also exceeding permitted flows. Water and sewer rates were skyrocketing and the City faced the need for major water infrastructure projects. In 1992, NYC conducted a cost analysis of supply alternatives and found conservation to be the most economical option.

NYC's conservation plan had four main elements that are described below:

- **Education program -** The City conducted door-to-door water efficiency surveys to 220,000 homeowners. Citizens were provided with educational information, free water saving fixtures, and a free leak inspection. The City also provides Home Water Saving Kits free of charge upon request and offers water conservation classes to building managers.
- **Metering -** The City installed meters at unmetered properties. Water savings from meter installation equal about 0.75 mn m3/day.
- **Leak Detection -** The City uses computerized sonar leak detection and advanced flow monitoring programs to help detect leaks. Water savings from the leak detection program equate to about 0.15 mn m3/day.
- **High Efficiency Toilet Program -** The City replaced over 1.3 million toilets with high efficiency toilets that use 1.6 gallons of water per flush. This program saves about 0.28 mn m3/day.

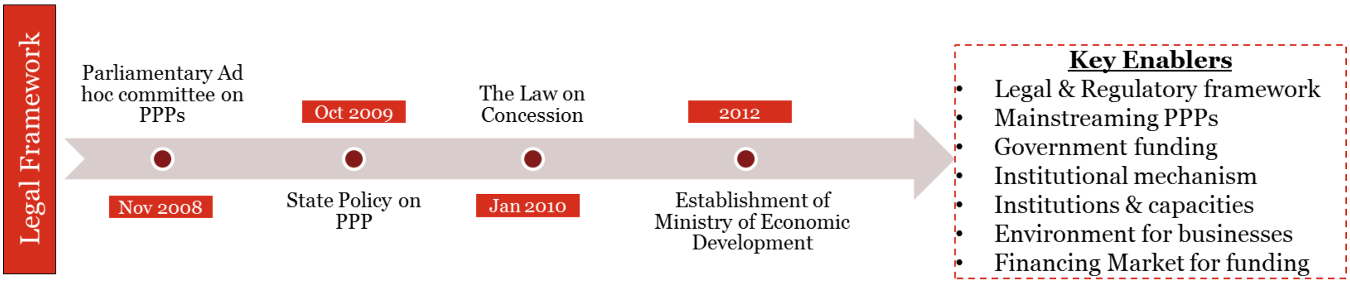
Overall the per capita use in NYC dropped from 0.73 m3/day in 1991 to 0.63 m3/day (about 14 percent) in 1998. Customers also saved between 20 and 40 percent in total water and wastewater bills.

Source: http://www.nyc.gov/

5.5. Unlocking PPPs as mode of implementation for Ulaanbaatar

Considering the extent of investments required by the government to implement projects, it becomes critical for the government to consider alternate sources of financing long term infrastructure investments. PPPs have been accepted widely across the world as an alternative to public sector investment in infrastructure which attracts private sector investment as well as brings in technical capabilities of private sector. The Government of Mongolia has taken reforms in laws and regulations to facilitate private investments through PPPs in the country. The "Law on Concession" is the current legal framework that enables PPP projects in the country which was passed in the Cabinet in 2010. However, PPPs are still in nascent stage in Mongolia with only few projects being implemented on Built Transfer (BT) basis with less or no transfer of risks to the private sector.

Figure 16 Timeline of the legal framework around PPPs in Mongolia



The current environment in Mongolia needs to be supported with enablers for mainstreaming of PPPs in the country. Some of the key enablers for PPPs are:

A. **Legal & Regulatory Framework** – The existing "Law on Concessions" is the only legal document on PPPs in the country. Given the nature of services of PPP projects, the public sector sponsoring agency/department requires a legal-regulatory and policy framework to enter into contracts based on :

   i. Transparent and objective processes for project and concessionaire selection with funding support from government as an option;

   ii. Clearly defined approval, compliance, and oversight jurisdiction over PPP projects, especially with regard to the rights of municipal and local government authorities; and

   iii. Clear definitions of the roles, responsibilities, and rights of parties in the governing instruments (concession agreement, regulations, etc.).

B. **Support for mainstreaming PPPs** - There is a need to develop a PPP manual based on the policy guidelines that would provide guidance on the development of PPP projects. Further this could be supplemented with PPP toolkits, standardized documents (RFPs, Concession Agreements etc. specific to sectors), and successful PPP case studies from around the world to guide or give direction to implementing departments/agencies on procedural and operational aspects of PPP implementation.

C. **Strong institutional mechanism** - There seems to be lack of clarity among the departments, agencies involved in managing infrastructure of the UB City and Ulaanbaatar City Development (UBDC) (nodal Corporation for all PPP projects) on aspects related to the ownership of project, process to be adopted, approvals required etc. It is important to streamline institutional aspects for smoother processing of PPP projects within the government circles which could be done through defining processes that could be adopted by implementing agencies, line departments, and concerned ministries on implementing projects through PPPs without disturbing the existing powers, rights and obligations of all concerned in the process.

D. **Improving enabling environment for businesses**– One of the key partners in PPPs is the private sector which brings in investment and technical know-how into the project. Considering the extent of risks to be borne by the private sector in the project, it is important to have conducive environment for the private sector to participate in PPPs in Mongolia. This could be done through business friendly policies like – easy exit policies upon completion of the project, availability of long term financing, tax exemptions for certain infrastructure projects etc.

E. **Developing strong financing market to fund infrastructure –** It is important to have alternate funding options to finance infrastructure projects through PPPs as the private sector is likely to depend mostly on market borrowings. The current status of financial market in Mongolia need to be strengthened to support financing of private sector investments through long term financing options and provisioning of raising bonds by private sectors in the market.

F. **Financial support from the government -** The "Law on Concessions" provisions for financial support from the State to the concessionaire. However it does not define the extent of financial support that can be rendered and the conditions for getting the financial support. There is a need to create a mechanism for providing financial support for projects that are inherently unviable (i.e. the revenues expected from all sources of the project facility is not able to cover the project cost and expected return to the private sector investor) through provision of viability gap funding . This could be guided and monitored at the central government level with a defined cap for such support.

G. **Blending financial instruments to catalyse private capital** – Besides the development of a strong financing market and financial support from the government, finding the right blend of these and additional financial instruments can catalyse private capital. To mobilise private capital for water related infrastructure projects in Mongolia, support is required either in the form of reducing risks or in increasing returns. For example, financial support via grants for the Government of Mongolia to absorb transaction costs or certain risks could improve investment viability. Incorporating debt or equity into the capital structure of any project with highly flexible terms can unlock financial returns. Further, these instruments could be supplemented in cooperation with development agencies, such as MCC, to provide additional funding options and thereby increasing the availability of funding for the private sector developers.

The basic financial instruments that could be explored include grants, guarantees, debt and equity.

1. **Grants** - A financial award with no expectation of returns over a period of time. A grant could be in the form of –
    a. ***Technical Assistance*** - Technical assistance (TA) would be required in the water sector as the solutions identified to meet the demand supply gap are technology and knowledge intensive and thus would require investment in terms of bringing in newer technologies into the Mongolian context, developing private sector interest in the market, attracting new technologies from international players, etc. Further, additional studies and policy changes are required to allow for effective implementation of the identified solutions to close the water gap. Once completed, this will set the stage for actual implementation of projects and would attract private investment. Further, TA could also be used to provide support during incubation phase of the project in form of operational assistance, training and other professional assistance for developing new projects.
    b. ***Risk Underwriting*** - Risk underwriting reduces the specific risks associated with transaction which can be in form of direct compensation for specific negative events or providing financial support in lieu of risks in the project which would make project unviable.
2. **Guarantees** – Guarantees provide protection from various forms of risks which could result in capital losses for the private sector.
   Debt – A debt is lent money for repayment at a later date, usually with interest.
3. **Equity** – Equity is the ownership in a project or company involved in project development

Stakeholders involved: UBDC, UB City Governor's Office, USUG, OSNAAUG, Ministry of Energy, UBDS, Millennium Challenge Corporation (MCC), Asian Development Bank (ADB), JICA, IFC, (International) companies providing services in water sector. .

Appendix A. - Annexes

A.1. Overview of consulted stakeholders and stakeholder consultation process

The stakeholder consultation process consisted of the following activities:

- Kick off meeting: 4 April 2016 at Khangarid Palace, Ulaanbaatar City Governor's Office, Ulaanbaatar
- Focus Group Discussion (Private Sector): 12 April 2016 at PwC Office, Ulaanbaatar
- Focus Group Discussion (Civil Society): 13 April 2016 at PwC Office, Ulaanbaatar
- Results presentation to 2030 WRG workstream members and MEDGT: 10 June 2016 at MEGDT, Ulaanbaatar
- Capacity building on hydro-economic analysis (2/2): 8 June 2016 at Prestige Engineering LLC office, Ulaanbaatar
- Capacity building on hydro-economic analysis (1/2): 9 June 2016 at IFC office, Ulaanbaatar
- Final conference: 22 June 2016 at Best Western, Ulaanbaatar

Please see an overview of stakeholders attending the above mentioned activities in the tables below.

Table 24 Overview of interviewed stakeholders

#	Name	Organisation	Organisation type	Position
1	Khishigt	Newcom Group - CHP V	Government	Project Director
2	Sevjidmaa	MEGDT	Government	Specialist for waste water issues
3	Khorolmaa	MEGDT	Government	Specialist for environmental standards
4	Enkhtaivan	MoE	Government	Senior Specialist
5	Badrakh	National water committee	Government	Chairman
6	Tsedemdamba	OSNAAUG	Government	Water supply specialist
7	Purevjamts	OSNAAUG	Government	Heat supply senior specialist
8	Ankhbat	Office of the Capital City Governor	Government	Senior Specialist, Strategy Policy and Planning Dept.
9	Oyunjargal	Master Planning Agency of Capital City	Government	Water supply, sewerage specialist
10	Batsukh	USUG	Government	Chief Engineer
11	Chimgee	USUG	Government	Wastewater Specialist
12	Altangerel	UB Heating Network	Government	Chief Engineer
13	Ms. Maruyama	JICA	NGO, Int. Organisations	Project Formulation Adviser
14	Batjargal	Association of Hydrogeologists	NGO, Int. Organisations	Director
15	Solongo	Rivers without Boundaries	NGO, Int. Organisations	Specialist
16	Purevdorj	WWF	NGO, Int. Organisations	Freshwater & Climate Change Specialist
17	Narantuya	Makh Impex	Private Sector	Water supply engineer

18	J. Ariunjargal	MCS Coca Cola	Private Sector	Technical manager
19	Budkhand	Premium Concrete	Private Sector	Chief Accountant
20	Sugardorj	MCS Sky resort	Private Sector	Environment & Water supply engineer
21	Davaa	Gobi Cashmere	Private Sector	Environmental technician
22	Ganzorig	Prestige Engineering	Private Sector	Chief Executive Officer
23	Saranmandal	Prestige Engineering	Private Sector	Project manager
24	Enkhbold	UBDC	Private Sector	Specialist, PPP Department
25	Sugarsuren	UBDC	Private Sector	Business Development Director
26	Enerelt	UBDC	Private Sector	Investment Director
27	Solongo	Goyo cashmere	Private Sector	Executive Director

Table 25 Overview of participants of kick-off meeting

#	Person	Organisation	Organisation Type	Position
1	Altangerel	UB City Gov	Government	Specialist
2	Ankhbat	UB City Gov	Government	Senior Specialist, Strategy Policy and Planning Dept.
3	Badrakh	National Water council	Government	Chairman
4	Batsukh	USUG	Government	Deputy Director
5	Dambasuren	UB City Gov	Government	UB city green development plan
6	Dolgorsuren	Tuul RBA	Government	Head of RBA
7	Erdenetsetseg	UB Grid planning dept	Government	Water supply engineer
8	Oyunjargal	UB City Planning Dept.	Government	Water supply and sewerage engineer
9	Saikhanjargal	MEGDT	Government	Specialist of water issues
10	Sandagdorj	UB city Gov	Government	Specialist
11	Unen	USUG	Government	Director
12	Dorjsuren	2030 WRG	NGO, Int. Organisations	Mongolian Representative
13	Enkhtuya	The Nature Conservancy	NGO, Int. Organisations	Director
14	Erdene	Environmental Citizens Council	NGO, Int. Organisations	Director
15	Ganzorig	Prestige Engineering	Private sector	CEO
16	Mark Newby	OT	Private sector	Head of Environmental Dept.
17	Myagmarjav	MCS LTD	Private sector	CEO
18	Saranmandal	Prestige Engineering	Private sector	Project Manager

Table 26 Overview of participants at the Focus Group Discussion (Private Sector)

Name	**Organisation**	**Organisation type**	**Position**
Narantuya	Makh Impex	Private Sector	Water supply engineer
J. Ariunjargal	MCS Coca Cola	Private Sector	Technical manager
Sugardorj	MCS Sky resort	Private Sector	Environment & Water supply engineer
Davaa	Gobi Cashmere	Private Sector	Environmental technician
Solongo	Goyo cashmere	Private Sector	Executive Director
Budkhand	Premium Concrete	Private Sector	Chief Accountant

Table 27 Overview of participants at the Focus Group Discussion (Civil Society)

Name	Organisation	Organisation type	Position
Batjargal	Association of Hydrogeologists	NGO, Int. Organisation	Director
Solongo	Rivers without Boundaries	NGO, Int. Organisations	Specialist
Purevdorj	WWF	NGO, Int. Organisations	Freshwater & Climate Change Specialist

Table 28 Overview of participants at initial presentation of results for 2030 WRG work stream members

#	Name	Organisation	Organisation type	Position
1	J. Davaasuren	MEGDT	Government	Head of Water Resources Dept.
2	Puntsagsuren	MEGDT	Government	Specialist in Water Resources Dept.
3	Otgonbayar	MEGDT	Government	Specialist in Water Resources Dept.
4	Badamdorj	MEGDT	Government	Specialist in Water Resources Dept.
5	Ankhbat	UB City Gov	Government	Senior Specialist, Strategy Policy and Planning Dept.
6	Batima	ADB	NGO, Int. Organisations	Mongolian Water Forum
7	Erdene	Environmental Citizens Council	NGO, Int. Organisations	Director
8	Purevdorj	WWF	NGO, Int. Organisations	Freshwater & Climate Change Specialist
9	Myagmarjav	MCS Coca Cola	Private sector	CEO
10	Mark Newby	Oyu Tolgoi	Private sector	Head of Environmental Dept.

