2030 Water Resources Group

MONGOLIA

Prioritized solutions to close the water gap

June 2016

Hydro-economic analysis on the coal mining regions in Mongolia's Gobi desert

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.

The economic development in Mongolia puts a strain on the water resources in areas where demand of water requires large water supplies. Hence, in some cases, water is not only a limiting factor for economic growth and development, but also an opportunity. The focus of this analysis lies on the coal mining regions Tavan Tolgoi and Nyalga Shivee Ovoo, in which many investments in coal value adding technologies, including power plants, coal washing, coal-to-liquid and coal-to-briquette, are planned. This study assesses the water demand-supply gap by 2040 in each region and prioritises implementable solutions to close the gap to allow for sustainable economic development.

The water supply-demand situation

For each region, water demand was estimated for three scenarios, namely low, medium and high demand, for the years 2030 and 2040. In addition, a distinction was made between implemented and non-implemented planned projects. In Nyalga Shivee Ovoo region, the implementation of all planned projects, if left unaddressed, would result in a water supply demand gap of 35% (34.25 mn m3/yr) in the high water demand scenario and 30% and 31% in the low and medium demand scenarios by 2040 respectively. In Tavan Tolgoi region, the implementation of all planned projects, if left unaddressed, would result in a water supply demand gap of 60% (18.85 mn m3/yr) in the high water demand scenario and 33% in the medium demand scenario.

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

This study identifies a wide range of water demand reduction and water supply augmentation measures. All identified measures jointly have the potential to make 67.34 mn m^3/yr (gap: 34.25 mn m^3/yr) in Nyalga Shivee Ovoo and 53.11 mn m^3/yr (gap: 18.85 mn m^3/yr) in Tavan Tolgoi of water resources available, thus closing the gap. Consequently, water resource availability does not pose a constraint to further socio-economic development, if selected water demand reduction or supply augmentation measures are implemented.

The outcome of the holistic hydro-economic analysis shows that the water supply demand gap in the high scenario in Nyalga Shivee Ovoo region can be closed at an incremental cost of 33.2 mn USD/ yr when compared to the baseline technology alternatives.[1] The most cost effective solutions are demand reduction measures at the mines and (planned) projects, including changes in dust suppression, efficiency improvements related to cooling systems and cooling water treatment, as well as the installation of FGD and efficient sprinklers. Jointly, these measures have the potential to close 86% of the gap. The remaining gap (4.7 mn m^3/yr) can be closed in the most cost effective way by developing selected new groundwater boreholes. However, given that analysed groundwater resources are non-renewable in the Gobi region, preference may be given to less cost-effective water demand solutions before additional groundwater is abstracted. This would increase the incremental costs to close the gap to 36.5 mn USD/yr, necessitating only 2.95 mn m^3/yr (instead of 4.7 mn m3/yr) to be abstracted from local groundwater sources.

In Tavan Tolgoi region, the holistic hydro-economic analysis suggests that the water supply demand gap in the high scenario can be closed at an incremental cost of 21.0 mn USD/ yr when compared to the baseline technology alternatives. The most cost effective demand reduction solutions include changes in dust suppression measures and implementation of dry coal cleaning technologies. Jointly, these demand reduction solution measures can close 50% of the water supply demand gap. The remaining gap (9.5 mn m^3/yr) can be closed most cost-effectively by development of selected new groundwater boreholes (Figure 2). As analysed groundwater resources are non-renewable, preference may be given to implement all possible water demand reduction measures first. A total of 11.5 mn m^3/yr can be saved by implementing all identified water demand reduction measures. This would increase the incremental costs to close the gap to 22 mn USD/yr, necessitating 7.4 mn m^3/yr (instead of 9.5 mn m3/yr) to be abstracted from local groundwater sources. The gap could also be closed by construction of the

[1] All costs estimates mentioned above refer to "Equivalent Annual Costs (EAC)", i.e. the annual capital, operation and maintenance costs annualised over the assets' lifetime.

Orkhon-Gobi Water Transfer. However, this would result in much higher costs (212 mn USD EAC) and is linked to risks related to uncertainties of river runoff and uncertainties of future demand.

Figure 1 Nyalga Shivee Ovoo – Holistic cost curve (financial, economic and environmental criteria)

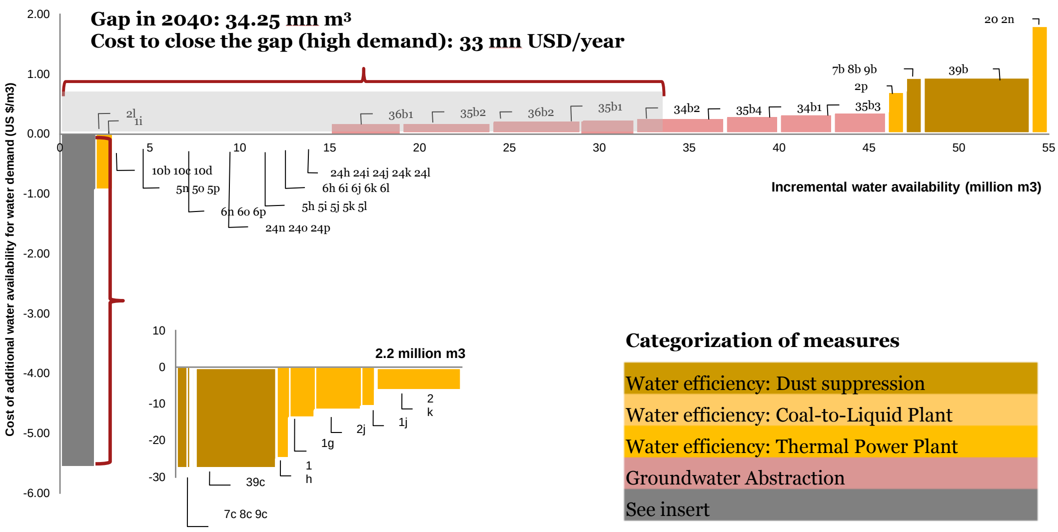
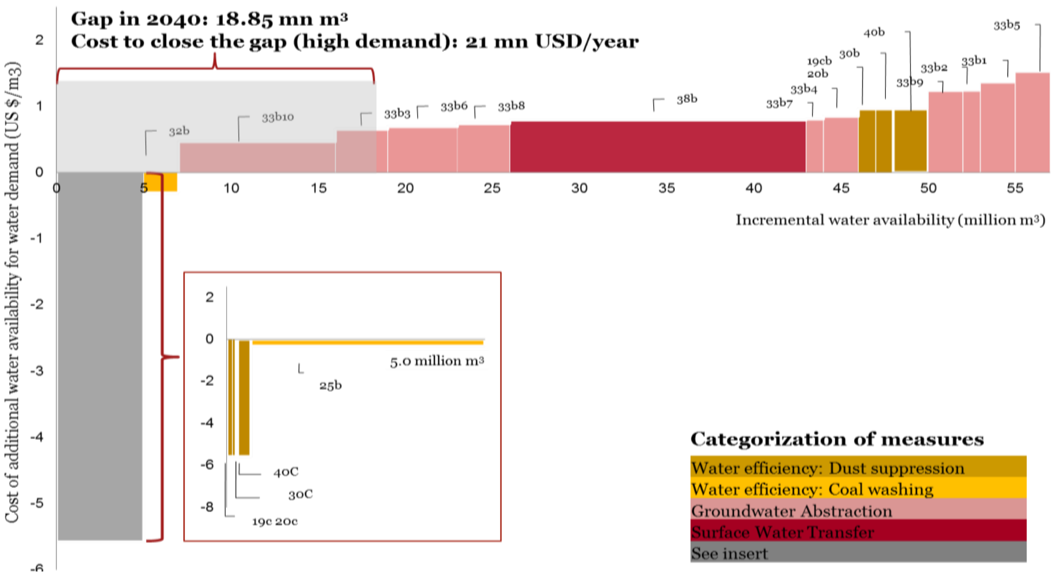


Figure 2 Tavan Tolgoi – Holistic cost curve (financial, economic and environmental criteria)



Next Steps

A big share of future water demand will stem from planned mining related projects, which are at very different stages of planning/ development. All projects are related to coal, a resource characterised by a volatile and changing market. If the high uncertainty on project implementation persists, decisions on solutions to close the high demand scenario gap should be taken. Given the high share of water demand from planned thermal power plants, discussions should consider the water-energy nexus and decide on strategic priorities for Mongolia Further, a fundamental decision needs to be taken among all stakeholders in Mongolia on the willingness to use non-renewable groundwater reserves and on the subsequent preferred solutions to be implemented. As all water demand reduction measures relate to companies (private/ public), their ability and willingness to invest in these measures needs to be understood. Incentives and financial support for these measures, such as preferential loans from leading banks, (import) tax rebates and conditional water permits can be identified for this purpose. Finally, additional research and validation is required to confirm water availability of government approved and newly identified aquifers, especially with respect to environmental impacts, as well as feasibility and environmental and social impact studies need to be conducted before implementing identified solutions.