Table 29 Overview of participants attending the capacity building session on hydro-economic analysis

#	Name	Organisation	Organisation type	Position
1	J. Davaasuren	MEGDT	Government	Head of Water Resources Dept.
2	D. Chuluunkhuu	MEGDT	Government	Specialist in Water Resources Dept.
3	H. Sevjidmaa	MEGDT	Government	Specialist in Water Resources Dept.
4	B. Purevjamts	MEGDT	Government	Specialist in Water Resources Dept.
5	P. Badamdorj	MEGDT	Government	Specialist in Water Resources Dept.
6	Ch. Puntsagsuren	MEGDT	Government	Specialist in Water Resources Dept.
7	M. Suvd	Tuul RBA	Government	Specialist
8	B. Gantuya	USUG	Government	Technology improvement project engineer
9	H. Otgonbayar	USUG	Government	Economist
10	P. Batima	ADB	NGO, Int. Organisations	Director of Mongolian Water Forum
11	D. Batjargal	Association of Hydrogeologists	NGO, Int. Organisations	Director
12	B. Erdenechimeg	Institute of Geo-ecology	NGO, Int. Organisations	Specialist
13	Sh. Baranchuluun	University of Argiculture	NGO, Int. Organisations	Department Head
14	Sh. Munkhbayar	Nomin-Us LLC	Private sector	CEO

15	D. Puntsagdorj	Tanan Impex	Private sector	Specialist
16	N. Munkhbaatar	Tanan Impex	Private sector	Specialist
17	I. Battsetseg	Water Resources Corp. Project	Private sector	Specialist
	In addition, there was a separate training session at Prestige Engineering, in which 9 employees of Prestige attended.			

A.2. Water supply and water demand

A.2.1. Water supply estimates

Table 30 Overview of surface and groundwater data

	Surface water						**Groundwater**			
mn m³/year	**Surface water resource 1)**		**Ecological resource 1)**		**Possible use of resource 1)**		**Possible resource for use 1)**	**Resource for use 1)**	**Groundwater reserves (Resolution 2015/4)2)**	**Total water availability**
0	**P=50 %**	**P=90 %**	**P=50 %**	**P=90 %**	**P=50 %**	**P=90 %**				
2010	536.82	298.3326	506.9403	282.1093	29.8797	16.22327	121.6	138.3	103.62	119.85

Sources: 1) Data derived from MEGDT (2012) Integrated Water Management Plan of Mongolia, 2) Water Reserve Committee Resolution No. 2015/4 approved by Munkh-Erdem, Head of Water reserve committee, MEGDT, date: 7 September 2015

Note: For this report the updated groundwater reserve estimates from Water Reserve Committee Resolution No. 2015/4 were chosen, instead of the data from the MEGD (2012) Integrated Water Management Plan of Mongolia report. The groundwater reserve estimates of both sources cover the same area (Ulaanbaatar and upstream Tuul).

Table 31 Groundwater reserve estimates

Methodology		***Hydrodynamic method***					
#	Source name	GW reserve category (m3/day)			Potential reserve (Guess)	Total reserve	
		Cat - A	Cat- B	Cat- C	Category-P	m3/day	mn m3/yr
1	Upstream	40,953.60	23,328.00	9,072.00		73,353.60	26.77
2	Gachuurt				3,924.00	3,924.00	1.43
3	Central	32,928.00	35,160.00	25,752.00		93,840.00	34.25
4	Factory			16,027.20		16,027.20	5.85
5	Yarmag			14,428.80		14,428.80	5.27
6	Meat factory			8,018.62		8,018.62	2.93
7	Airport			8,640.00		8,640.00	3.15
Central water supply total reserve		73,882.00	58,488.00	81,939.00	3,924.00	218,232.20	79.65
8	CHP-2			4,795.20		4,795.20	1.75
90	CHP-3			33,868.80		33,868.80	12.36
10	CHP-4			30,931.20		30,931.20	11.29
Industrial water supply total reserve				69,595.00		69,595.20	25.40
Total amount		73,882.00	58,488.00	151,534.00	3,924.00	287,827.40	105.06

Source: Water Reserve Committee Resolution No. 2015/4, approved by Munkh-Erdem, Head of Water reserve committee, MEGDT, date: 7 September 2015

Note: Due to high uncertainty, Category P aquifers, i.e. Gachuurt, were not included in the water supply estimates for this report. These can be added once water resource potential is confirmed.

A.2.2. Water and wastewater tariffs

A.2.2.1. Direct abstraction

The tariffs for direct water abstraction are calculated based on Government Resolutions 326, 327 and 302. They apply to Tuul River Basin (Ulaanbaatar).

Water use purpose (direct abstraction)		MNT/m3 Water Tariff (SW)	MNT/m3 Water Tariff (GW)
For every cubic meter of water used for drinking and domestic use of population		265.10	944.00
For every cubic meter of water used for heavy industry		26.51	188.80
For every cubic meter of water used for construction and construction material manufacturing		26.51	188.80
For every cubic meter of water used for auto road and repair		26.51	188.80
For every cubic meter of water used for light industry		26.51	94.40
For every cubic meter of water used for food manufacturing	Vodka, beer, alcoholic drink	26.51	188.80
	Soft drink, pure water	26.51	94.40
	Bread, candy, pastry and other	15.91	56.64
For every cubic meter of water used for mining	Mining and concentrating mineral resources	212.08	1,510.40
	Concentrating copper concentrate and fluorspar	185.57	1,321.60
	Draining of mine extracting for domestic supply	39.77	212.40
	Exploration drilling	212.08	1,510.40
For every cubic meter of water used for electricity/energy manufacturing		13.26	70.80
For every cubic meter of water used for agronomy/farming production		2.65	94.40
For every cubic meter of water used for green facility		2.12	7.55
For every cubic meter of water used for animal husbandry		10.60	37.76
For every cubic meter of water used by For every cubic meter of water used by citizens, entities and organisations engaged in production, service and economy of for other profit making		18.56	99.12

A.2.2.2. USUG water and wastewater charges

Table 32 USUG service tariff for households

№	Service type		Unit	Price MNT (excl. VAT)	Price USD (excl. VAT)	Resolution
1	**clean water**	Metered	1 m3	500	0.25	Water Service Regulation Committee (2015/7/31 No. 44)
		Not- metered	1 person	6500	3.26	
2	**Wastewater**	Metered	1 m3	310	0.16	
		Not- metered	1 person	350	0.18	

Table 33 USUG water tariff for businesses (VAT excluded)

No.	Service type	Unit	Price MNT	Price USD	Resolution
Clean water	Factory, business, offices	1m3 (1000 l)	950	0.48	Water Service Regulation Committee (2014/6/13 No. 23)
	Beverage factories	1m3 (1000 l)	1250	0.63	
	Wool, cashmere, tannery, gut processing	1m3 (1000 l)	950	0.48	
Wastewater	Factory, business, offices	1m3 (1000 l)	750	0.38	
	Beverage factories	1m3 (1000 l)	960	0.48	
	Wool, cashmere, tannery, gut processing	1m3 (1000 l)	1500	0.75	

Table 34 USUG base tariff for water usages by businesses (excluding VAT)

№	Diameter of input pipe (mm)	Price (MNT)	Price (USD)	Resolution
1	15	4400	2.21	Water Service Regulation Committee (2014/6/13 No. 23)
2	20	6000	3.01	
3	25	9200	4.61	
4	32	13680	6.86	
5	40	20400	10.23	
6	50	32080	16.09	
7	65	39840	19.98	
8	80	52720	26.44	
9	100	76400	38.31	
10	125	93200	46.74	
11	150	126480	63.43	
12	200	156000	78.23	
13	250	215040	107.84	
14	300	284400	142.63	
15	400 +	384000	192.58	

A.2.2.3. OSNAAUG service charges

Table 35 OSNAAUG service charges for households

Ng	Service type		Unit	Tariff (MNT)	Pipe leakage (MNT)	VAT	Total tariff (MNT)	Total tariff (USD)	Reference to resolution
1	Apartment heating (dormitory, basement, bathroom heating)		MNT/m2	460.00		46.00	506.00	0.25	Regulation committee resolution of 2015/7/6 No. 204, effective
			MNT/Gkal	11356.00	567.80	1192.38	13116.18	6.58	
			MNT/GJ	2713.00	135.65	284.87	3133.52	1.57	
2	Heat used for	in heating season	MNT/person / month	1700.00		170.00	1870.00	0.94	

	domestic hot water	in non-heating season	MNT/person / month	2551.00		255.10	2806.10	1.41	from 2015/7/25
		by water consumption	MNT/m3	1484.00		148.40	1632.40	0.82	
		by measurement	MNT/Gcal	13023.00	651.15	1367.42	15041.57	7.54	
			MNT/GJ	3110.00	155.50	326.55	3592.05	1.80	
3	Base tariff for heating service	area up to 40m2	Household/ month	3000.00		300.00	3300.00	1.65	Regulation committee resolution of 2015/7/6 No. 204, effective from 2015/7/25
		between 41m2 area 80 m2	household/ month	5000.00		500.00	5500.00	2.76	
		area over 81 m2	household/ month	10000.00		1000.00	11000.00	5.52	
4	Clean water	metered	m3	500.00		50.00	550.00	0.28	Regulation committee resolution of 2015/7/31 No. 44, 45, effective from 2015/9/1
		non-metered	person/ month	4485.00		448.50	4933.50	2.47	
5	Wastewater	metered	m3	310.00		31.00	341.00	0.17	
		non-metered	person	2415.00		241.50	2656.50	1.33	
6	Base tariff for water		household	2500.00		250.00	2750.00	1.38	Regulation committee resolution No. 23 from 2014/6/13

Table 36 OSNAAUG service charges for businesses

No.	Service type		Unit	Price (MNT)	Pipe leakage	VAT	Total price MNT	Total price USD	Reference to resolution
1	Heating service for factories and businesses	Heating	MNT/m3	429.00		42.90	471.90	0.24	Regulation committee No. 204 from 2015/7/6 (effective from 2015/7/25)
		Heating and energy used for heating hot water	MNT/Gcal	27692.00	1384.60	2907.66	31984.26	16.04	
			MNT/GJ	6615.00	330.75	694.58	7640.33	3.83	
2	Basement, toilet		MNT/m2	460.00		46.00	506.00	0.25	
3	Fans		MNT/Gcal	14093.00		1409.30	15502.30	7.77	
			MNT/GJ	3366.00		336.60	3702.60	1.86	
4	Energy used for heating office hot water		MNT/person	5414.00		541.40	5955.40	2.99	
			MNT/m3	1873.00	93.65	196.67	2163.32	1.08	
	Hot water for technology use (based on capacity of engineering design)		MNT/GCal	14093.00		1409.30	15502.3	7.77	
			MNT/GJ	3366.00		336.60	3702.6	1.86	
5	Clean water	Factory, businesses, offices	m3	950.00		95.00	1045.00	0.52	Regulation committee No. 41 from 2015/7/31 (effective
		Beverage factories, car wash		1250.00		125.00	1375.00	0.69	

		Cashmere, wool, tannery, gut processing		950.00	95.00	1045.00	0.52	from 2015/9/1)
6	Wastewater	Factory, businesses, offices	m3	720.00	72.00	792.00	0.40	
		Beverage factories		960.00	96.00	1056.00	0.53	
		Cashmere, wool, tannery, gut processing, car wash		1500.00	150.00	1650.00	0.83	
7	Base price	Input line diameter (mm)	15	4400.00	440.00	4840.00	2.43	Regulation committee No. 23 from 2014/6/13
			20	6000.00	600.00	6600.00	3.31	
			25	9200.00	920.00	10120.00	5.08	
			32	13680.00	1368.00	15048.00	7.55	
			40	20400.00	2040.00	22440.00	11.25	
			50	32080.00	3208.00	35288.00	17.70	
			65	39840.00	3984.00	43824.00	21.98	
			80	52720.00	5272.00	57992.00	29.08	
			100	76400.00	7640.00	84040.00	42.15	
			125	93200.00	9320.00	102520.00	51.41	
			150	126480.00	1264800	139128.00	69.77	
			200	156000.00	15600.00	171600.00	86.06	
			250	215040.00	21504.00	236544.00	118.63	
			300	284400.00	28440.00	312840.00	156.89	
			400 and above	384000.00	38400.00	422400.00	211.84	

A.2.3. Wastewater treatment

Table 37 Overview of existing wastewater treatment plants in Ulaanbaatar

WWTP name	Location	Capacity m3/ day	Category of treatment	Where does wastewater dump into?	Equipment status	Further action
Biocombinat WWTP	Khan-Uul, Ulaanbatar	80-90	mechanical, biological	Dump into the soil	needs to be repaired	Increase capacity of equipment
Nisekh WWTP	Khan-Uul, Ulaanbatar	1000	mechanical, biological	Dump into surface water	needs to be repaired	Increase capacity and repair old ones
Advanced WWTP	Khan-Uul, Ulaanbaatar	3000	mechanical, chemical	Dump into Central WWPT through 13B line.	needs to be repaired	Increase capacity, repair old ones and construct the sand traps by sandwiches.
Dambadarja WWTP	Sukhbaatar, Ulaanbaatar	35	mechanical, biological	Dump into soil	needs to be repaired	Improve the control and capacity of air pump and repair old ones
Central WWTP	Songinokhairkhan, Ulaanbaatar	165000 - 170000	mechanical, biological, chemical	Dump into surface water	needs to be repaired and increase the capacity	Repair old ones
Bayangol wastewater Bureau WWTP	Songinokhairkhan, Ulaanbaatar	400	mechanical, biological	Dump into soil	Normal and needs to be repaired	Upgrade the equipment
Khargia industrial WWTP	Khan-Uul, Ulaanbaatar	13000 (generally only 4000 m3/day are treated, max 7000 m3/day		Dump into central WWTP	Needs to be repaired	Extensive rehabilitation works or replacement of the plant by a new one are 2 options that have been being considered for several years but an alternative scenario appears to be more likely, whereby the factories connected to the Khargia treatment plant

Source: USUG (2016)

A.2.4. Water demand estimates

A.2.4.1. Underlying data for water demand estimates for years 2010-2021

Table 38: Assumptions about various socio-economic variables used for projecting water demand in Ulaanbaatar (2010-2021)

	Low scenario	Medium scenario	High scenario
Drinking water use			
Population growth	2010-2015: 1.17% 2015-2021: 1.03%	2010-2015: 1.38% 2015-2021: 1.20%	2010-2015: 1.51% 2015-2021: 1.28%
% urban population in 2021	69.4%	70.7%	71.9%
Private connections and connected kiosks	2015: 45.9% 2021: 53.6%	2015: 48.3% 2021: 56.4%	2015: 53.5% 2021: 62.2%
Water consumption norm	Similar as medium scenario	For apartment dwellers: 200 l/day/person in 2015 and 160 l/day/person in 2021; For users of kiosks and protected sources:	Similar as medium scenario

	Low scenario	Medium scenario	High scenario
		10-25 l/day/person in 2015 and 15-30 l/day/person in 2021	
Municipal water use			
Utilities growth rate	0.7%	1.4%	4%
Services growth rate	4.5%	7.6%	14.5%
Industrial water use			
Manufacturing growth rate	4%	6.9%	12.6%
Heavy industries growth rate	4%	6.9%	12.6%
Construction growth rate	4%	6.9%	10%
Energy growth rate	2.5%	6%	10.2%
Existing mines New mines	3% growth 50% lower than MMRE estimates	10.5% growth According MMRE estimates	23% growth 20% higher than MMRE estimates
Livestock water use			
Livestock numbers	5% lower than medium scenario	Projection according MFALI (35.6 million in 2021)	Projection according Davaadorj G. (2010)- 52.6 million in 2021
Consumption norm	Unchanged	Unchanged	Unchanged
Irrigation water use			
Irrigated area *	According trend 1998- 2010, 63,000 ha in 2021: 2010-2015: 4.8% 2015-2021: 4.8%	Projection according MFALI, 92,000 ha in 2021: 2010-2015: 9.8% 2015-2021: 7.4%	Projection according Davaadorj G. (2010) , 137,000 ha in 2021: 2010-2015: 15.5 % 2015-2021: 10%
Crop water requirement	Unchanged	Unchanged	Unchanged
Tourism water use			
Water demand growth	20% lower than medium scenario	2010-2015: 14.9% 2015-2021: 16.5%	20% higher than medium scenario
Green areas water use			
Water use	20% lower than medium scenario	2010-2015: 8% 2015-2021: 12%	20% higher than medium scenario

Legend of table: For projecting future water demand in Mongolia, 2010 has been taken as the base year due to availability of sufficient data for the incomplete year of 2013 during the time of writing. MMRE = Ministry of Mineral Resources and Energy, MFALI =Ministry of Food, Agriculture and Light Industry.
Source: MEGDT: Integrated Water Management Plan of Mongolia, 2013

The future domestic water demand is calculated based on predictions of population and type of connections and using water consumption norms. The population of Ulaanbaatar is expected to rise from 1.125 million in 2010 to 1.485 million in 2021 according to the medium scenario. The water consumption per person is assumed to drop to 160 l/person/day in 2021 for private connections and rise to 20-30 l/person/day in 2021 for public connections (kiosks). The future water also incorporates the One Hundred Thousand Household Apartments programme with required approximately 50,000 m³ water per day.[60]

A.2.4.2. Underlying data for water demand estimates for years 2021-2030

Table 39 Water demand projections from Implementation Plan for Ulaanbaatar City Master Plan 2030

Water user type	Projected time		
	2010	2020	2030
	m^3/day	m^3/day	m^3/day
Apartment population	110,991.10	182,868.40	275,618.20

[60] Note that only 75,000 apartments are planned to be built in Ulaanbaatar. And on the basis that one household consists of four persons.

Gher district population	17,036.30	14,102.00	8,544.30
Non-domestic water usage	168,600.00	261,000.00	321,700.00
Food industry water usage	6,320.00	7,370.00	8,520.00
Total	**302,947.40**	**465,340.40**	**614,382.50**
Domestic	6,443.50	30,595.00	40,893.00
Non-domestic water usage	11,000.00	63,334.00	82,920.00
Total	**17,444.00**	**93,929.00**	**123,813.00**
% food to total water demand	**2.09%**	**1.58%**	**1.39%**

A.2.4.3. Water demand estimates 2010-2030 for low, medium and high water demand scenarios

Table 40 Water demand estimates 2010-2030 for low, medium and high water demand scenarios - detailed sectoral overview

	Low			**Mid**			**High**		
Mn m3/yr	2010	2021	2030	2010	2021	2030	2010	2021	2030
Domestic demand (urban)	***38.40***	***47.04***	***62.90***	***38.40***	***51.08***	***68.97***	***38.40***	***57.40***	***78.37***
Utility service (hospital, school, office and public service)	***6.83***	***9.33***	***12.37***	***6.83***	***11.81***	***15.85***	***6.83***	***20.91***	***28.30***
Industry subtotal	***3.68***	***4.95***	***5.34***	***3.68***	***7.09***	***7.72***	***3.68***	***11.08***	***12.07***
Light industry	2.99	4.02	4.34	2.99	5.75	6.27	2.99	8.99	9.80
Heavy industry	0.30	0.40	0.44	0.30	0.58	0.63	0.30	0.90	0.98
Construction and its material industry	0.39	0.53	0.57	0.39	0.76	0.83	0.39	1.18	1.29
Non-food industry subtotal	*2.63*	*3.59*	*3.62*	*2.63*	*5.41*	*5.59*	*2.63*	*8.76*	*9.13*
Energy	***22.50***	***30.25***	***37.98***	***22.50***	***43.31***	***54.40***	***22.50***	***67.68***	***84.49***
Agriculture sub-total	***2.32***	***3.95***	***2.99***	***2.32***	***5.72***	***4.71***	***2.32***	***7.56***	***6.50***
Livestock (pastoral and farming)	0.54	0.96		0.54	1.01		0.54	1.07	
Irrigated area	1.78	2.99	2.99	1.78	4.71	4.71	1.78	6.50	6.50
Other sub-total	***2.20***	***2.25***	***2.25***	***2.20***	***2.25***	***2.25***	***2.20***	***2.25***	***2.25***

Tourism	0.04	0.09	0.09	0.04	0.09	0.09	0.04	0.09	0.09
Green area	2.15	2.16	2.16	2.15	2.16	2.16	2.15	2.16	2.16
Total	**75.93**	**97.77**	**123.84**	**75.93**	**121.27**	**153.90**	**75.93**	**166.90**	**211.99**

A.2.5. Underlying data for water supply demand gap

Table 41 Underlying data of the water supply demand gap

mn m³ /yr	Surface water						Groundwater							Gap based on total water availability			Gap based on groundwater only		
Year	Surface water resource (*)		Ecological resource(*)		Possible use of resource(*)		Possible resource for use (*)	Resource for use (*)	Groundwater reserves (Resolution 2015/4) (#)	Total water availability (incl. SW)	High demand (~)	Medium demand (~)	Low demand (~)	Gap - high	Gap - medium	Gap -low	Gap - high	Gap - medium	Gap - low
	P=50%	P=90%	P=50%	P=90%	P=50%	P=90%													
2010	536.82	298.3326	506.9403	282.1093	29.8797	16.22327	121.6	138.3	103.62	119.848012	75.93	75.93	75.93	43.92	43.92	43.92	27.69	27.69	27.69
2015	536.82	298.3326	506.9403	282.1093	29.8797	16.22327	121.6	138.3	103.62	119.848012	117.86	101.15	90.86	1.98	18.70	28.99	(14.24)	2.48	12.76
2021	536.82	298.3326	506.9403	282.1093	29.8797	16.22327	121.6	138.3	103.62	119.848012	166.90	121.27	97.77	(47.05)	(1.42)	22.08	(63.27)	(17.64)	5.85
2025	536.82	298.3326	506.9403	282.1093	29.8797	16.22327	121.6	138.3	103.62	119.848012	185.99	135.12	108.48	(66.14)	(15.27)	11.37	(82.37)	(31.49)	(4.85)
2030	536.82	298.3326	506.9403	282.1093	29.8797	16.22327	121.6	138.3	103.62	119.848012	211.99	153.90	123.84	(92.14)	(34.05)	(3.99)	(108.36)	(50.28)	(20.21)

Sources:

(*) MEDGT (2012) Integrated water management assessment report: Underlying dataset (Conducted as part of the Strengthening Integrated Water Resource Management in Mongolia project)

(#)Water Reserve Committee Resolution No. 2015/4, approved by Munkh-Erdem, Head of Water reserve committee, MEGDT, date: 7 September 2015

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For water demand data between 2010 and 2021: MEGDT (2012) Integrated water management assessment report: Underlying dataset

For water demand data between 2021 and 2030, water demand growth estimates (per sector) were taken from JICA (2013) Strategic Planning of Water Supply and Sewerage Service in Ulaanbaatar and used to forecast future water demand based on MEGDT (2012) data.

A.3. Methodology on Assessment Framework

A.3.1. Review of criteria

A.3.1.1. Financial criteria

A.3.1.1.1. Financial costs of the project alternatives

Capex or capital investment costs stand for fixed, one-off costs associated with bringing a project to a full operational state and include costs associated with technical equipment, buildings and land acquisition (wherever necessary), construction, and equipment installation.

Within the context of the projects considered capital costs may refer to the cost of the major system components of the different project alternatives (i.e. condenser, cooling tower) and other related elements (i.e. circulating water pumps, circulating water lines, intake and discharge facilities, wastewater treatment facilities). For each of the system components, capital costs also include cost of delivery to the site, installation costs, and costs pertaining to interconnection of the plant systems.

Opex or annual operational costs reflect the variable costs associated with continuous operation and maintenance of the project.

In the context of the project types considered, operational costs may include energy costs for water pumps and cooling fans, the cost of make-up water to the cooling system, and general, recurrent maintenance costs (i.e. heat transfer, rotating equipment and water quality control for wet systems; component and structural repair and replacement, mainly for wet systems; periodic major surface cleaning for dry systems). However, opex information is often aggregated and it is thus difficult to isolate operational costs referred to the previously listed items.

This consideration of the costs of different project alternatives (in particular capital project costs) is critical to assess the overall financial feasibility of different projects, together with information on revenues throughout the project lifespan. This is clearly a very relevant criterion for private investors in general terms, and when appraising trade-offs between different technological project alternatives.

Most importantly, financial data are instrumental to perform; together with information on technical effectiveness (see below), a cost-effectiveness analysis (CEA) of different investment alternatives allowing comparison between different project alternatives. Capital and operational costs are used at three different levels:

1. The cost is a variable for decision-making in itself since sometimes a high cost might be directly unaffordable for investors, either private or public (especially in a context of doubts as per the financial feasibility of some of these projects as a result of the current economic environment).
2. As a critical element for the estimation of a cost-effectiveness ratio (see below).
3. For the comparative analysis of different alternatives.

Upfront capital and annual operational costs of different project alternatives have been expressed in USD (capex) and USD/year (opex) per project alternative.