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ACRONYMS

AFW	Amec Foster Wheeler
AUSAID	Australian Agency for International Development
BAT	Best Available Technologies
CFB	Circulating fluidised bed
Chalco	Aluminium Corporation of China
CTB	Coal to Briquette
CTL	Coal to Liquid
EAC	Equivalent Annual Costs
GWMS	Groundwater Management Solutions
IBRD	The International Bank for Reconstruction and Development
IC	Incremental costs
IFC	International Finance Corporation
MEGDT	Ministry of Environment, Green Development and Tourism
MINIS	Mining Infrastructure Investment Support Project
MRAM	Mineral Resource Authority of Mongolia
OTIA	Oyu Tolgoi Investment Agreement
PwC	PricewaterhouseCoopers
SDC	Swiss Agency for Development and Cooperation
SEFIL	Strategic Entities Foreign Investment Law
SGR	Southern Gobi Region
TC	Total Costs
TNC	The Nature Conservancy
TPP	Thermal Power Plants

WEIGHTS AND MEASURES

km	kilometres
kWh	kilowatt hours
l	litre
m	meter
mn	million
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 Management Solutions (GWMS).** In addition, a peer review on the Orkhon-Gobi water transfer was conducted by Amec Foster Wheeler (AFW) and Groundwater Management Solutions (GWMS) to allow for inclusion to this study.

Please note that the additional report supplements are available to allow for a deeper understanding of the analysis and data sources used, which can be found in Annex A.1 of this report.

1.1. Importance and current developments of Mongolia's coal mining sector

With large proven reserves of coal and copper as well as many deposits of gold, tin, tungsten and other minerals, Mongolia is immensely rich in terms of mineral resources. In fact, much of Mongolia's mineral potential remains untapped – only 15% of the country is fully mapped, and only 17% is under exploration.[2] As on November 2013, only 29% of the landmass in Mongolia was covered by satellite imagery. [3]However, some of the largest deposits in the world for coal, copper and gold are found in Mongolia.

Mongolia's proven coal reserves are estimated to be around 170 billion tons, and at large not yet developed. Tavan Tolgoi, Mongolia's largest coal reserve is one of the largest coal deposits in the world (est. 7.42bil tons of coal). Thermal coal, which is used mostly for domestic consumption, amounts to 75% of the reserve. The remaining 25% is coking coal, a key ingredient in steel production, and mostly exported to China. Shivee Ovoo, Mongolia's second largest coal reserve with an estimated 2.7 billion tons of coal, mostly provides thermal coal to Ulaanbaatar's thermal power plants. In Mongolia, 53% of produced coal is exported, 30% is used for consumption as fuel and 17% for manufacturing.[4]

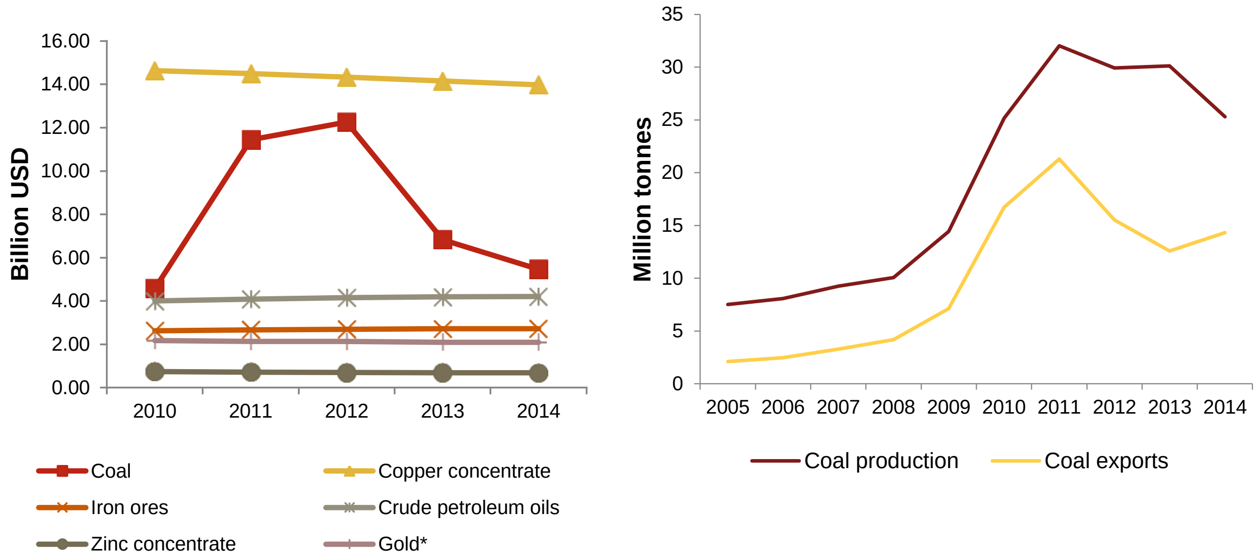
The mining industry plays an important role in the Mongolian economy; it accounted for 17% of GDP and 83% of export value in 2014. Over the last few years, mineral products have consistently accounted for more than 80% of total export revenues, with copper and coal being the drivers of revenue). However, coal prices have a high volatility, which has a direct impact on coal production, export and thus on Mongolia's economy as a whole (see Figure 3). Thus, technologies which add value to the coal, such as power plants, coal to liquid, coal to briquette and coal to washing, are key to allow for higher and more stable export earnings.

2 Prestige Co Ltd, MINIS, MEGDT, World Bank (2014) – Report on initial economic, financial, environmental and social screening: Preparation of Terms of Reference for feasibility studies on flow regulation of Orkhon River and construction of water reservoir complex

3 Oxford Business Group (2014) The Report Mongolia, pages (91 - 102)

4 National Statistical Office of Mongolia (September 2015)

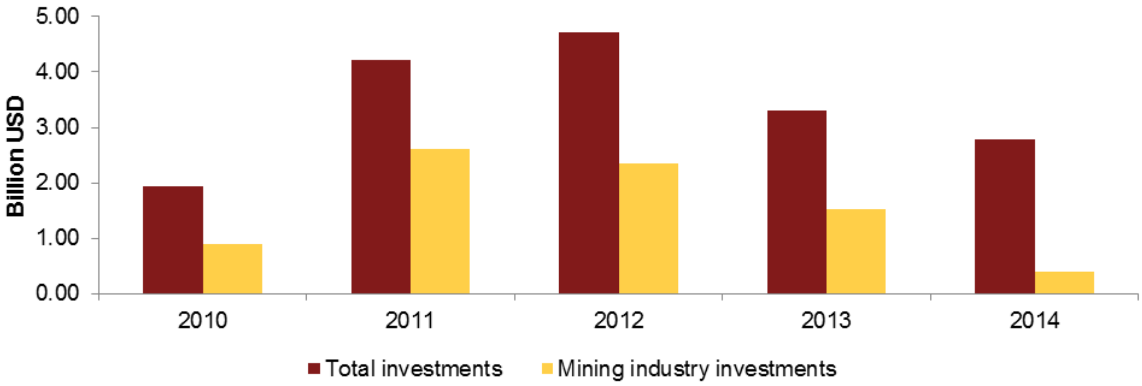
Figure 3 Coal production and exports, 2005-2014 (left) and Mongolia's revenue from mining exports (right)



Source: National Statistical Office of Mongolia, September 2015

More than 50% of the coal production in Mongolia is undertaken by mining companies from the private sector. As Figure 4 shows, total investments, and specifically investments in the mining industry reached their peak in 2012 and consistently fell until 2014.

Figure 4: Investments in the mining industry of Mongolia



Source: National Statistical Office of Mongolia, September 2015

The sudden surge in investment in the mining industry between 2010 and 2012 can be attributed to key contributing factors: 1) Rising mineral demand from China and 2) Signing of the Oyu Tolgoi Investment Agreement (OTIA) for the development of Oyu Tolgoin copper and gold deposits in South Gobi between the Government of Mongolia and the Canada-based miner Ivanhoe Mines backed by Anglo-Australian Rio Tinto. It can be said that this agreement sustained the growth of the economy from 2010 to 2012 as it recovered from the global financial crisis. The slowing down of investments in the mineral industry since 2013 can be attributed to 1) Slump in global coal prices; 2) Slump in mineral demand from China combined with increased competition from Australia and 3) Perceived challenges with political stability and effectiveness of the government. The latter was mainly caused by three policy and law related government decisions:

a) **Ambiguous Law regarding investments -** The Strategic Entities Foreign Investment Law (SEFIL) was passed in May 2012 to prevent Aluminium Corporation of China (Chalco) in its attempt to buy out South Gobi Resources. The law specified that if a foreign investment in those entities exceeded a threshold of 49%, such investment would need the Parliament's approval.

b) **Revoking of licences -** 106 licences were revoked in 2013 with the criminal conviction of the Mineral Resource Authority of Mongolia (MRAM) chairman with corruption charges by the Supreme Court.

c) **Policy reversals -** Cancellation of four double taxation treaties in 2012 as well as the dispute with Rio Tinto over the Oyu Tolgoi project leading to significant delays.