Information on capital and annual operational and maintenance costs has been sourced from investors, feasibility studies and from consultation with relevant ministries. In case the information needed for this field was not available for a particular project, estimates from the literature have provided elements for its calculation. The level of detail of available costing information is clearly asymmetric but not in all cases, for instance, opex can be said to be broken down to differentiate cost related to the major system components. In some cases, capex (or opex) for the whole project were available rather than for the specific technology to be assessed. In such instances, estimates available in the literature were used to apportion part of the total capex and/or opex costs to reflect water related investments only. For example, there are estimates (i.e., Zhai and Rubin, 2010) for CHPs of the share of total investment that corresponds to that of the cooling system. In other cases, installed capacity of the project (e.g. MW for CHP), constituted the only data available. In such a case, information sources reporting the estimated amount of investment per unit of installed capacity (i.e., Zhai and Rubin, 2010; PPIAF, 2011), or per GWh of energy generated.

Information on revenues is very often lacking; yet this does not pose an obstacle for the analysis of potential savings due to the use of more efficient technologies. These revenues, anyway, are very unlikely to be able to be apportioned to water investments within energy projects. They would be more relevant if appraising these projects themselves, which is not the case.

A.3.1.1.2. Technical effectiveness

The criterion reflects how much water will be saved or supplied by different project alternatives considered. Thus, it allows comparison of different project alternatives based on their contribution to water savings.

Technical effectiveness data is instrumental to perform, together with information on Capex and Opex (as above), a cost-effectiveness analysis (CEA) of different investment alternatives allowing for comparison of different project alternatives.

It is also indicative of the potential to alleviate or exacerbate water scarcity in the region affected. This criterion allows sequencing the project alternatives in terms of the volume of water saved or supplied per year, if comparing baseline scenarios (current technology) with those that are more water efficient.

It is actually measured as the resulting total water demand per alternative. It is expressed in m^3 of water per year per project alternative. The impact of water supply measures, e.g. reuse of treated wastewater or surface water transfers is expressed in m^3 of water supplied per year.

The assessment builds on the information on anticipated water withdrawals for different projects corresponding to the planned baseline technological alternative and collated international benchmark water demand data for different technologies. The total water withdrawal of the different project alternatives is then estimated based on benchmark figures for the same technologies applied elsewhere -- discussed and validated for the Mongolian context. These numbers can be transferred since this information is technology-driven and technological options ("key in hand" projects) are equivalent among different countries.

A.3.1.1.3. Cost- effectiveness ratio

The criterion reflects cost-effectiveness of different project alternatives; in other words, what is the cost of saving or supplying an additional unit of water through the use of more efficient alternatives or new water supply options. The cost-effectiveness ratio is the single most important financial criterion allowing identification of the least cost option to provide an additional volume of water (either through additional new water supply or implementation of water efficiency measures.

This ratio also allows prioritizing different project alternatives considered based on the relative costs of water supplied / saved. It is expressed as USD/m^3 of water per year per project alternative.

The ratio is calculated using information on capex and opex expressed as an Equivalent Annual Cost (EAC) to allow for comparison of projects with different lifetimes (i.e. cooling technology alternatives vs. using treated wastewater).

A.3.1.2. Economic criteria

A.3.1.2.1. Reduced human health risks

This criterion aims to reflect economic impacts associated with reduced human health risks upon implementation of project alternatives. Welfare might be enhanced as a result of the use of more sustainable technologies for water-cooling of energy plants or of the use of treated wastewater for industrial activities.

Instances where implementation of more water efficient project alternatives would result in the uptake of relatively cleaner production processes, health of the local communities may be positively affected.

This criterion is used in the prioritization of different project alternatives. Depending on the type of the project, emission of air pollutants owing to the implementation of different project alternatives have been calculated based on the information on energy use, installed capacity. This information on emissions does not reflect actual emissions from these plants but rather data from life-cycle analyses (LCA) of lignite-fuelled CHP plants etc. for a wide number of environmental loads (atmospheric and water pollutants, etc.).

Following an impact pathway approach, emission data has been translated into physical impact cases per increased concentration of a given pollutant. Those physical impacts can be expressed in monetary units through the use of unit cost / damage cost values. The data required for this analysis, i.e. emission inventories; dispersion models, epidemiological functions, and unit damage costs are not yet available for Mongolia. Values from a similar context are taken and adjusted to fit the Mongolian context. Following a precautionary approach, this data is provided as a reference value (rather than a definite value) to illustrate the impact.

More precisely, assessment of the health impacts of different project alternatives is based on the energy consumption (kWh/m^3) linked to the water requirement (m^3/year) of each of the alternatives. The energy consumption value is then monetized using unit estimates (USD 2008/kWh) of health impacts associated with electricity produced at coal based power plants as reported in the coal life cycle analysis carried out by Epstein et al., 2011 (for the Appalachia region, US). Unitary monetized damages (external costs) due to coal mining, transport, and combustion used in the analysis for Mongolia were: carcinogens, public health burden of mining communities, fatalities in the public due to coal transport, emissions of air pollutants from combustion, lost productivity from mercury emissions, excess mental retardation cases from mercury emissions, and excess cardiovascular disease from mercury.

See section A.3.1.4. on assumptions for more detailed information on coefficients and unit damage values

A.3.1.3. Environmental criteria

A.3.1.3.1. Impact on available water quantity

This criterion aims to reflect on availability of water for environmental needs (in addition to meeting domestic, industrial (including power and heat generation) and agricultural water demand).

Implementation of different project alternatives would result in additional and significant water demand potentially leading to adverse environmental impacts, should additional water abstraction levels be unsustainable.

This criterion can be used in the prioritization of project alternatives at a semi-qualitative level (using a scale) focusing on presenting available evidence on the impacts of different project alternatives on water availability for environmental needs.

A.3.1.3.2. Chemical pollution of water and land

This criterion is aimed at reflecting anticipated impacts of different project alternatives considered on the basis of (non-thermal) pollution of land and water. Depending on the quantity and quality of discharges of cooling and other type of wastewater, or solid waste from CHPs and industrial wastewater treatment plants substantial chemical pollution of land and water can occur.

This criterion can be used in the prioritization of different project alternatives at a semi-qualitative level (using a scale) focusing on presenting available evidence on the impacts of different project alternatives on water quality.

A.3.1.3.3. Thermal pollution of water and land

This criterion is aimed at reflecting the anticipated impacts of different project alternatives considered on grounds of thermal pollution of land and water as a result of wastewater discharge. Discharge of large quantities of thermally polluted cooling waters to soil, particularly from CHPs, can result in substantial adverse impacts to the land ecosystem, as these change oxygen levels in the surrounding environment.

This criterion can be used in the prioritization of different project alternatives at a semi-qualitative level (using a scale). In general terms discharges of cooling waters associated with alternative projects should be expressed in m^3 of wastewater per year per project alternative, however, this information, is often not available at a project level.

A.3.1.3.4. Air quality and climate change

This criterion is aimed to reflect anticipated impacts of different project alternatives considered on grounds of air pollution generated and emission of greenhouse gases (GHGs) contributing to climate change.

Implementation of different project alternatives in power production and industrial sectors as well as development of water storage is associated with significant energy use (e.g. for pumping of cooling water, operation of wastewater treatment plant as a preparation for its reuse, etc.) and subsequent emission of air pollutants (such as NOx, SO_2 etc.) resulting in adverse environmental and human health impacts.

This criterion is used in the prioritization of different project alternatives. Depending on the type of the project, emission of air pollutants, and GHG due to implementation of different project alternatives, assessment is done based on the information on energy use or installed capacity.

These are then translated into environmental loads using emission conversion factors and can be monetized using unit cost/ damage cost values. The latter, however, are not available for Mongolia, which necessitates using values from different study sites. These estimates are discussed in the Mongolian context.

Specifically, the assessment of air quality and climate change impacts of the project alternatives is also based on the energy consumption (kWh/m^3) linked to the water requirement (m^3/year) of each of the alternatives. The value of energy consumed by a project alternative is then converted into climate damage costs using unit estimates (USD 2008/kWh) of damages caused by emissions of CO_2 and N_2O emitted during electricity production at coal based power plants as reported in the coal life cycle analysis by Epstein et al., 2011 (for the Appalachia region, US).

See sectionA.3.1.4 on assumptions for more detailed information on coefficients and unit damage values.

A.3.1.3.5. Impacts on habitats and biodiversity

The criterion aims to reflect anticipated impacts of different project alternatives on habitats and biodiversity. Different types of projects considered in power production and industrial sectors have a potential to adversely affect habitats and local biodiversity, for instance, through creation of artificial water bodies. However, establishing and quantifying causal links between water use in industrial and energy projects, as well as new water storage schemes and biodiversity & habitats loss is extremely challenging in general terms and in relation to individual project alternatives.

This criterion is used in the prioritization of different project alternatives. The assessment is based on estimating the impact of different project alternatives on habitats and biodiversity based on the information available on energy use or installed capacity. These are then translated into environmental loads using emission conversion factors and can be monetized using unit cost/ damage cost values. The latter, however, are not available for Mongolia which necessitates the use of values from different study sites. These estimates are discussed in the Mongolian context.

The assessment of habitat and biodiversity impacts of different project alternatives is, again, based on anticipated energy consumption (kWh/m^3) linked to the water requirement (m^3/year) of each of each of the alternatives. Estimated energy consumption is then converted into emission of air pollutants (g/kWh) using Spath et al. (1999) study that reports average air emissions of NH_3, Non-methane Hydrocarbons, including VOCs, NOX and SO_2 per kWh of net electricity produced. These emissions are then monetized using unit damage cost estimate (USD/t) on biodiversity (vegetation and fauna) covering air pollutants included in the EU NEEDS project.

See sectionA.3.1.4 on assumptions for more detailed information on coefficients and unit damage values.

A.3.1.4. Summary of applied criteria

The following table presents a summary description of the applied criteria and the way these are assessed:

- Quantitative criteria: criteria for which there is actual quantitative information or it is possible to estimate a value. These criteria have been then converted into semi-qualitative values to be used in the ranking of technological alternatives.

Criteria	Description
Financial costs of the project alternatives (capex and opex)	Information of capex and opex for all different technological alternatives was not available. Where it was not it was estimated – in most cases calculations were based on the installed capacity and unit investment factors available in the literature.
Technical effectiveness (water saving or water supply augmentation)	The total water withdrawal of the different project alternatives was estimated based on benchmark figures for the same technologies applied elsewhere, discussed and validated for the Mongolian context (including discussion with stakeholders).
Cost- effectiveness ratio	The ratio is calculated using information on capex and opex expressed as an Equivalent Annual Cost (EAC) to allow for comparison of projects with different lifetimes
Reduced human health risks	• These values are based on the energy consumed to provide water to the process for each alternative. Health damages of coal normalized to kWh of electricity produced were used, to get a monetised value (USD). • Unit monetized damages (external costs) due to coal mining, transport and combustion taken into account in the analysis for Mongolia were: carcinogens, public health burden of mining communities, fatalities in the public due to coal transport, emissions of air pollutants from combustion, lost productivity from mercury emissions, excess mental retardation cases from mercury emissions, and excess cardiovascular disease from mercury.
Air quality and climate change	Depending on the type of the project, emissions of air pollutants and GHG due to implementation of different project alternatives are calculated based on the information on energy used to provide water. Climate damages from combustion emissions of CO_2 and N_2O of coal normalized to kWh of electricity produced were used, to get a monetised value (USD).
Impacts on habitats and biodiversity	• It presents available evidence on the impacts of different project alternatives on habitats and biodiversity. It is calculated using the average air emissions per kWh consumed to provide water to the project alternatives, and then monetized using a unit damage costs on biodiversity for air pollutant. • Air pollutants were estimated considering the following average air emissions per kWh of net electricity produced (surface mining): NH_3 (0.0988 g/t), Non-methane Hydrocarbons, including VOCs (0.21 g/t), NOX (3.35 g/t) and SO_2 (6.7 g/t). Coefficients of unit-monetized damages on biodiversity (vegetation, fauna) were used for NH_3, Non-methane Hydrocarbons, including VOCs, NOX and SO_2.

A.3.2. Bringing all criteria together

The hydro-economic assessment tool developed to prioritize different project alternatives can in essence be considered as a weighted sum of a series of factors. A hydro-economic assessment tool, by definition, integrates hydrological and economic information. Yet, the tool developed goes beyond that. Within an analysis framework, based on various different criteria, financial costs and cost-effectiveness (financial expenditures to achieve a technical water resource outcome), are integrated with economic and environmental criteria for the assessment of different project alternatives. In a very simplified sense, the final "score" of each project alternative considered is computed as:

Final score = Weight cost eff. * Value cost eff. + Weight econ. * Value econ. + Weight environ. * Value environ.

Weights are used to balance the relative importance of each criterion. The following table shows the weights used in the present analysis:

Criteria	Weight
Financial & technical effectiveness	0.2
Economic	0.3
Environmental	0.5

A.3.3. Assumptions used in the assessment

The section presents the assumptions used in the assessment covering financial, economic and environmental criteria for different project types. Assumptions used for calculating energy consumption by different project alternatives (underlying calculations of some of the economic and environmental impacts) are presented as well.

A.3.3.1. Financial criteria

Assumptions used in calculating financial criteria for different types of projects are presented below.

A.3.3.1.1. Combined Heat and Power Plants

Capital and O&M costs				
	Dry	Hybrid	Wet	Source
USDMM	133.2	111.4	114.2	TTP Partners, 2011 (USD2009)
Capital requirement (USD/kW)	224	-	90	Zhai and Rubin, 2010 (USD2007)
Share of total capex	12%	-	5%	Zhai and Rubin, 2010 (USD2007)
Cooling system levelled annual cost (USD/MWh)	7.2		3.9	Zhai and Rubin, 2010 (USD2007)

O&M Costs in USD MM (million) / Source: TTP Partners, 2011			
O&M Costs, USD 2009/year (760MW plant)	**Costs in USD mn**		
Cooling system, water and wastewater treatment, CC online	Dry	Hybrid	Wet
Raw Water	0.3	4.1	9.6
Operations	0.6	2.4	4.1
Maintenance	0.6	0.6	0.8
Total	1.5	7.1	14.5

Lifetime	Years	Source
TPP	35	Bauer et al., 2004 NEEDS
TPP – hard coal condensing plants	30	EUSUSTEL
TPP – lignite condensing plants	35	EUSUSTEL
TPP	30	Zhai and Rubin, 2010

Summary of cost information of FGD – Wet and Dry Scrubbers (EPA, Fact Sheet) (USD2001)					
Scrubber type	Unit size (MW)	Capital cost (USD/kW)	O&M cost (USD/kW)	Annual cost (USD/kW)	Cost per ton of pollutant removed (USD/ton)
Wet	> 400	100 – 250	2 – 8	20 – 50	200 – 500
	< 400	250 – 1,500	8 – 20	50 – 200	500 – 5,000
Dry	> 200	40 – 150	4 – 10	20 – 50	150 – 300
	< 200	150 – 1,500	10 – 300	50 – 500	500 – 4,000

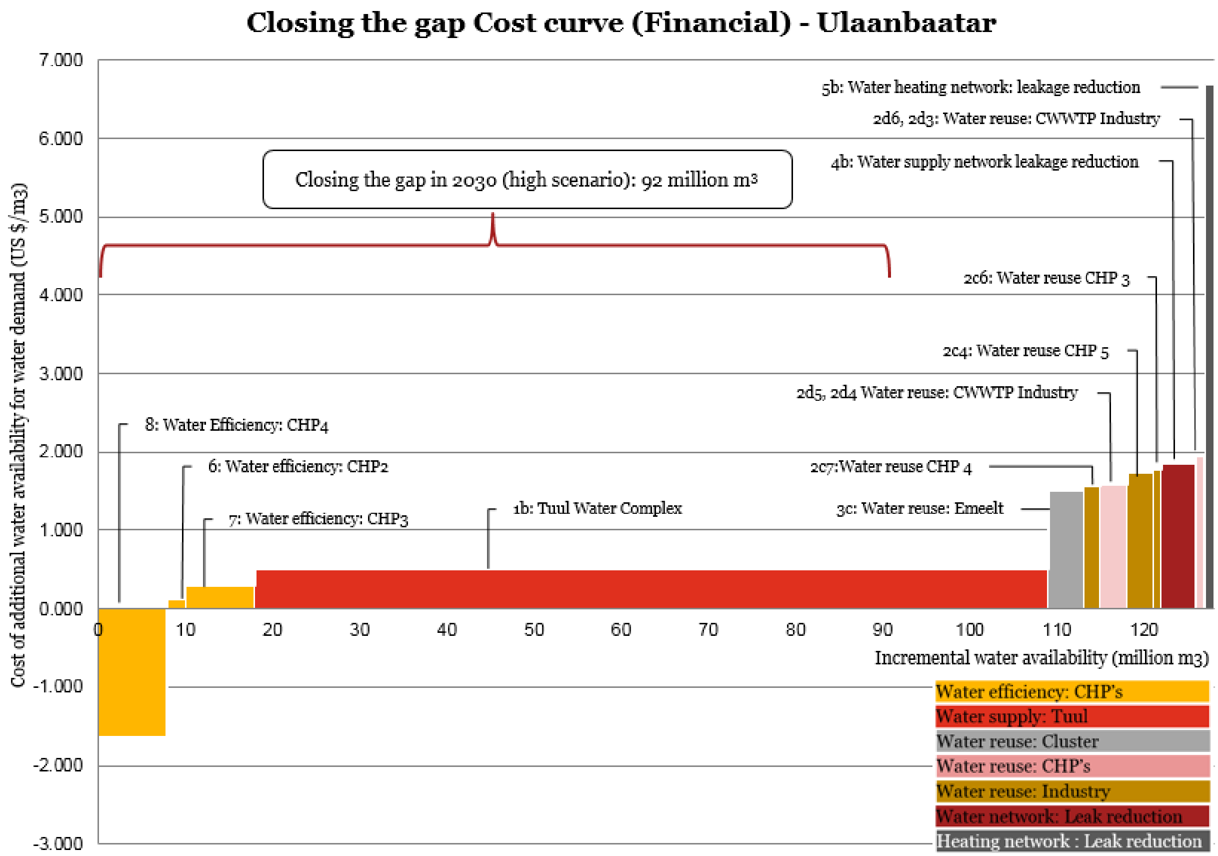
A.4. Financial cost curves

A.4.1. Financial cost curves – Ulaanbaatar

The Incremental costs of closing low water demand scenario gaps in Ulaanbaatar are about -10.2 mn USD/ year (i.e. cost savings) and about 38.8 mn USD/year for closing medium and high water demand scenario gap until 2030. In the low scenario, 8.6 mn m³ of water are made available to close the low gap of 3.99 mn m³. In the medium and high scenario, 109.7 mn m³ of water are made available to close the gap of 34.05 mn m³ and 92.14 mn m³ in 2040 respectively.

Figure 17 below shows the financial cost curve for Ulaanbaatar region. A detailed list of all measures underlying the cost curve can be found in *Annex A.6.1*. Please note that in some cases multiple measures are summarized for projects.

Figure 17 Ulaanbaatar – Financial cost curve



Once the financial cost curve is developed setting out the most cost-effective sequence of implementing different technological alternatives, the effort required in order to close high water demand scenario gaps can be established. A number of cost-effective technological alternatives may relate to the same plant or sites. For instance, six technological alternatives for the CHP IV Ulaanbaatar are ranking high in terms of their cost-effectiveness including 8i, 8j, 8k, 8l, 8m and 8n options. In practice, these technological alternatives will not be implemented (and dismantled/ upgraded) sequentially. Instead, one would invest in a step change from baseline technology for this TPP to the most advanced technology from the list of available alternatives. In this particular case, this would mean going from Wet Closed Cycle Recirculating cooling system with PC boiler and Boiler Water Blowdown Reuse (baseline) to dry/air cooled cooling system with CFB boilers and Boiler Water Blowdown Reuse (alternative 8n). In order to determine the *net* impact of such a shift in terms of costs and changes to water availability, one would need to consider IC and incremental water availability of 8n alternative against the baseline (as opposed to its previous alternative, 8m).

Therefore,

In addition to considering incremental costs of implementing these technological alternatives (i.e. in comparison to their baseline technologies), one may also wish to consider the total costs of implementing these measures assuming that there was no existing technology to build on (which will be higher than incremental costs).

In particular, total costs of implementing of these measures in Ulaanbaatar (i.e. disregarding the costs of baseline project alternatives) are about 14.2 mn USD/ year for low water demand scenarios and 65 mn USD/ year for medium and high water demand scenarios (see Annex A.6.2)

Considering the results of holistic cost-effectiveness analysis in the Ulaanbaatar region, key highlights include:

- Alternatives related to installation of **dry/air cooled cooling systems** for CHPs demonstrate negative cost-effectiveness ratios ranging from -0.33 USD/m3 to 0.21 USD/m3. Cumulatively, these measures add 18.4 mn m3 of water in Ulaanbaatar (in comparison to baseline technologies installed at each affected CHP).

- Development of **Tuul Water complex** has significant water augmenting potential of 91.25 mn m3 per year with cost-effectiveness ratio of 0.14 USD/m3.

Table 12 that lists prioritised solutions accounts for such *step changes* in technologies and presents MC and incremental water availability for each technological alternative considered in comparison to baseline (i.e. the starting point). A tabular overview of the measures ranked as per cost curve, i.e. without considering step changes, is available in Annex A.6.1.

Table 42 Ulaanbaatar - Prioritized list of solutions (financial criteria)

Rank	ID	Name - Project title	Baseline technology	Complete Technology Description	Total cost (USD, EAC)	Incremental costs (USD, EAC against baseline)	Incremental water availability (mn m^3/year, against baseline)	Cost Effectiveness Ratio (USD / m^3)
	8 i,j,k,l,m,n	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	14,163,109	-10,202,653	8.55	From -0.33 to -0.21
Sub-total - low (3.99 mn m^3)					**14,163,109**	**-10,202,653**	**8.55**	
	6 f,g,h j,k,l,m,n	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler	435,168	268,003	1.99	From 0.03 to 0.07
	7 i,j,k,l,m,n	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, CFD Boiler, Boiler Blowdown reuse	3,747,281	2,307,806	7.88	From 0.06 to 0.10
	1b	Tuul Water Complex (Dam #3)	NA	Tuul Water Complex (Dam #3 with reservoirs; water treatment plant and conveyance pipeline)	46,424,334	46,424,334	91.25	0.14
Total (medium (34.05 mn m^3) and high (92.14 mn m^3) gaps					**64,769,892**	**38,797,490**	**109.7**	

In addition to considering incremental costs of implementing these technological alternatives (i.e. in comparison to their baseline technologies), one may also wish to consider the total costs of implementing these measures (which will be higher than incremental costs).

In particular, Total Costs of implementing of these measures in Ulaanbaatar (i.e. disregarding the costs of baseline project alternatives) are about 14.2 mn USD/ year for low water demand scenarios and 65 mn USD/ year for medium and high water demand scenarios.

Considering the results of financial cost-effectiveness analysis in the Ulaanbaatar region, key highlights include:

- Alternatives related to installation of **dry/air cooled cooling systems** for CHPs demonstrate negative cost-effectiveness ratios ranging from -0.33 USD/m^3 to 0.10 USD/m^3. Cumulatively, these measures add 18.4 mn m^3 of water in Ulaanbaatar (in comparison to baseline technologies installed at each affected CHP).

- Development of **Tuul Water complex** has significant water augmenting potential of 91.25 mn m^3 per year with cost-effectiveness ratio of 0.14 USD/m^3 to 1.61 USD/m^3 (See Appendix A.7.1).

In Ulaanbaatar, prioritized list of technological alternatives remains the same under holistic assessment. Subsequently, there are no changes to the marginal and total costs of closing the gap under low, medium and high water demand scenarios. Most changes relate to a relative lower cost-effectiveness ratio, with no changes in the sequence of the prioritisation observed. This can be explained by the conservative estimates used given uncertainty in some of the data provided and correlation of some of these impacts with water requirements, which were key to the estimation of potential water savings and therefore of cost-effectiveness ratios.

A.5. Detailed overview of prioritized solutions to close Ulaanbaatar's future water gap (holistic cost curve)

Table 43 Prioritized solutions to close Ulaanbaatar's future water gap (holistic cost curve)

Rank	ID	Name- project title	Complete Technology Description	Capex (capital investment costs), USD	Opex (annual operational costs), USD	EAC (Equivalent Annual Cost), Capex, USD	Total cost (US$, Equivalent Annual Costs)	Incremental costs (US$, EAC against baseline)	Incremental water availability (mn m3 / year, against baseline)	Cost-effectiveness ratio (USD/m3)
1	8 i,j,k,l,m,n	CHP4 - Ulaanbaatar IV	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	123,210,000	1,387,500	12,775,609	14,163,109	-10,202,653	8,550,021	From -0.33 to -0.21
2	6 f,g,h j,k,l,m,n	CHP2 - Ulaanbaatar II	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler	3,785,684	42,632	392,536	435,168	268,003	1,993,939	From 0.03 to 0.07
3	7 i,j,k,l,m,n	CHP3 - Ulaanbaatar III	Dry/Air Cooled, Boiler Makeup, Other, CFD Boiler, Boiler Blowdown reuse	32,598,947	367,105	3,380,175	3,747,281	2,307,806	7,879,848	From 0.06 to 0.10
4	1b	Tuul Water Complex (Dam #3)	Tuul Water Complex (Dam #3 with reservoirs; water treatment plant and conveyance pipeline)	353,988,654	10,605,060	35,819,274	46,424,334	46,424,334	91,250,000	0.14
5	3c	Industrial Wastewater Treatment Plant with reuse (cluster based)	Wastewater treatment (cluster based) and reuse - with additional treatment	14,722,875	4,776,065	1,490,882	6,266,947	6,266,947	4,139,100	0.31