Thus, it is crucial for Mongolia to revive investor interests – a key area is the provision of water assurance not being a key constraint to development.

1.2. Past and ongoing initiatives on mining in the Gobi region

There have been many historic studies to quantify national water resources but it is only in recent times (post-2000) that the Southern Gobi Region (SGR) has received specific attention. This has been a response to the successes in mineral exploration, the planned development of a number of major mines and consequent increase in predicted industrial and municipal water demand. In the arid environment of the SGR, groundwater resources present the only viable development option for local, large-scale water supplies.

The SGR has been subject to numerous groundwater investigations since 1970 and a large number of groundwater deposits have been identified. Resource assessment and quantification of supply potential for all of these deposits have been made in accordance with established, national practices and provide a good foundation for regional resource assessment. A number of recent studies on water demand and supply in the SGR have been conducted, however, they vary in scale, approach, study area and terminology. Thus, care needs to be taken when comparing results from various studies- including the results from this report. If said study specifics are overlooked confusion and uncertainty, e.g. for development planning, can arise. .

Besides the official, government-led resource estimates, key reports on groundwater availability and demand estimates include the following: Groundwater Assessment in the Gobi region of Mongolia[5], Southern Gobi Regional Environmental Assessment[6] , Southern Mongolia Infrastructure Strategy[7], Integrated Water Management Plan Mongolia[8], Report on Initial Economic, Financial, Environmental and Social Screening – Preparation of Terms of Reference for Feasibility Studies on Flow Regulation of Orkhon River and Construction of Water Reservoir Complex[9] and Targeted Analysis on Water Resource Management Issues in Mongolia[10] [11].

Key ongoing water management initiatives around mining in the Gobi include the following:

- Convened by IFC, the South Gobi Water and Mining Industry Roundtable ("IFC Roundtable") engages in multi-stakeholder coordination on water management in mining (2013-2016) which focuses on improving water management practices of exploration and mining companies, improving stakeholder engagement practices, and informing the local residents on the activities and impacts of the mining industry to allow for an objective perception on the local water supply.

- World Bank and AUSAID funded the Strengthening Groundwater Management Initiative – which is a part of the Mining Infrastructure Investment Support Project (MINIS). This initiative focused on developing capacities of the public bodies in groundwater resources management and setting up a small Groundwater Management and Information Unit. The geographical focus of MINIS (2013-2016) lies in the three Aimags of Dornogovi, Omnigovi and Dundgovi, in which one Water Basin Council and three Water Basin Authorities have been established as part of the project.

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5 Tuinhof and Buyanhishig (2010) Groundwater Assessment in the Gobi region of Mongolia
6 World Bank (2010) Southern Gobi Regional Environmental Assessment
7 IBRD & World Bank (2009) Southern Mongolia Infrastructure Strategy
8 Ministry of Environment, Green Development and Tourism et al (2013) Integrated Water Management Plan Mongolia
9 Prestige Co Ltd, MINIS, MEGDT, World Bank (2014) – Report on initial economic, financial, environmental and social screening: Preparation of Terms of Reference for feasibility studies on flow regulation of Orkhon River and construction of water reservoir complex
10 2030 WRG (2014) Targeted Analysis on Water Resource Management Issues in Mongolia. Prepared by PwC/ Deltares.
11 More details can be found in Report Supplement # 2.2 Comparison of previous resource estimation studies.

- The Asia Foundation with the support of the Swiss Agency for Development and Cooperation (SDC) have launched the Engaging Stakeholders in Environmental Conservation II project aiming to mitigate negative environmental impacts (e.g. water and soil degradation) from past and current artisanal and small-scale mining. The project is designed to enhance the contribution that Mongolia's artisanal mining sector makes to sustainable local development, including promoting respect for the right to decent work and the right to a healthy environment.

1.3. Study areas in this report: Tavan Tolgoi and Nyalga Shivee Ovoo brown coal regions

1.3.1. Nyalga Shivee Ovoo brown coal region

The Nyalga Shivee Ovoo brown coal region is located south-east of Ulaanbaatar. This analysis focuses on three key mines – Shivee Ovoo, Tugrug Nuur and Buuruljuutyn Tal – and adjacent planned development projects. Currently, coal demand of Ulaanbaatar's power stations is met through state-run operations at Shivee-ovoo and Baganuur (north of the study area). Expansion of both mines is planned and new developments are proposed to exploit similar deposits at Tugrug Nuur and Buuruljuutiin Tal. A list of analysed planned development projects can be found in Table 1 Overview of planned developments in Nyalga Shivee Ovoo region below.

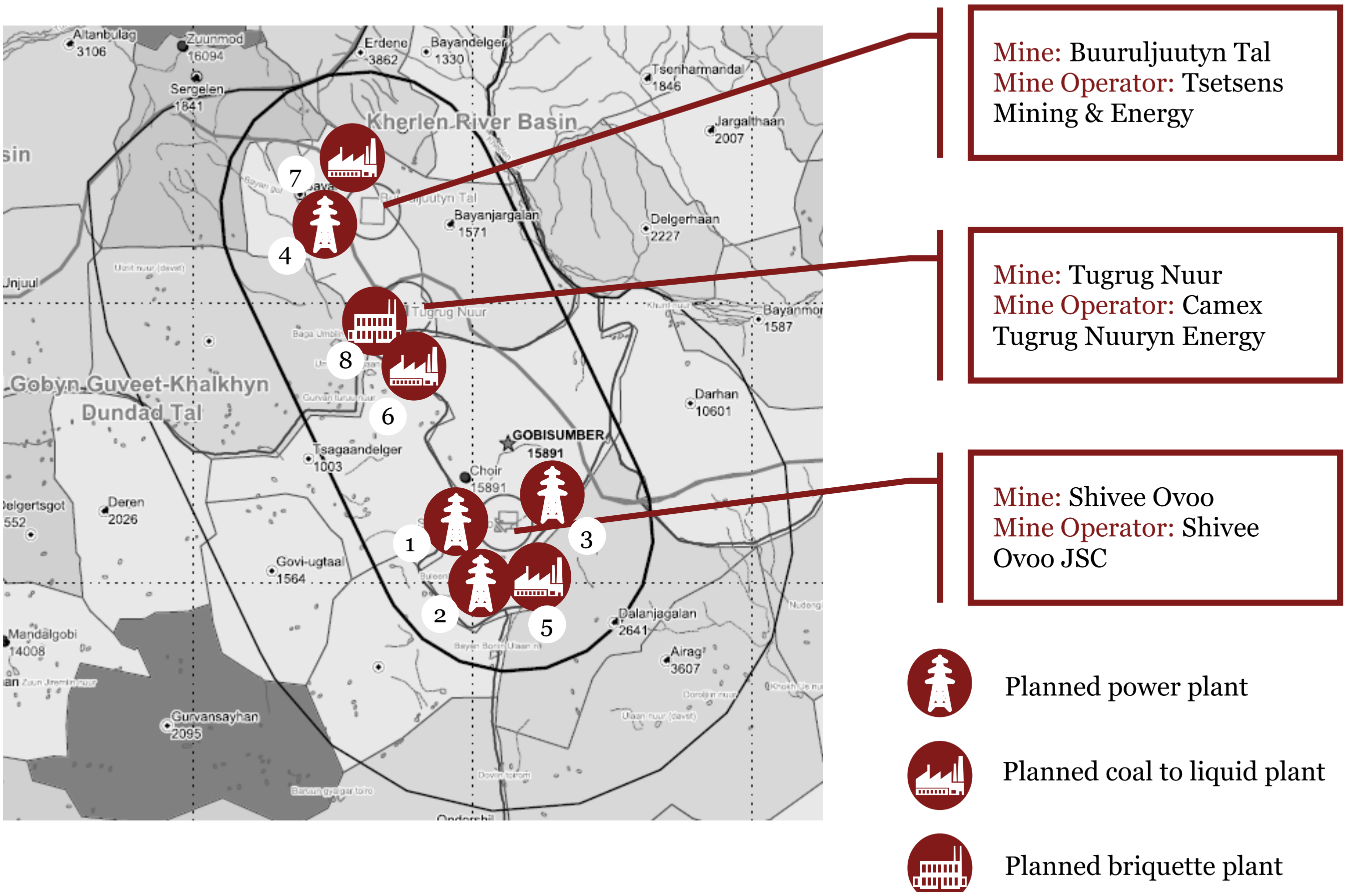
To allow for an integrative analysis on water demand and availability, the study area is extended by 50km and 100km around the mines (see *Figure 5*). The study area extends partially over two river basins, namely Kherlen River Basin and Umard Gobyn Guveet Khalkhyn Dundad Tal Basin, and partially over three aimags, namely Tuv, Govi-Sumber and Dundgovi. It envelops part of a large coal-bearing region, known as the Choir-Nyalga basin. In consideration of hydrological complexities, the study area boundaries were drawn such to exclude river basins with only small areas, i.e. Kherlen and Tuv river basins.