6	2c7	Reuse of treated wastewater from CWWTP at CHP plant 4 (Ulaanbaatar IV)	Wastewater treatment and conveyance (process water)	6,324,260	1,986,265	716,329	2,702,594	2,702,594	1,719,979	0.32
7	2d5	Reuse of treated wastewater from CWWTP for industrial uses - Bayangol	Wastewater treatment and conveyance	9,885,468	2,963,918	1,110,190	4,074,108	4,074,108	2,560,000	0.33
8	2d4	Reuse of treated wastewater from CWWTP for industrial uses - Songinokhairkhan	Wastewater treatment and conveyance	3,179,591	892,161	357,085	1,249,246	1,249,246	768,000	0.34
9	2c4	Reuse of treated wastewater from CWWTP at CHP plant 5 (Ulaanbaatar V)	Wastewater treatment and conveyance (process water)	14,083,503	3,288,527	1,595,194	4,883,720	4,883,720	2,820,000	0.36
10	2c6	Reuse of treated wastewater from CWWTP at CHP plant 3 (Ulaanbaatar III)	Wastewater treatment and conveyance (process water)	2,813,234	603,320	318,646	921,966	921,966	520,152	0.37
11	2d2	Reuse of treated wastewater from CWWTP for industrial uses - Khan Uul	Wastewater treatment and conveyance	4,218,867	891,577	473,801	1,365,378	1,365,378	768,000	0.37
12	4b	Leak detection and NRW reduction in central water supply network (USUG)	Replacement of water supply pipes to reduce leakage	61,363,636	20,275	7,095,133	7,115,408	7,115,408	3,832,500	0.37
13	2d3	Reuse of treated wastewater from CWWTP for	Wastewater treatment and conveyance	5,397,049	897,271	606,117	1,503,388	1,503,388	768,000	0.41

		industrial uses - Bayanzurkh								
14	2d6	Reuse of treated wastewater from CWWTP for industrial uses - Bayangol (Industrial area by Buyand-Ukhaa airport)	Wastewater treatment and conveyance	1,927,356	298,816	216,452	515,268	515,268	256,000	0.42
15	2c5	Reuse of treated wastewater from CWWTP at CHP plant 2 (Ulaanbaatar II)	Wastewater treatment and conveyance (process water)	1,070,314	122,894	121,231	244,125	244,125	106,061	0.47
16	5b	Water (and energy) leakage reduction in central heating supply system	Upgrade of the main heating network lines (UBDS), increase in the diameters and construction of new stations	18,008,000	0	1,867,244	1,867,244	1,867,244	279,291	1.34

A.6. Detailed information on measures illustrated in cost curves

A.6.1. Financial Cost Curves - Ulaanbaatar

Table 44 Cost effectiveness of measures to increase water availability in Ulaanbaatar (financial, against previous alternative)

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
1	8k	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	103,045,000	10,684,706	6,567,500	17,252,206	-7,113,556	356,251	-19.97	-7,113,556	5,993,511
2	7k	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	27,263,684	2,826,963	1,737,632	4,564,595	-1,882,107	107,737	-17.47	3,125,120	7,106,715
3	8i	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling,	Hybrid (Dry/Wet),	103,045,000	10,684,706	6,567,500	17,252,206	-7,113,556	442,820	-16.06	-7,113,556	4,355,167

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m^3) (against previous alternative)	CE Ratio (USD / m^3)	Incremental costs, USD (against baseline)	Incremental water availability (m^3) (against baseline)
				PC Boiler, Boiler blowdown reuse	Boiler Makeup, Other, Boiler Blowdown reuse									
4	6k	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler	3,166,105	328,293	201,789	530,082	-218,567	14,141	-15.46	362,917	1,892,458
5	7i	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Boiler Makeup, Other, Boiler Blowdown reuse	27,263,684	2,826,963	1,737,632	4,564,595	-1,882,107	133,916	-14.05	3,125,120	6,611,251
6	8l	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling	103,045,000	10,684,706	6,567,500	17,252,206	-7,113,556	819,377	-8.68	-7,113,556	6,812,888

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Water Blow Down Reuse, Boiler Blow Down Reuse									
7	8n	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	123,210,000	12,775,609	1,387,500	14,163,109	-3,089,097	356,251	-8.67	-10,202,653	8,550,021
8	7l	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	27,263,684	2,826,963	1,737,632	4,564,595	-1,882,107	247,794	-7.60	3,125,120	7,354,509

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
9	7n	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, CFD Boiler, Boiler, Boiler Blowdown reuse	32,598,947	3,380,175	367,105	3,747,281	-817,314	107,737	-7.59	2,307,806	7,879,848
10	6n	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler	3,785,684	392,536	42,632	435,168	-94,914	14,141	-6.71	268,003	1,993,939
11	6m	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other	3,785,684	392,536	42,632	435,168	-94,914	17,028	-5.57	268,003	1,979,798
12	8j	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other, Boiler Blowdown reuse	103,045,000	10,684,706	6,567,500	17,252,206	-7,113,556	1,282,093	-5.55	-7,113,556	5,637,260
13	7j	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond	Hybrid (Dry/Wet), Cooling	27,263,684	2,826,963	1,737,632	4,564,595	-1,882,107	387,728	-4.85	3,125,120	6,998,978

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
				cooling, PC Boiler	Water Treatment - Dry/Wet, Boiler Makeup, Other, Boiler Blowdown reuse									
14	6j	CHP	CHP2 - Ulaanbaatar II	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other	3,166,105	328,293	201,789	530,082	-218,567	50,893	-4.29	362,917	1,878,317
15	6l	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	3,166,105	328,293	201,789	530,082	-218,567	70,311	-3.11	362,917	1,962,770

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
16	8m	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Dry/Air Cooled, Boiler Makeup, Other, Boiler Blowdown reuse	123,210,000	12,775,609	1,387,500	14,163,109	-3,089,097	1,380,882	-2.24	-10,202,653	8,193,770
17	7m	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, Boiler Blowdown reuse	32,598,947	3,380,175	367,105	3,747,281	-817,314	417,603	-1.96	2,307,806	7,772,112
18	2c3	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 4 (Ulaanbaatar IV)	Use of freshwater at CHP plant	Conveyance of treated CWWTP effluent without additional treatment (plant water)	1,345,568	155,580	40,711	196,291	196,291	8,626,800	0.02	196,291	8,626,800
19	2c2	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 3 (Ulaanbaatar III)	Use of freshwater at CHP plant	Conveyance of treated CWWTP effluent without additional treatment (plant water)	2,222,583	256,985	40,485	297,470	297,470	7,224,000	0.04	297,470	7,224,000

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m3) (against previous alternative)	CE Ratio (USD / m3)	Incremental costs, USD (against baseline)	Incremental water availability (m3) (against baseline)
20	2c1	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 2 (Ulaanbaatar II)	Use of freshwater at CHP plant	Conveyance of treated CWWTP effluent without additional treatment (plant water)	906,124	104,770	14,052	118,822	118,822	1,806,000	0.07	118,822	1,806,000
21	1b	D -WT-P	Tuul Water Complex (Dam #3)	NA	Tuul Water Complex (Dam #3 with reservoirs; water treatment plant and conveyance pipeline)	353,988,654	35,819,274	10,605,060	46,424,334	46,424,334	91,250,000	0.51	46,424,334	91,250,000
22	3c	IWWTP-WR	Industrial Wastewater Treatment Plant with reuse (cluster based)	Use of freshwater for industrial uses	Wastewater treatment (cluster based) and reuse - with additional treatment	14,722,875	1,490,882	4,776,065	6,266,947	6,266,947	4,139,100	1.51	6,266,947	4,139,100
23	2c7	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 4 (Ulaanbaatar IV)	Use of freshwater at CHP plant	Wastewater treatment and conveyance (process water)	6,324,260	716,329	1,986,265	2,702,594	2,702,594	1,719,979	1.57	2,702,594	1,719,979

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
24	2d5	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Bayangol	Use of freshwater for industrial uses	Wastewater treatment and conveyance	9,885,468	1,110,190	2,963,918	4,074,108	4,074,108	2,560,000	1.59	4,074,108	2,560,000
25	2d1	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Emeelt	Use of freshwater for industrial uses	Wastewater treatment and conveyance	16,102,342	1,808,377	4,637,753	6,446,130	6,446,130	4,000,000	1.61	6,446,130	4,000,000
26	2d4	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Songinokhairkhan	Use of freshwater for industrial uses	Wastewater treatment and conveyance	3,179,591	357,085	892,161	1,249,246	1,249,246	768,000	1.63	1,249,246	768,000
27	2c4	CWWTP-CHPWR	Reuse of treated wastewater from CWWTP at CHP plant 5 (Ulaanbaatar V)	Use of freshwater at CHP plant	Wastewater treatment and conveyance (process water)	14,083,503	1,595,194	3,288,527	4,883,720	4,883,720	2,820,000	1.73	4,883,720	2,820,000
28	2c6	CWWTP-CHPWR	Reuse of treated wastewater from CWWTP at CHP plant 3 (Ulaanbaatar III)	Use of freshwater at CHP plant	Wastewater treatment and conveyance (process water)	2,813,234	318,646	603,320	921,966	921,966	520,152	1.77	921,966	520,152

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m3) (against previous alternative)	CE Ratio (USD / m3)	Incremental costs, USD (against baseline)	Incremental water availability (m3) (against baseline)
29	2d 2	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Khan Uul	Use of freshwater for industrial uses	Wastewater treatment and conveyance	4,218,867	473,801	891,577	1,365,378	1,365,378	768,000	1.78	1,365,378	768,000
30	4b	LR-W	Leak detection and NRW reduction in central water supply network (USUG)	NA	Replacement of water supply pipes to reduce leakage	61,363,636	7,095,133	20,275	7,115,408	7,115,408	3,832,500	1.86	7,115,408	3,832,500
31	2d 3	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Bayanzurkh	Use of freshwater for industrial uses	Wastewater treatment and conveyance	5,397,049	606,117	897,271	1,503,388	1,503,388	768,000	1.96	1,503,388	768,000
32	2d 6	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Bayangol (Industrial area by Buyand-Ukhaa airport)	Use of freshwater for industrial uses	Wastewater treatment and conveyance	1,927,356	216,452	298,816	515,268	515,268	256,000	2.01	515,268	256,000
33	2c 5	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 2	Use of freshwater at CHP plant	Wastewater treatment and conveyance	1,070,314	121,231	122,894	244,125	244,125	106,061	2.30	244,125	106,061

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m3) (against previous alternative)	CE Ratio (USD / m3)	Incremental costs, USD (against baseline)	Incremental water availability (m3) (against baseline)
			(Ulaanbaatar II)		(process water)									
34	7f	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, Boiler Blowdown reuse	27,948,947	2,898,018	3,548,684	6,446,702	5,007,228	1,115,504	4.49	5,007,228	6,121,804
35	6f	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other	3,245,684	336,544	412,105	748,649	581,485	108,634	5.35	581,485	1,763,180
36	5b	LR-H	Water (and energy) leakage reduction in	NA	Upgrade of the main heating network	18,008,000	1,867,244	0	1,867,244	1,867,244	279,291	6.69	1,867,244	279,291

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
			central heating supply system		lines (UBDS), increase in the diameters and construction of new stations									
37	6h	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Others, CFD Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	3,245,684	336,544	412,105	748,649	581,485	70,311	8.27	581,485	1,847,632
38	7h	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment	27,948,947	2,898,018	3,548,684	6,446,702	5,007,228	247,794	20.21	5,007,228	6,477,334

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					- Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse									
39	6g	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler	3,245,684	336,544	412,105	748,649	581,485	14,141	41.12	581,485	1,777,321
40	7g	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet	27,948,947	2,898,018	3,548,684	6,446,702	5,007,228	107,737	46.48	5,007,228	6,229,540

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD	Incremental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD / m³)	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse									
				Total							139,314,707			

A.6.2. Holistic Cost Curves - Ulaanbaatar

Table 45 Cost effectiveness of measures to increase water availability in Ulaanbaatar (financial, economic and environmental criteria against previous alternative)

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
1	8k	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup,	103,045,000	10,684,706	6,567,500	3,475,433	-1,426,043	356,251	-4.00	17,252,206	-7,113,556	5,993,511

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Other, CFB Boiler, Boiler Blowdown reuse										
2	7k	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	27,263,684	2,826,963	1,737,632	919,641	-377,318	107,737	-3.50	4,564,595	3,125,120	7,106,715
3	8i	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Hybrid (Dry/Wet), Boiler Makeup, Other, Boiler Blowdown reuse	103,045,000	10,684,706	6,567,500	3,475,433	-1,426,043	442,820	-3.22	17,252,206	-7,113,556	4,355,167
4	6k	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,,	3,166,105	328,293	201,789	107,027	-43,848	14,141	-3.10	530,082	362,917	1,892,458

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Boiler Makeup, Other, CFB Boiler										
5	7i	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Boiler Makeup, Other, Boiler Blowdown reuse	27,263,684	2,826,963	1,737,632	919,641	-377,318	133,916	-2.82	4,564,595	3,125,120	6,611,251
6	8l	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	103,045,000	10,684,706	6,567,500	3,475,433	-1,426,043	819,377	-1.74	17,252,206	-7,113,556	6,812,888

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
7	8n	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	123,210,000	12,775,609	1,387,500	2,872,608	-602,825	356,251	-1.69	14,163,109	-10,202,653	8,550,021
8	7l	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	27,263,684	2,826,963	1,737,632	919,641	-377,318	247,794	-1.52	4,564,595	3,125,120	7,354,509
9	7n	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other,	32,598,947	3,380,175	367,105	760,212	-159,429	107,737	-1.48	3,747,281	2,307,806	7,879,848

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m^3) (against previous alternative)	CE Ratio (USD/m^3) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m^3) (against baseline)
					CFD Boiler, Boiler Blowdown reuse										
10	6n	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler	3,785,684	392,536	42,632	88,651	-18,376	14,141	-1.30	435,168	268,003	1,993,939
11	8j	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other, Boiler Blowdown reuse	103,045,000	10,684,706	6,567,500	3,475,433	-1,426,043	1,282,093	-1.11	17,252,206	-7,113,556	5,637,260
12	6m	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other	3,785,684	392,536	42,632	88,651	-18,376	17,028	-1.08	435,168	268,003	1,979,798
13	7j	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment -	27,263,684	2,826,963	1,737,632	919,641	-377,318	387,728	-0.97	4,564,595	3,125,120	6,998,978

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Dry/Wet, Boiler Makeup, Other, Boiler Blowdown reuse										
14	6j	CHP	CHP2 - Ulaanbaatar II	Wet CL & pond cooling, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other	3,166,105	328,293	201,789	107,027	-43,848	50,893	-0.86	530,082	362,917	1,878,317
15	6l	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow	3,166,105	328,293	201,789	107,027	-43,848	70,311	-0.62	530,082	362,917	1,962,770

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Down Reuse										
16	8m	CHP	CHP4 - Ulaanbaatar IV	Wet CL cooling, PC Boiler, Boiler blowdown reuse	Dry/Air Cooled, Boiler Makeup, Other, Boiler Blowdown reuse	123,210,000	12,775,609	1,387,500	2,872,608	-602,825	1,380,882	-0.44	14,163,109	-10,202,653	8,193,770
17	7m	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Dry/Air Cooled, Boiler Makeup, Other, Boiler Blowdown reuse	32,598,947	3,380,175	367,105	760,212	-159,429	417,603	-0.38	3,747,281	2,307,806	7,772,112
18	2c3	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 4 (Ulaanbaatar IV)	Use of freshwater at CHP plant	Conveyance of treated CWWTP effluent without additional treatment (plant water)	1,345,568	155,580	40,711	72,038	72,038	8,626,800	0.01	196,291	196,291	8,626,800

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
19	2c2	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 3 (Ulaanbaatar III)	Use of freshwater at CHP plant	Conveyance of treated CWWTP effluent without additional treatment (plant water)	2,222,583	256,985	40,485	92,093	92,093	7,224,000	0.01	297,470	297,470	7,224,000
20	2c1	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 2 (Ulaanbaatar II)	Use of freshwater at CHP plant	Conveyance of treated CWWTP effluent without additional treatment (plant water)	906,124	104,770	14,052	35,079	35,079	1,806,000	0.02	118,822	118,822	1,806,000
21	1b	D - WT-P	Tuul Water Complex (Dam #3)	NA	Tuul Water Complex (Dam #3 with reservoirs; water treatment plant and conveyance pipeline)	353,988,654	35,819,274	10,605,060	13,020,707	13,020,707	91,250,000	0.14	46,424,334	46,424,334	91,250,000
22	3c	IWWTP-WR	Industrial Wastewater Treatment Plant with	Use of freshwater for industrial uses	Wastewater treatment (cluster based)	14,722,875	1,490,882	4,776,065	1,292,520	1,292,520	4,139,100	0.31	6,266,947	6,266,947	4,139,100

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
			reuse (cluster based)		and reuse - with additional treatment										
23	2c7	CWWTP-CHPWR	Reuse of treated wastewater from CWWTP at CHP plant 4 (Ulaanbaatar IV)	Use of freshwater at CHP plant	Wastewater treatment and conveyance (process water)	6,324,260	716,329	1,986,265	553,010	553,010	1,719,979	0.32	2,702,594	2,702,594	1,719,979
24	2d5	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Bayangol	Use of freshwater for industrial uses	Wastewater treatment and conveyance	9,885,468	1,110,190	2,963,918	839,517	839,517	2,560,000	0.33	4,074,108	4,074,108	2,560,000
25	2d1	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Emeelt	Use of freshwater for industrial uses	Wastewater treatment and conveyance	16,102,342	1,808,377	4,637,753	1,333,151	1,333,151	4,000,000	0.33	6,446,130	6,446,130	4,000,000
26	2d4	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Songinokhairkhan	Use of freshwater for industrial uses	Wastewater treatment and conveyance	3,179,591	357,085	892,161	259,662	259,662	768,000	0.34	1,249,246	1,249,246	768,000
27	2c4	CWWTP-CHPWR	Reuse of treated wastewater	Use of freshwater at	Wastewater treatment	14,083,503	1,595,194	3,288,527	1,022,939	1,022,939	2,820,000	0.36	4,883,720	4,883,720	2,820,000

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
			from CWWTP at CHP plant 5 (Ulaanbaatar V)	CHP plant	and conveyance (process water)										
28	2c6	CWWTP-CHP WR	Reuse of treated wastewater from CWWTP at CHP plant 3 (Ulaanbaatar III)	Use of freshwater at CHP plant	Wastewater treatment and conveyance (process water)	2,813,234	318,646	603,320	190,296	190,296	520,152	0.37	921,966	921,966	520,152
29	2d2	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Khan Uul	Use of freshwater for industrial uses	Wastewater treatment and conveyance	4,218,867	473,801	891,577	282,418	282,418	768,000	0.37	1,365,378	1,365,378	768,000
30	4b	LR-W	Leak detection and NRW reduction in central water supply network (USUG)	NA	Replacement of water supply pipes to reduce leakage	61,363,636	7,095,133	20,275	1,424,310	1,424,310	3,832,500	0.37	7,115,408	7,115,408	3,832,500
31	2d3	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Bayanzurkh	Use of freshwater for industrial uses	Wastewater treatment and conveyance	5,397,049	606,117	897,271	314,605	314,605	768,000	0.41	1,503,388	1,503,388	768,000

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
32	2d6	CWWTP-IWR	Reuse of treated wastewater from CWWTP for industrial uses - Bayangol (Industrial area by Buyand-Ukhaa airport)	Use of freshwater for industrial uses	Wastewater treatment and conveyance	1,927,356	216,452	298,816	107,475	107,475	256,000	0.42	515,268	515,268	256,000
33	2c5	CWWTP-CHPWR	Reuse of treated wastewater from CWWTP at CHP plant 2 (Ulaanbaatar II)	Use of freshwater at CHP plant	Wastewater treatment and conveyance (process water)	1,070,314	121,231	122,894	49,928	49,928	106,061	0.47	244,125	244,125	106,061
34	7f	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, Boiler	27,948,947	2,898,018	3,548,684	1,296,959	1,006,824	1,115,504	0.90	6,446,702	5,007,228	6,121,804

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Blowdown reuse										
35	6f	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other	3,245,684	336,544	412,105	150,876	117,106	108,634	1.08	748,649	581,485	1,763,180
36	5b	LR-H	Water (and energy) leakage reduction in central heating supply system	NA	Upgrade of the main heating network lines (UBDS), increase in the diameters and construction of new stations	18,008,000	1,867,244	0	373,449	373,449	279,291	1.34	1,867,244	1,867,244	279,291

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
37	6h	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Others, CFD Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	3,245,684	336,544	412,105	150,876	117,106	70,311	1.67	748,649	581,485	1,847,632
38	7h	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed	27,948,947	2,898,018	3,548,684	1,296,959	1,006,824	247,794	4.06	6,446,702	5,007,228	6,477,334

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
					Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse										
39	6g	CHP	CHP2 - Ulaanbaatar II	Cooling Ponds, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler	3,245,684	336,544	412,105	150,876	117,106	14,141	8.28	748,649	581,485	1,777,321

Rank	ID	Project Type	Project title	Baseline Technology	New measure	**Capex (capital investment costs), USD**	**EAC (Equivalent Annual Cost), Capex, USD**	**Opex (annual operational costs), USD**	Total EAC costs, USD (holistic)	Incremental costs, USD (against previous alternative) (holistic)	Incremental water availability (m³) (against previous alternative)	CE Ratio (USD/ m³) (holistic)	Total EAC costs, USD	Incremental costs, USD (against baseline)	Incremental water availability (m³) (against baseline)
40	7g	CHP	CHP3 - Ulaanbaatar III	Wet CL & pond cooling, PC Boiler	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	27,948,947	2,898,018	3,548,684	1,296,959	1,006,824	107,737	9.35	6,446,702	5,007,228	6,229,540
				Total							139,314,707				

A.7. Identifying a wide range of potential solutions to close the water gap

A.7.1. Solutions – Water demand reduction Combined Heat and Power Plants (CHPs)

Information on existing and planned technical configuration of the CHP plants has been received from the Ministry of Energy and estimates for baseline annual water requirements were obtained as shown in Table 46.

The water demands at CHPs are the same as those at TPPs and the different technological alternatives are documented in detail in the Report Supplement 3 from the Hydro-Economic Analysis study in the Gobi[61].

Table 46 Technical configuration of CHPs and water demands.

Configuration	CHP2	CHP3	CHP4	CHP5
Installed Capacity (MW)	21.6	186	703	450
Annual Power Generation (MWh)	148	1,000	3,550	3,055
Efficiency (Inefficiency) (%)	21	39	40	
Thermal Energy by Hot Water for DHS (Gcal)	159,255	1,918,943	3,315,681	3,000
Thermal Energy by Steam For factory (Gcal)	18,890	249,935	201,523	
Water Demand (m^3/day)	5,700	23,000	30,400	9,600
Annual water demand (Mm^3)	2.10	8.40	10.27	3.00
Does this water demand include makeup water for district heating? (Yes/No)	Yes	Yes	Yes	Yes
Water makeup for district heating (m^3/day)	456	5,568	6,288	6,000
Hot water flow for district heating	740	8,000	12,000	8,200
Water used for ash removal, washing etc (Mm3/year)	0.00	2.76	2.10	
Water used for cooling (Mm3/year)	0.40	4.40	6.50	
Water used for Internal cycle (Mm3/year)	1.70	1.24	1.67	
Open wet recirculating systems (Yes/No)	No	no	no	Air cooling
Closed cycle recirculating systems (Yes/No)	no	Yes	yes	N/A
Cooling ponds (Yes/No)	yes	Yes	no	N/A
Boiler Type	Pulverised Coal Boiler	Pulverised Coal Boiler	Pulverised Coal Boiler	Circulating Fluidised Bed Boiler
Cooling water treatment (Yes/No)	no	no	no	
Boiler blowdown reuse (Yes/No)	no	yes	yes	
Wet FGD (Yes/No)	no	no	no	
Semi Dry FGD (Yes/No)	no	no	no	
Dry FGD (Yes/No)	no	no	no	
Waste Water treatment plant present (Yes/No)	no	no	no	
Additional Information			Evaporation from cooling towers • Summer 131 tons/hr • Winter 156 tons/hr	

[61] PwC, AFW & GWS (2016) Prioritised solutions to close the water gap: Hydro-economic analysis on the coal mining regions in Mongolia's Gobi desert. Report Supplement #3 – Water Demand Reduction Solutions as part of the report

Configuration	CHP2	CHP3	CHP4	CHP5
			Ash removal • Summer 74 tons/hr • Winter 73 tons/hr	

Estimates of the best practice benchmark water use required per MWh of power generated for each technological alternative were used to validate the annual water demand data provided for each CHP based on its known configuration. Where there was a variance between actual and theoretical demands, the benchmark water use values were adjusted to achieve a match. Updated benchmark figures are shown in Table 47.

Table 47 Benchmark water withdrawal estimates obtained from the literature were updated to match the total annual water demands for the CHP plants in Ulaanbaatar.

		Baseline	Water withdrawals following application of option when applied to Baseline							
		Water withdrawals (m^3/MWh)	Cooling water treatment	% Reduction	Boiler blowdown reuse	% Reduction	Cooling water blowdown reuse	% Reduction	CFB boilers	% Reduction
Cooling system	Cooling water ponds	14.00[7]	1.400[7]	90%						
	Closed cycle recirculating	2.300[7]	1.533[5]	33%						
	Hybrid wet/dry	0.777[7]	0.718[5]	33%						
	Dry/air cooled	0.000[3]								
Other	Boiler makeup	0.800[7]			0.153[7]	33%	0.000[6]	100%	0.70[5]	13%
	Other	0.050[4]								

Source: [1.] S. Bushart (2014); [2.]DOE (2010) [3.] EC (2001); [4.] Carpenter (2012); [5.] 2030 WRG (2009); [6.] Koch Membrane (2010); [7.] Amec Foster Wheeler (2015);

The calculated water withdrawals with the application of technological alternatives for each CHP plant are provided in Table 48.