Table 1 Overview of planned developments in Nyalga Shivee Ovoo region

No.	Planned development	Capacity	Operator Name	Location	Water withdrawal (m³/year)	Status	ID in analysis
1	Power Plant	270 MW	One Power Global Limited	Shivee Ovoo	860,000	Planned	1
2	Power Plant	750 MW	IM Power Plc	Shivee Ovoo	4,793,472	Planned	2
3	Power Plant	5280 MW	State Grid Corporation of China	Shivee Ovoo	15,700,000	Planned	3
4	Power Plant	600 MW	Tsetsens Mining and Energy	Booroljuutyn Tal	2,000,000	Planned	4
5	Coal-to-Liquid	600,000 tons diesel/gasoline per year	Germon Gas LLC	Shivee Ovoo	4,777,536	Planned	24
6	Coal-to-Liquid	880,000 tons diesel/gasoline; 84,00 tons LPG; 50,000 tons of other products per year	CTL Mongolia LLC	Tugrug Nuur	10,000,000	Planned	5
7	Coal-to-Liquid	500,000 tons diesel/gasoline per year	Tsetsens Mining and Energy	Buuruljuuty Tal	4,500,000	Planned	6
8	Coal-to-Briquette	57,600 tons coking coal per year	Camex LLC	Tugrug Nuur	57,600	Planned	10

Note: The ID number is referred to later in the cost curves and further analysis.

Figure 5 Study area - Nyalga Shivee Ovoo



1.3.2. Tavan Tolgoi Coal Region

Tavan Tolgoi, located in Southern Gobi, is Mongolia's largest coal reserve (estimated 6.4 bn tons), which hosts significant high quality coking coal deposits. It is divided into six sections: Ukhaa Khudag, Tsankhi (East and West), Bor tolgoi, Borteeg, and Southwest and Eastern coalfields. In the following, all but Ukhaa Khudag are referred collectively as Tavan Tolgoi.

The study focusses on the mines and developments at Ukhaa Khudag and Tavan Tolgoi. To allow for an integrated assessment, a study area including the area of 50km and 100km radius around the mines was chosen (see *Figure 6*). Thus, the area includes Xanadu mine lease, but excludes Oyu Tolgoi (both copper mines). Further, the study area includes key urban settlements, namely Dalanzadgad (aimag center) and Tsogttsetsii (soum center and mining hub).

The study area is located in the Umnogovi aimag and extends partially over three river basins, namely Galba Uush Doloodyn Gobi, Umard Gobyn Guveet Khahkhyn Dundad Tal and Ongi. In consideration of hydrological complexities, the study area boundaries were drawn such to exclude river basins with only small areas, i.e. Altain Uvur Govi river basin.

The mining areas highlighted in *Figure 6 Study area - Tavan Tolgoi region* are all operational. Mining in West Tsankhi is currently in the process of being contracted to a consortium of international mining companies. Once completed, this would have a significant impact, with expected coal output increasing from 3.6 mn tons/yr[12] to 20 mn tons/ yr[13] and planned developments constructed, including a railway, a 450 MW power

[12] Mongolia Extractive Industries Transparency Initiative, Ninth EITI Reconciliation Report 2014, by KPMG, December 2015
[13] "Mega Projects in Mongolia", Mongolian Economy Magazine, 2013-10-09

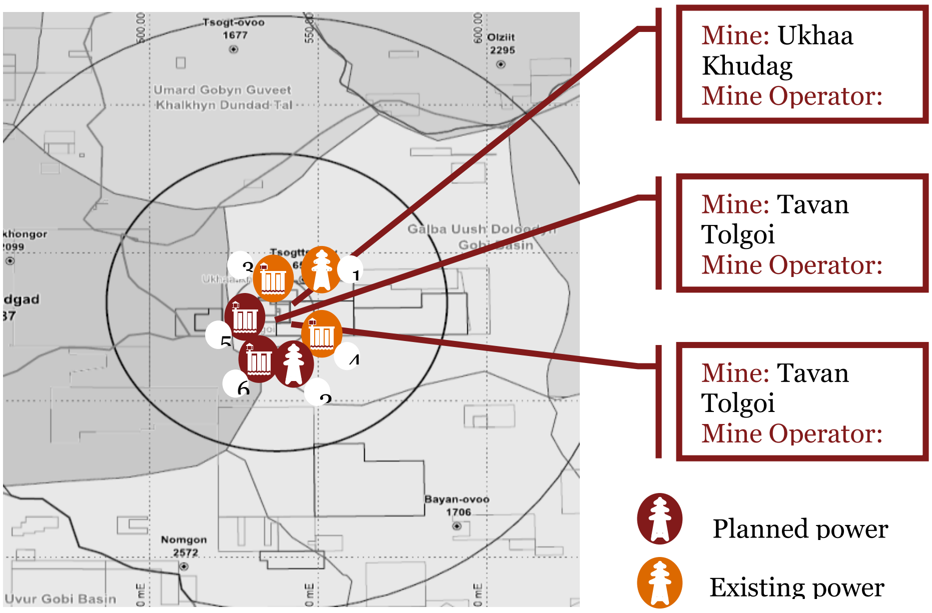
plant and coal washing plants to be constructed. For a complete overview of existing and planned developments, please see Table 2 Overview of existing and planned developments in Tavan Tolgoi region below.

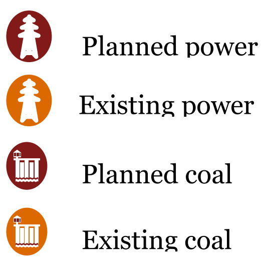
Table 2 Overview of existing and planned developments in Tavan Tolgoi region

No.	Existing/ planned development	Capacity	Operator Name	Location	Water withdrawal (m³/year)	Status	ID in analysis
1	Power Plant	18 MW	Mongolian Mining Corporation	Ukhaa Khudag	132,000	Existing	17
2	Power Plant	450 MW	Consortium in discussion/ Lead MCS Energy	Tavan Tolgoi	1,200,000	Planned	18
3	Coal washing	15 mn ROM	Mongolian Mining Corporation	Ukhaa Khudag	756,864	Existing	28
4	Coal washing	No information (dry technology)	Tavan Tolgoi JSC	Tavan Tolgoi	0	Existing – currently not operational	27
5a	Coal washing	15 mn ROM	Consortium in discussion/ Lead MMC	Ukhaa Khudag	2,270,592	Planned	32
5b	Coal washing	30 mn ROM	Consortium in discussion/ Lead Erdenes Tavan Tolgoi	Tavan Tolgoi	4,541,184	Planned	25
5c	Coal washing	5 mn ROM	Erdenes Tavan Tolgoi JSC	Tavan Tolgoi	0	Planned	27
6	Coal washing	No information (dry technology)	Tavan Tolgoi JSC	Tavan Tolgoi	0	Planned	27

***Note:** Coal washing plants **#5a, #5b and #5c** are mutually exclusive and depend on ongoing planning. Please see Chapter 3 for more details. For projects with ID for analysis #27, no further improvements can be made and are thus not analyzed further.*

Figure 6 Study area - Tavan Tolgoi region



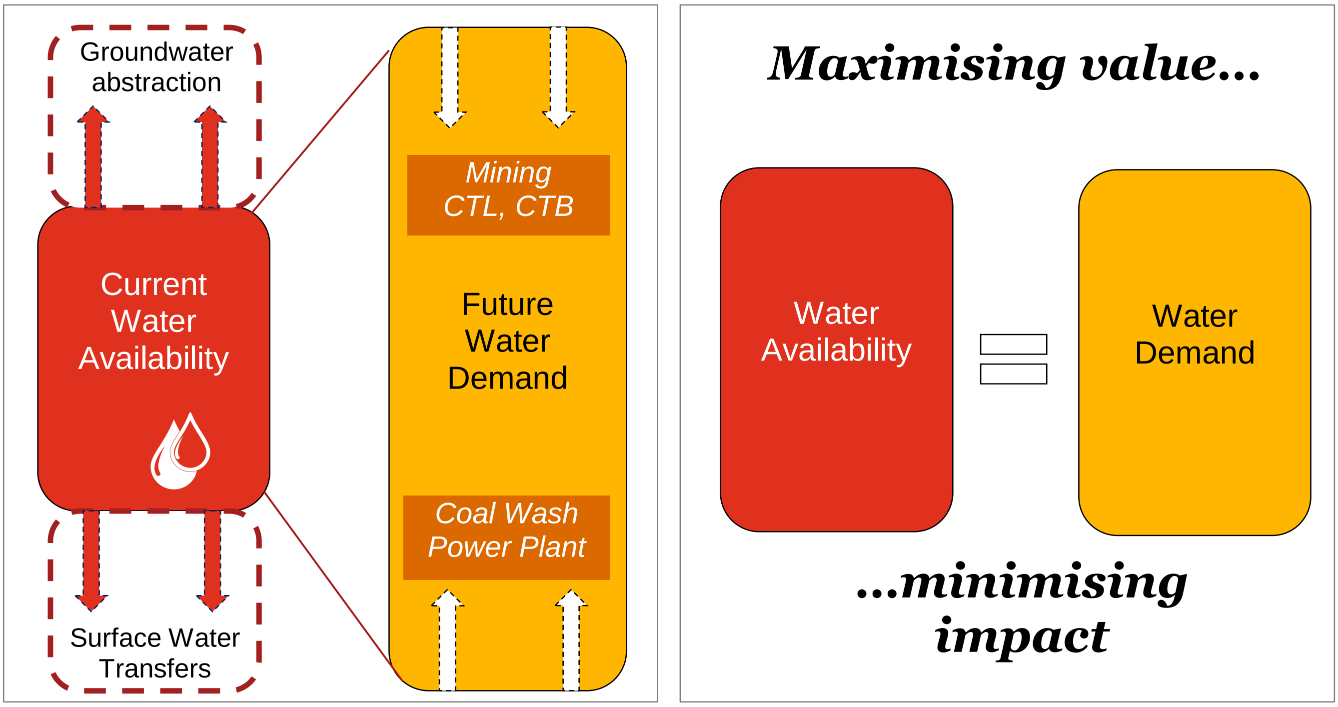


2. The study at a glance

2.1. Objective

The focus of this analysis lies on the coal mining regions Tavan Tolgoi and Nyalga Shivee Ovoo[14], in which many investments in coal value adding technologies, including power plants, coal washing, coal-to-liquid and coal-to-briquette are planned. Water is a critical element to these new developments. The objective of this study is to shed light on the urgency of the water resource challenge by quantifying the water supply demand gap today, in 2030 and in 2040. To allow for a more differentiated understanding, water demand was estimated for three scenarios, namely low, medium and high demand. In addition, to reflect the impact of the planned projects on the water supply demand gap and given high uncertainties of project implementation a distinction was made in the analysis between the scenario that all planned projects would be implemented in future or that none of the planned projects would be implemented. Once identified, a wide range of solutions to close the gap are identified. Solutions include water demand reduction and water supply augmentation measures. These options are then prioritised and recommendations are offered on how to implement these solutions that contribute to enhance Mongolian citizens' welfare or the welfare of Mongolia as a whole at least cost.

Figure 7 High level objective of the study



2.2. The study at a glance

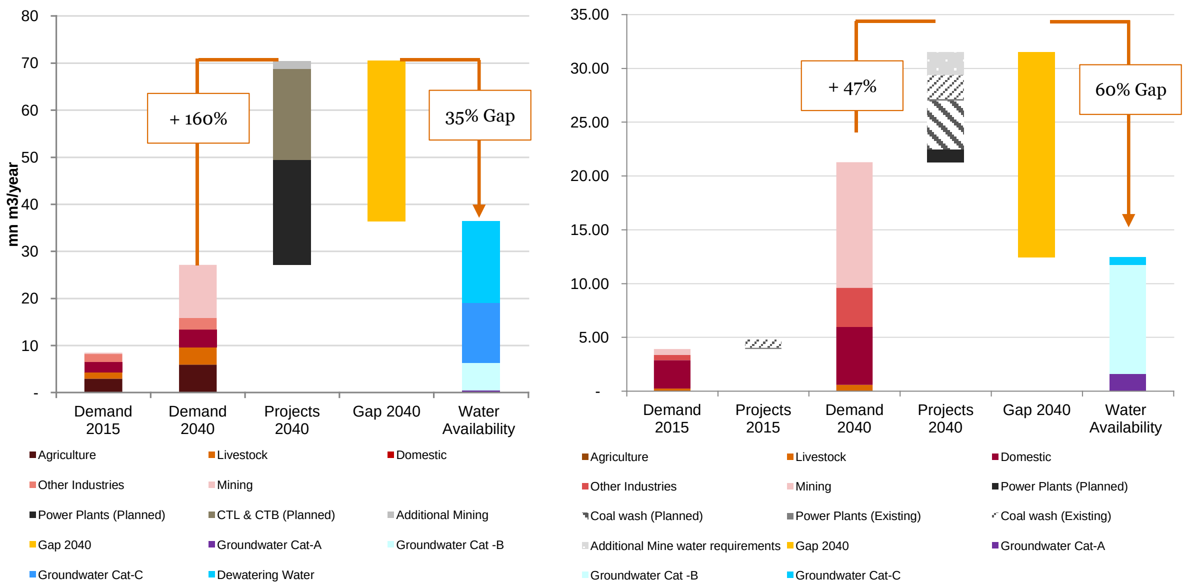
In both regions, the water demand-supply assessment reveals that available water resources, including dewatering and re-used water, are insufficient to meet future water demands in 2040 when all planned projects are executed.[15]

In Nyalga Shivee Ovoo region, the implementation of all planned projects, if left unaddressed, would result in a water supply demand gap of 35% (34.25 mn m³/yr) in the high water demand scenario and 30% and 31% in the low and medium demand scenarios by 2040 respectively. In Tavan Tolgoi region, the implementation of all planned projects, if left unaddressed, would result in a water supply demand gap of 60% (18.85 mn m³/yr) in

[14] The analyzed regions cover a radius of 50 and 100 km around the mining sites, as these are the distances in which groundwater abstraction is deemed as a feasible financial option.
[15] As an exception, the low water demand scenario in Tavan Tolgoi does not result in a water-demand supply gap.

the high water demand scenario and 33% in the medium demand scenario (see Figure 8 Water supply demand gap in the high demand scenario for Nyalga Shivee Ovoo (left) and Tavan Tolgoi (right)).

Figure 8 Water supply demand gap in the high demand scenario for Nyalga Shivee Ovoo (left) and Tavan Tolgoi (right)



For more information on the water demand and water supply estimates, as well as on the scenario development, please refer to Chapter 3.

To close the water gap and enable sustainable development, a wide range of technical solutions are identified, including water demand reduction and water supply augmentation measures. Water demand reduction solutions are about finding ways in which the same activities can be carried out with less water, i.e. increasing water efficiency. Augmenting supply relates to solutions which make more water available, e.g. by diverting water away from where it is to where it is actually needed, storing water when it is available for those moments in which it may not be, pumping water out of the ground, etc. These solutions are tailored to the existing and planned projects and follow international best practices. All identified measures jointly have the potential to make 55.64 mn m^3/yr (gap: 34.25 mn m^3/yr) in Nyalga Shivee Ovoo and 57.12 mn m^3/yr (gap: 18.85 mn m^3/yr) in Tavan Tolgoi of water resources available, thus closing the gap.

For more information on the technical solutions and their water saving/ augmenting potential, please refer to Chapter 4.

As the implementation of all identified solutions would exceed the water requirements to close the water-supply demand gap, the solutions are prioritised. The prioritisation is based on an assessment framework which includes financial, economic and environmental criteria and allows for the identification of solutions, which make most water available at least cost to the Mongolian society, i.e. the most cost-effective solutions. The most cost-effective solution either reduces water demand or augments water supply at the lowest cost per m^3 of water (USD/m^3). The solutions are ranked by their cost effectiveness, which results in a graph known as “cost curve”. Thus, the most preferred solutions, i.e. those reducing water demand or increasing water supply at the least cost per m^3 of water, are located on the left side of the graph. When moving towards the right side of the graph, the solutions become more expensive per m^3 of water, i.e. they are less cost effective. The width of each column, i.e. each solution, indicates how much water is made available. Narrow columns thus result in low water savings or water supply augmentation potential, while broad columns result in high water savings or water supply augmentation potential. The cost curves for Nyalga Shivee Ovoo region and Tavan Tolgoi are illustrated in Figure 9 Nyalga Shivee Ovoo - Holistic cost curve (financial, economic and environmental criteria) and Figure 10 Tavan Tolgoi - Holistic cost curve (financial, economic and environmental criteria) respectively.