Table 48 Calculated water withdrawals with the application of technological alternatives for CHP Plants

ID	CHP Plant	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m^3/MWh)	Estimated Water withdrawals (m^3/yr)
	CHP2	Baseline - Cooling Ponds, Boiler Makeup, Other	Baseline	149,481	14.85	2,100,000
	CHP2	Cooling Ponds, Cooling Water Treatment-Cooling Ponds, Boiler Makeup, Others	Cooling water treatment	149,481	2.25	318,182

ID	CHP Plant	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m^3/MWh)	Estimated Water withdrawals (m^3/yr)
	CHP2	Cooling Ponds, Cooling Water Treatment-Cooling Ponds, Boiler Makeup, Others, CFB Boiler	CFB Boiler	149,481	2.15	304,040
	CHP2	Cooling Ponds, Cooling Water Treatment-Cooling Ponds, Boiler Makeup, Others, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	149,481	1.6528	233,729
	CHP2	Wet Closed Cycle Recirculating, Boiler Makeup, Other	Wet Closed Cycle Recirculating	149,481	3.15	445,455
	CHP2	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other	Cooling water treatment	149,481	2.3818	336,820
	CHP2	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler	CFB Boiler	149,481	2.2818	322,679
	CHP2	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Others, CFD Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	149,481	1.7846	252,368
	CHP2	Hybrid (Dry/Wet), Boiler Makeup, Other	Hybrid (Dry/Wet)	149,481	1.9275	272,576
	CHP2	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other	Cooling water treatment	149,481	1.567615	221,683
	CHP2	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler	CFB Boiler	149,481	1.467615	207,542
	CHP2	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	149,481	0.970415	137,230
	CHP2	Dry/Air Cooled, Boiler Makeup, Other	Dry/Air Cooled	149,481	0.85	120,202
	CHP2	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler	CFB Boiler	149,481	0.75	106,061
	CHP2	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Makeup reuse	Boiler Makeup reuse	149,481	0.4828	68,275
	CHP3	Baseline - Cooling Ponds, Boiler Makeup, Other, Boiler Blowdown reuse	Baseline	993,910	7.7968	8,400,000

ID	CHP Plant	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m^3/MWh)	Estimated Water withdrawals (m^3/yr)
	CHP3	Cooling Ponds, Cooling Water Treatment-Cooling Ponds, Boiler Makeup, Other, Boiler Blowdown reuse	Cooling water treatment	993,910	2.059244	2,218,558
	CHP3	Cooling Ponds, Cooling Water Treatment-Cooling Ponds, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	CFB Boiler	993,910	1.959244	2,110,821
	CHP3	Cooling Ponds, Cooling Water Treatment-Cooling Ponds, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse	993,910	1.729244	1,863,027
	CHP3	Wet Closed Cycle Recirculating, Boiler Makeup, Other, Boiler Blowdown reuse	Wet Closed Cycle Recirculating	993,910	3.15	3,393,700
	CHP3	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, Boiler Blowdown reuse	Cooling water treatment	993,910	2.1146	2,278,196
	CHP3	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	CFB Boiler	993,910	2.0146	2,170,460
	CHP3	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse	993,910	1.7846	1,922,666
	CHP3	Hybrid (Dry/Wet), Boiler Makeup, Other, Boiler Blowdown reuse	Hybrid (Dry/Wet)	993,910	1.6603	1,788,749
	CHP3	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other, Boiler Blowdown reuse	Cooling water treatment	993,910	1.300415	1,401,022
	CHP3	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	CFB Boiler	993,910	1.200415	1,293,285
	CHP3	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse	993,910	0.970415	1,045,491
	CHP3	Dry/Air Cooled, Boiler Makeup, Other, Boiler Blowdown reuse	Dry/Air Cooled	993,910	0.5828	627,888

ID	CHP Plant	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m^3/MWh)	Estimated Water withdrawals (m^3/yr)
	CHP3	Dry/Air Cooled, Boiler Makeup, Other, CFD Boiler, Boiler Blowdown reuse	CFB Boiler	993,910	0.4828	520,152
	CHP3	Dry/Air Cooled, Boiler Makeup, Other, CFD Boiler, Boiler Makeup reuse, Boiler Blowdown reuse	Boiler Makeup reuse	993,910	0.4828	520,152
	CHP4	Baseline -Wet Closed Cycle Recirculating, Boiler Makeup, Other, Boiler Blowdown reuse	Baseline	3,694,968	2.8828	10,270,000
	CHP4	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, Boiler Blowdown reuse	Cooling water treatment	3,694,968	2.1146	7,533,281
	CHP4	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	CFB Boiler	3,694,968	2.0146	7,177,030
	CHP4	Wet Closed Cycle Recirculating, Cooling Water Treatment - Wet Closed Cycle Recirculating, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse	3,694,968	1.7846	6,357,653
	CHP4	Hybrid (Dry/Wet), Boiler Makeup, Other, Boiler Blowdown reuse	Hybrid (Dry/Wet)	3,694,968	1.6603	5,914,833
	CHP4	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other, Boiler Blowdown reuse	Cooling water treatment	3,694,968	1.300415	4,632,740
	CHP4	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	CFB Boiler	3,694,968	1.200415	4,276,489
	CHP4	Hybrid (Dry/Wet), Cooling Water Treatment - Dry/Wet,, Boiler Makeup, Other, CFB Boiler, Cooling Water Blow Down Reuse, Boiler Blow Down Reuse	Cooling Water Blow Down Reuse	3,694,968	0.970415	3,457,112
	CHP4	Dry/Air Cooled, Boiler Makeup, Other, Boiler Blowdown reuse	Dry/Air Cooled	3,694,968	0.5828	2,076,230
	CHP4	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Blowdown reuse	CFB Boiler	3,694,968	0.4828	1,719,979

ID	CHP Plant	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m^3/MWh)	Estimated Water withdrawals (m^3/yr)
	CHP4	Dry/Air Cooled, Boiler Makeup, Other, CFB Boiler, Boiler Makeup reuse, Boiler Blowdown reuse	Boiler Makeup reuse	3,694,968	0.4828	1,719,979
	CHP5	Baseline -Dry/Air Cooled, Boiler makeup, Other, CFB Boiler	-	3,942,000	0.75	3,000,000

A.7.2. Solutions – Tuul Water Complex (Dam #3)

CAPEX and OPEX estimates for the Tuul Water Complex, as shown in Table 49, were taken from the Tuul Water Complex Feasibility Report[62] in relation to Dam Site #3 and has been used in the analysis.

Table 49 CAPEX and OPEX estimates for the Dam #3 Tuul Water Complex

CAPEX			OPEX	
Component	**Total Cost (USD)**	**Lifetime (year)**	**Component**	**Annual Cost (USD)**
Dam construction	168,459,841	100	Dam	585,360
WWTP	132,124,813	40	WWTP	10,019,700
Pipeline	53,404,000	40	Depreciation	6,313
Total	**353,988,654**		**Total**	**10,605,060**

The feasibility report inconsistently reported the value for surface water capacity. A figure of 250,000 m^3/day or 91.25 m^3/yr has been used in the analysis. The feasibility report also provides estimates of energy consumption which are shown in Table 50.

Table 50 Energy consumption estimates for the Dam #3 Tuul Water Complex

Component	Energy (kWh/year)
Dam	318,000
WWTP and booster pumps	65,963,000
Total	66,281,000
Total (kWh/year/m^3)	0.726

[62] Yooshin Engineering Corp (2016) Feasibility Study and Basic Engineering Design Development of Tuul Water Complex Project 2nd Consultation Workshop

A.7.3. Solutions – Reuse of treated wastewater from CWWTP for CHPs

Estimates for CAPEX and OPEX for the new CWWTP are shown in Table 51 and were taken from Ulaanbaatar Waste Water Expansion Programme Feasibility Study[63].

Table 51 CAPEX and OPEX for the new CWWTP

Component	Cost (USD)
CAPEX CWWTP inclusive of VAT	342,666,562
Annual OPEX	13,209,266
Net Electricity Consumption (kWh)	23,159,859

These estimates form the baseline cost for the CWWTP and have not been included within the reuse options. Details of the water requirements for each CHP, once the selected water efficiency measures have been implemented, are shown in Table 52 The reuse of treated wastewater could replace the water demand from existing groundwater supplies. The estimated CAPEX and OPEX for a new pumping station and pipeline to link each CHP plant with the CWWTP and the associated annual electricity consumption and related costs are also provided[64]. The estimated CAPEX and OPEX of the additional treatment with sand and cartridge filters are also provided.

Table 52 CAPEX and OPEX costs for pipelines and pumping stations linking the CWWTP to CHP plants and the cost of additional treatment.

CHP Plant	Distance (km)	Water Requirement (m3/year)	Pipe Diameter (mm)	PVC Pipeline Cost (USD)	Pumping Station Cost (USD)	Electricity tariff (USD/ kWh)	Annual Electricity costs for pumping (USD)	Electricity consumption (kWh)	Additional treatment CAPEX (USD)	Additional treatment OPEX (USD)
CHP2	5.26	106,061	300	664,227	58,000	0.07	925	13,208	9,255,137	3,243,000
CHP3	8.3	520,152	600	1,048,115	58,000	0.07	5,146	73,509	348,087	121,970
CHP4	3.99	1,719,979	700	621,351	58,000	0.07	8,289	118,420	1,707,119	598,175
CHP5	28	2,820,000	400	4,639,866	188,500	0.07	45,527	650,381	5,644,909	1,977,976

Indicative costs for pipeline construction for different pipeline diameters have been taken from the Feasibility Study[63]. Our analysis indicates that these costs are on the low side so suggest overall costs are underestimated.

[63] Artelia (2015) Rehabilitation and Construction of Ulaanbaatar City Central Waste water Treatment Plant Reference: NKhAAG14/0221 Consultancy Services for Design Work: Feasibility Study
[64] Amec Foster Wheeler (2016)

A.7.4. Solutions –Cluster-based industrial WWTPs and reuse of treated wastewater (Emeelt)

Estimates of CAPEX and OPEX of the new industrial wastewater treatment plant were taken from the Feasibility report and are shown in Table 53[65]. These estimates form the baseline cost for the WWTP and have not been included within the reuse options.

Table 53 CAPEX and OPEX for the new industrial WWTP at Emeelt

Component	Cost (USD)
CAPEX CWWTP	67,163,531
Annual OPEX	11,799,000
Net Electricity Consumption (kWh)	10,731,000

The estimated CAPEX and OPEX for a new pumping station and pipeline to link the WWTP plant back to the Emeelt industrial park and the associated annual electricity consumption and related costs are also provided are shown in Table 54[66]. The estimated CAPEX and OPEX of the additional treatment with sand and cartridge filters are also provided.

Table 54 CAPEX and OPEX costs for pipelines and pumping stations linking the industrial WWTP plant back to the Emeelt business park and the cost of additional treatment.

Industrial Cluster	Distance (km)	Water Requirement (m3/year)	Pipe Diameter (mm)	PVC Pipeline Cost (USD)	Pumping Station Cost (USD)	Electricity tariff (USD/ kWh)	Annual Electricity costs (USD)	Electricity consumption (kWh)	Additional treatment CAPEX (USD)	Additional treatment annual OPEX (USD)
Emeelt	4.2	4,140,000	450	448,500	690,000	0.07	14,000	694,261	13,584,375	4,759,965

[65] EBRD (2015) Ulaanbaatar Wastewater Expansion Programme Feasibility Study, Final Report
[66] Amec Foster Wheeler (2016)

A.7.5. Solutions –Reuse of treated wastewater from CWWTP for industrial uses

Details of the water requirements for each industrial cluster and estimated CAPEX costs for new pipeline to link to each industrial cluster with the CWWTP and pumping stations are provided in Table 55. Data on water requirements were estimated by allocating total water industrial water demand to key industrial areas based on estimated size. The estimated CAPEX and OPEX of the additional treatment with sand and cartridge filters are also provided.

Table 55 CAPEX and OPEX costs for pipelines and pumping stations linking the CWWTP with industrial clusters and the cost of additional treatment.

Industrial Cluster	Distance (km)	Water Requirement (m3/year)	Pipe Diameter (mm)	PVC Pipeline Cost (USD)	Pumping Station Cost (USD)	Electricity tariff (USD/ kWh)	Annual Electricity costs (USD)	Electricity consumption (kWh)	Additional treatment CAPEX (USD)	Additional treatment annual OPEX (USD)
Emeelt	15.1	4,000,000	450	2,814,988	159,500	0.07	37,753	1,335,655	16,102,342	4,637,753
Khan Uul	12.76	768,000	200	1,611,319	87,000	0.07	8,377	539,323	4,218,867	891,577
Bayanzurkh	22.09	768,000	200	2,789,501	87,000	0.07	14,071	119,668	5,397,049	897,271
Songinokhairkhan	4.53	768,000	200	572,043	87,000	0.07	8,961	201,019	3,179,591	892,161
Bayangol	8.69	2,560,000	350	1,396,642	87,000	0.07	19,918	128,017	9,885,468	2,963,918
Bayangol (Industrial area by Buyand-Ukhaa airport)	8.15	256,000	250	1,029,173	58,000	0.07	4,416	284,547	1,927,356	298,816

Indicative costs for pipeline construction for different pipeline diameters have been taken from the Ulaanbaatar Wastewater Expansion Programme Feasibility Study[67]. Our analysis indicates that these costs are on the low side so overall costs are therefore underestimated.

[67] Artelia (2015) Rehabilitation and Construction of Ulaanbaatar City Central Wastewater Treatment Plant Reference: NKhAAG14/0221 Consultancy Services for Design Work: Feasibility Study

A.7.6. Solutions –Leak detection and non-revenue water reduction in central water supply network (USUG)

The USUG provide 150,000 m^3/d into supply excluding that provided direct to some industries. Current losses from the 540km supply network are 14%[68] which equates 7,665,000 m^3/year.

USUG provided the cost of replacing 44km of pipeline as USD10m using trenchless technology. Assuming leakage is equal across the whole network, to reduce the NRW down to 7% would require 270km to be rehabilitated. Using the per unit costs from above this equates to USD 61,363,636.

A.7.7. Solutions –Water and energy leakage reduction in central heating supply system

The three existing CHP plants pump hot steam at 135° to the 280km long central heating network which is maintained by the Ulaanbaatar City Heating Company (UBDS). There is a planned investment to rehabilitate 11.7km of heating network which will replace the pipes and reduce the makeup water required costing USD 18,008,000. Assuming equal leakage across the whole network this equates to 279,291m^3/year.

[68] Interview with USUG's Chief Engineer Batsukh (7 April 2016)

2030 Water Resources Group

2121 Pennsylvania Avenue, NW
Washington, D.C., 20433 USA

www.2030wrg.org

For further information, please contact
2030wrg@ifc.org