Figure 9 Nyalga Shivee Ovoo - Holistic cost curve (financial, economic and environmental criteria)

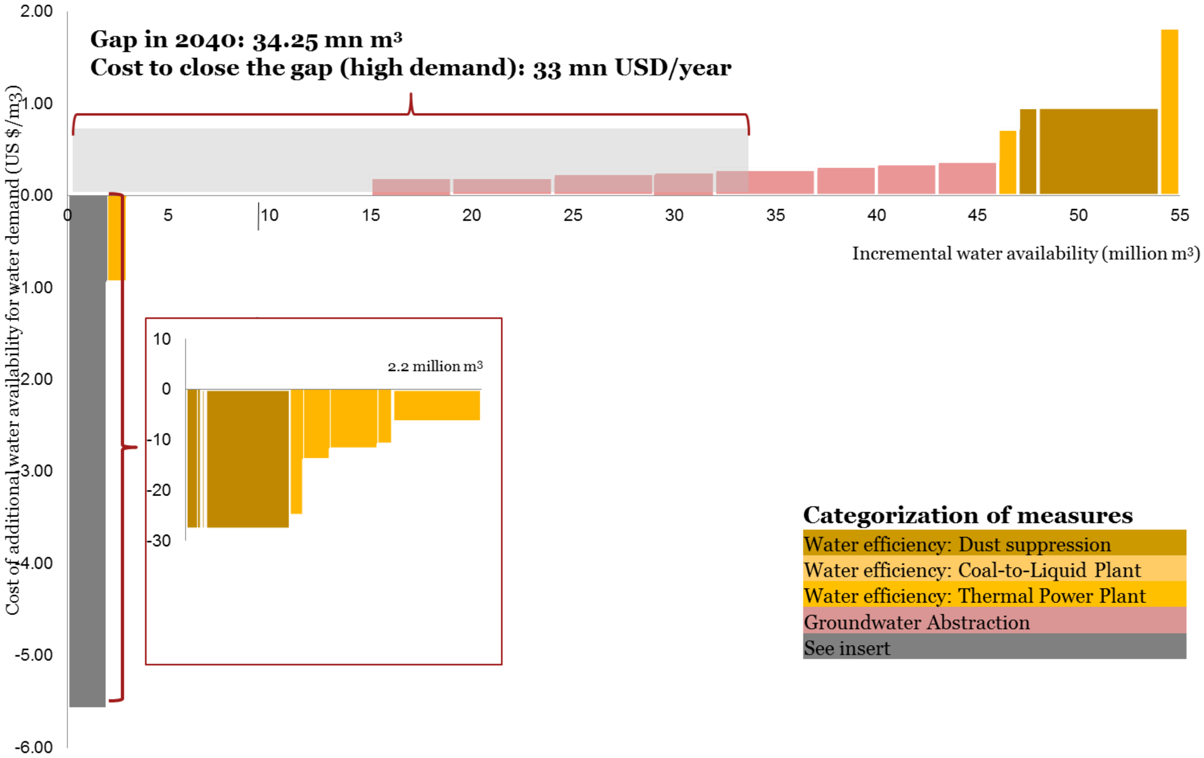
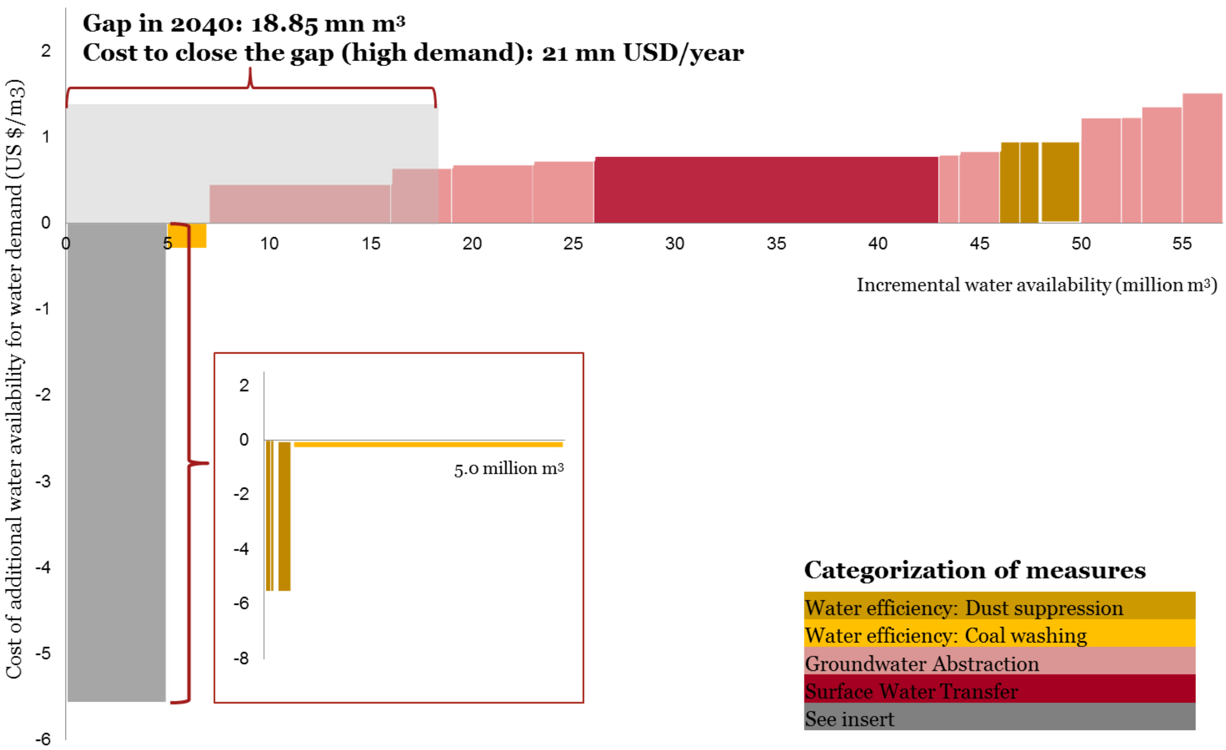


Figure 10 Tavan Tolgoi - Holistic cost curve (financial, economic and environmental criteria)



The area shaded in grey illustrates the extent of the water supply-demand gap. The colours of the columns refer to groups of measures which are detailed in the legend.

The outcome of the holistic hydro-economic analysis shows that the water supply demand gap in the high scenario in Nyalga Shivee Ovoo region can be closed at an incremental cost of 33.2 mn USD/ yr when compared to the baseline technology alternatives.[16] Incremental costs refer to the costs which are required to invest given the existing technology, i.e. upgrading these, if available, as opposed to costing the entire technology to be built anew, i.e. total costs. The most cost effective solutions are demand reduction measures at the mines and (planned) projects, including changes in dust suppression, efficiency improvements related to cooling systems and cooling water treatment, as well as the installation of FGD and efficient sprinklers. Jointly, these measures have the potential to close 86% of the gap. The remaining gap (4.7 mn m^3/yr) can be closed in the most cost effective way by developing selected new groundwater boreholes. However, given that analysed groundwater resources are non-renewable in the Gobi region, preference may be given to less cost-effective water demand solutions before additional groundwater is abstracted. This would increase the incremental costs to close the gap to 36.5 mn USD/yr, necessitating only 2.95 mn m^3/yr (instead of 4.7 mn m3/yr) to be abstracted from local groundwater sources.

In Tavan Tolgoi region, the holistic hydro-economic analysis suggests that the water supply demand gap in the high scenario can be closed at an incremental cost of 21.0 mn USD/ yr when compared to the baseline technology alternatives. The most cost-effective demand reduction solutions include changes in dust suppression measures and implementation of dry coal cleaning technologies. Jointly these demand reduction solution measures can close 50% of the water supply demand gap. The remaining gap (9.5 mn m^3/yr) can be closed most cost-effectively by development of selected new groundwater boreholes (Figure 2). As analysed groundwater resources are non-renewable, preference may be given to implement all possible water demand reduction measures first. A total of 11.5 mn m^3/yr can be saved by implementing all identified water demand reduction measures. This would increase the incremental costs to close the gap to 22 mn USD/yr, necessitating 7.4 mn m^3/yr (instead of 9.5 mn m3/yr) to be abstracted from local groundwater sources. The gap could also be closed by construction of the Orkhon-Gobi Water Transfer. However, this would result in much higher costs (212 mn USD in total) and is linked to risks related to uncertainties of river runoff and uncertainties of future demand, to mention a few.

For more information on the assessment framework, costs curves and concrete measures for the existing and planned projects, please refer to Chapter 5. In addition to holistic cost curves, which include financial, economic and environmental criteria, also financial cost curves, i.e. based on financial criteria alone, are illustrated.

In the study areas, a big share of future water demand will stem from planned mining related projects. All projects are related to coal, a resource characterised by a volatile and changing market. Currently, there is a high uncertainty around the actual implementation of planned projects and these are at very different stages of planning/ development. In case no projects were to be implemented, there would be no water gap, except for the Tavan Tolgoi high water demand scenario, and thus no solutions would be required. However, if the high uncertainty on project implementation persists, a conservative approach is recommended and decisions on solutions which are sufficient to close the high demand scenario gap should be taken anyway. Certainty on future water supply in the "worst case scenario" is expected to lead to higher investor trust and thus - potentially - to higher inclusive economic growth.

Actions driven by the Government: A fundamental decision needs to be taken among all stakeholders in Mongolia, but driven by the Government, on the willingness to use non-renewable groundwater reserves and on the subsequent preferred solutions to be implemented. Further, given the high share of water demand from planned thermal power plants, discussions should consider the water-energy nexus and decide on strategic priorities for Mongolia. High-level policy and strategic documents on Energy and Water should be coordinated and integrated by the MEDGT, Ministry of Energy, Ministry of Mining and Ministry of Industry. Further, decisions need to be made on which areas should be managed with regulations, i.e. stakeholders need to comply, or with incentives, i.e. stakeholders can choose their actions accordingly. The result of the decision requires to be implemented, enforced and monitored to ensure the desired outcome. Close links can be made to the parallel 2030 WRG Work Stream on Water Valuation and Incentives, where potential amendments to the water valuation methodology, the water abstraction and pollution fees, and urban water tariffs are discussed.

[16] All costs estimates mentioned above refer to "Equivalent Annual Costs (EAC)", i.e. the annual capital, operation and maintenance costs annualised over the assets' lifetime to allow for comparison of solutions with different time horizons.

Actions related to companies/ investors: As all analysed water demand reduction measures relate to companies (private/ public), their ability and willingness to invest in these measures, as well as the options for sourcing the technologies needs to be understood. Incentives and financial support for these measures, such as preferential loans from leading banks, (import) tax rebates and conditional water permits can be identified for this purpose. Knowledge transfer between companies within Mongolia and abroad, as well as capacity building, shall support the companies/ investors in identifying and implementing the optimal and most cost effective solution. For this, a voluntary mining group with water focus could be set up. Close links can be made to the IFC Mining Roundtable.

Importance of multi-stakeholder consultations: Given that these decisions have the potential to affect all Mongolians, directly or indirectly, a multi-stakeholder consultation process is of great importance.

Finally, additional research and validation is required to confirm water availability of government approved and newly identified aquifers, especially with respect to environmental impacts, as well as feasibility and environmental and social impact studies need to be conducted before implementing identified solutions.

For more information on recommendations, next steps and key stakeholders to be consulted, please refer to Chapter 6.

2.3. *Multi-stakeholder consultations*

Consultation of stakeholders from the private and public sector, as well as from civil society was paramount in all phases of this analysis. Emphasis was set to consult local stakeholders, e.g. the herders, mines and local governors in the mining regions, as well as national level stakeholders, such as national level government, headquarters of companies, national NGOs, etc. Input from stakeholder consultation was used for:

- Primary and secondary data collection
- Validation of information due to data limitations and recent changes in coal and coal-related sectors
- Inclusion in deriving solutions and developing assessment framework
- Consultation on feasibility of identified solutions

In total, 47 stakeholders were consulted in face-to-face interviews (see Table 19 Stakeholder list of interviews conducted). Of these 47 interviewees, 19 represented the public sector, 12 the private sector and 15 represented NGOs, local residents, development agencies and Intergovernmental Organisations. Further, we held two focus group discussions - one with the objective to develop and validate the assessment framework for prioritising solutions and one to validate interim findings of the study. In addition, interim findings were presented at the IFC Mining Roundtable meeting in Dalanzadgad (capital of Ömnögovi aimag) to receive further inputs from the experts present.

A list of stakeholders consulted is available in Annex A.2

3. Regional water challenges: Identifying the water supply-demand gaps

3.1. Water demand assessment and scenario development

Water demand is assessed for the baseline (2015) as well as for the years 2030 and 2040. To allow for a more diversified understanding of future water usage, water demand is estimated for three water demand scenarios: low, medium and high water demand.

3.1.1. Water demand assessment

Water demand is assessed based on the primary and secondary data collection. In cases in which no actual water usage data was available, water use norms, as outlined in Resolution No A 301, were used.

Water demand has been calculated exclusively for the study area. In some cases, suoms are only partially included in the study area. In this case, urban domestic water demand is dependent on whether the suom center is included in the study area or not. For livestock and rural water demand, the proportion of area included in the study area is proportional to water demand included in the analysis.

	Description	Data sources
Agriculture	Based on agricultural crop production in suoms and water usage norms for produced crop and region.	• Primary data from suom offices and/ or websites; • Resolution No A 301 (water norms)
Livestock	Based on data on the population of livestock (horse, cow, camel, sheep, and goat) and water usage norms for each category of livestock.	• National Statistical Office of Mongolia (http://en.nso.mn/) • Resolution No A 301 (water norms)
Domestic	Rural and urban water demands are assessed separately. Actual water usage data were used where available (mostly suom centers). If unavailable, statistics on suom population were used to derive water demand based on different water usage categories (central water system, gher district etc.).	• River Basin Administrations • National Statistical Office of Mongolia (http://en.nso.mn/) • Resolution No A 301 (water norms)
Mining	Water demand for all key mines, incl. scenarios, is based on primary data collection. Water demand from additional mines (outside of core study area in 100km radius) is estimated based on mining licenses, annual production and water usage per unit of production.	• Consultation, data review and validation with key mining companies (see Annex A.2) • River Basin Administrations • Expert interviews • Mineral Resources Authority of Mongolia (MRAM) RAM (Mining licenses)
Industries (excl. mining)	Water demand is based on actual water usage.	• River Basin Administrations • Ministry of Environment, Green Development and Tourism (MEGDT)
Existing & planned developments	Estimates for key mines and investment plans are based on actual (planned) water demand and type of technologies requested from companies and authorities providing permits. Data was cross-checked on internal consistency and with international benchmarks. In cases in which companies could not be contacted, official sources were used and cross-checked with international benchmark.	• Ministry of Energy • Ministry of Mining • Ministry of Industry • Ministry of Environment, Green Development and Tourism (MEGDT) • River Basin Administrations • Involved companies • International benchmarks

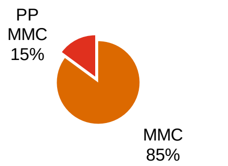
3.1.2. Water demand scenario development

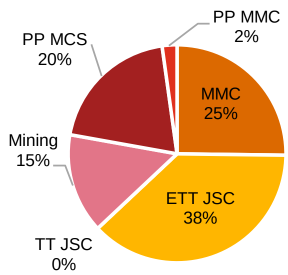
Water demand scenarios were developed based on concrete development plans and expert interviews. In cases where these were not available, water usage scenarios and forecast estimates were applied from the widely accepted Water Demand Handbook (2012) – an outcome of the "Strengthening Integrated Water Resource Management Project"[17]. This shall further provide consistency across various studies on water resource management in Mongolia.

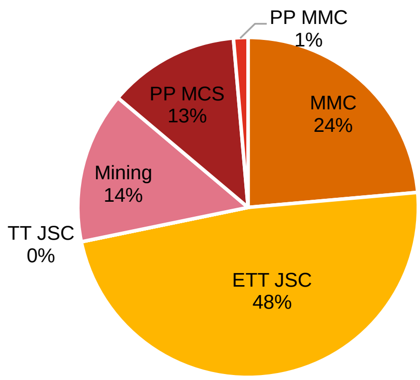
In Tavan Tolgoi region, additional scenarios were developed for planned developments, as 1) Some investments, such as for coal washing, are mutually exclusive and 2) The companies stated different future low, medium and high scenarios for their development plans. The scenarios are thus based on actual development plans. No such scenarios were included for Nyalga Shivee Ovoo region as considerations mentioned above did not apply.

Please see the scenarios – only referring to the planned investments – in Tavan Tolgoi below in Table 3 .

Table 3 Investment and water demand scenarios for planned developments in Tavan Tolgoi







Low (0.89 mn m³/yr)	***Med (6.01 mn m³/yr)***	***High (9.62 mn m³/yr)***
Coal washing options: • *ETT JSC sand washing plant with 5 mn ROM/ yr cap* • *MMC existing plant operating at 5 mn/ yr ROM* • *TT JSC no operations*	***Coal washing options*** • *ETT JSC wet washing plant with 15 mn ROM/ yr cap* • *MMC existing plant operating at 10 mn ROM/ yr* • *TT JSC existing dry enrichment plant operating*	***Coal washing options*** • *ETT JSC wet washing plant with 30 mn ROM/ yr cap.* • *MMC existing plant operating at full capacity (15 mn ROM/ yr)* • *TT JSC existing and planned dry enrichment plants operating*
Power plants (PP) • *MMC Power Plant 18 MW*	***Power plants (PP)*** • *MMC Power Plant 18 MW* • *MCS Consortium Power Plant 450 MW*	***Power plants (PP)*** • *MMC Power Plant 18 MW* • *MCS-led Consortium Power Plant 450 MW*

[17] The project was implemented at the Ministry of Environment and Green Development with support from the Government of The Kingdom of the Netherlands. The Water Demand Handbook was prepared by G. Dolgorsuren, Wim van der Linden and Ch. Puntsagsuren.

3.1.3. Overview total water demand

Please see an overview of total water demand in Nyalga Shivee Ovoo and Tavan Tolgoi in Table 4 and Table 5, respectively.

Table 4 Total water demand in Nyalga Shivee Ovoo

Mn m^3/year	Baseline	Low demand scenario		Medium demand scenario		High demand scenario	
Water Demand – Baseline	**2015**	**2030**	**2040**	**2030**	**2040**	**2030**	**2040**
Agriculture	2.94	3.96	4.83	4.21	5.34	4.49	5.91
Livestock	1.43	2.19	3.02	2.19	3.02	2.50	3.72
Domestic (Urban)	1.59	2.08	2.54	2.14	2.61	2.26	2.75
Domestic (Rural)	0.54	0.65	0.78	0.71	0.84	0.86	1.00
Industrial	1.72	1.75	1.78	1.78	1.88	1.92	2.46
Mining water demand	0.28	1.13	1.13	2.13	2.13	11.28	11.28
Sub-total Baseline	8.49	11.76	14.08	13.17	15.82	23.30	27.12
Water Demand - Projects							
Power Plants (Planned)		22.33	22.33	22.33	22.33	22.33	22.33
CTL & CTB (Planned)		19.34	19.34	19.34	19.34	19.34	19.34
Additional Mine water		1.83	1.83	1.83	1.83	1.83	1.83
Sub-total Planned Projects	-	43.50	43.50	43.50	43.50	43.50	43.50
Total Water Demand	**8.49**	**55.25**	**57.58**	**56.66**	**59.32**	**66.79**	**70.62**

Table 5 Total water demand in Tavan Tolgoi

Mn m^3/year	Baseline	Low demand scenario		Medium demand scenario		High demand scenario	
Water Demand - Baseline	**2015**	**2030**	**2040**	**2030**	**2040**	**2030**	**2040**
Agriculture	0.01	0.01	0.02	0.01	0.02	0.01	0.02
Livestock	0.24	0.34	0.47	0.34	0.47	0.39	0.57
Domestic (Urban)	2.13	3.31	4.46	3.33	4.48	3.37	4.53
Domestic (Rural)	0.50	0.57	0.65	0.63	0.71	0.74	0.83
Industrial	0.25	0.38	0.53	0.63	1.17	1.25	3.65
Mining water demand	0.34	1.12	1.12	6.15	6.15	12.71	12.71
Sub-total Baseline	3.66	6.87	8.38	10.46	12.38	17.43	21.28
Water Demand - Projects							
Power Plants (Planned)		-	-	1.20	1.20	1.20	1.20
Coal wash (Planned)		-	-	2.27	2.27	4.54	4.54
Power Plants (Existing)	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Coal wash (Existing)	0.76	0.76	0.76	1.51	1.51	2.27	2.27
Additional Mine water		-	-	1.17	1.17	1.88	1.88
Sub-total Planned Projects	0.89	0.89	0.89	6.28	6.28	10.03	10.03
Total Water Demand	**4.55**	**7.76**	**9.27**	**16.75**	**18.66**	**27.46**	**31.31**

Please consult Annex A.1 for reference to the report supplement for a detailed description of assumptions, data sources and methodologies.

3.2. Water availability assessment

At present, groundwater resources are the only available water source in both the study regions. Groundwater resources can be distinguished between shallow and deep groundwater aquifers.

Shallow aquifers are associated with drainage courses where relatively thin and narrow, unconsolidated alluvial sediments occur from surface to depths in the order of 10m; depths to water tend to be <5m. These aquifers are seasonally replenished by run-off following significant rainfall events; water quality ranges from fresh to brackish. Deep aquifers may be found to depths up to 400m in the extensive sedimentary basins that are common in the region. The deep aquifers are typically overlain by thick clay sequences and receive little or no recharge, i.e. non-renewable; water quality is brackish.

Shallow aquifers serve as an important water source for domestic uses, as well as for livestock and occasional local groundwater dependent vegetation. Overall, total water usage from shallow aquifers is small.

This study only focuses on water available from the deep aquifers as (a) it is only these sources that have the storage capacity to sustain large-scale abstraction and (b) the available shallow resources are committed or subject to priority local demands.

Available groundwater availability is based on established and Government approved groundwater reserve estimates. There are four groundwater reserves categories, distinguished by the certainty of available water resources: A (measured/proven); B (indicated/ possible); C1/C (inferred/ potential) and C2/P (probable/ predicted).

Prior investigations of C1/C and C2/P aquifers have shown that while total available groundwater can be verified, the actual water available for usage may be lower. This is mainly due to technical and environmental constraints and considerations. Recent debates on the Balgasiin Ulaan Nuur aquifer (Tavan Tolgoi study area), which is partially categorised as C1/C aquifer, provide a case in point. The reserve at this location was initially estimated at 444 l/sec. Subsequent investigations by the mining company QGX, which focussed on the central basin area, reduced this estimate to 150l/sec with the associated Environmental Impact Assessments, accompanied by groundwater modelling predicting water level drawdowns across the entire wetland area, listing a number of potential negative impacts arising from groundwater abstraction[18] . Notwithstanding, a reserve of 125l/s was formally approved in 2008. Recently, the estimates have been revisited by a governmental gremium and increased again to 404 l/ sec.

Previous investigations by GWMS and others, that take account of varying sedimentary and hydrogeological characteristics, conclude that C1/C aquifer conditions in Nyalga Shivee Ovoo region provide higher level of certainty of estimated reserves. As a consequence, and to provide conservative estimates until certainty prevails via additional feasibility and environmental impact assessments, this study will only include A and B classified groundwater aquifers in Tavan Tolgoi and A, B and C1 aquifers in Nyalga Shivee Ovoo regions.

The decision to consider only selected aquifer categories, as well as excluding shallow aquifers provides this study with conservative estimates with respect to the presented water balance. Thus, the identified water gaps are expected to be over-, rather than underestimated. This approach was chosen, considering the importance of shallow aquifers for locals and given the non-renewable nature of deep aquifers. Please note that water availability is seen as a total value, rather than considering existing and negotiated allocation of water use rights.

[18] EcoTrade (2008) Environmental Impact Assessment Report For Balgasyn Ulaan Nuur Groundwater Resource Abstraction Project

3.2.1. Re-use of dewatering and recycled water from coal mines

Re-use of dewatering water

At a depth at which the extracted coal reserves are below the groundwater level, dewatering of mines is required to efficiently extract the coal. The depth and amount of dewatering required, differs from location to location being dependent on formation characteristics.

At the Shivee Ovoo mine, e.g. in which operations are about 100 m deep, the pit floods within two days of non-pumping. In Ukhaa Khudag mine (Tavan Tolgoi region), in which extraction has reached a similar depth (~110m), there are much smaller quantities pumped out of the pit via dewatering.

Please see the overall potential dewatering yield for both mining sites below. Data is based on actual current rates of dewatering from operating mines and preliminary exploration findings at other sites.

Table 6 Potential Future Water Availability from Mine Dewatering Operations in Nyalga Shivee Ovoo

Mine	Dewatering yield (l/sec)	Dewatering yield (mn m^3/year)
Shivee Ovoo	175	5.52
Tugrug Nuur	200	6.31
Buuruljuutin Tal	175	5.52
Total NSO	**550**	**17.34**

Table 7 Potential Future Water Availability from Mine Dewatering Operations in Tavan Togoi

Mine	Dewatering yield (l/sec)	Dewatering yield (mn m^3/year)
Ukhaa Khudag	15	0.47
Baruun Naran	2	0.06
Erdenes Tavan Tolgi and Tavan Tolgoi JSC	N/A	N/A
Total TT	**17**	**0.54**

Notes: *Estimates for Erdenes Tavan Tolgoi and Tavan Tolgoi JSC are not available. However, based on hydro-geology and interviews with ETT total dewatering water is expected to be minimal. Ukhaa Khudag and Baruun Naran are operated by Mongolian Mining Corporation (Energy Resources). Dewatering rates are based on a minimum production of 5Mt/ year or production volumes specified by mining companies.*

Given the overall water quality of dewatering water in both regions, re-use is possible without requiring major treatment processes. This is already done, e.g. in Shivee Ovoo mine, and planned for other investments. Dewatering is a necessity for mining operations, and can thus be considered as sunk costs, i.e. no additional pumping costs are required. As water required for the planned investments analyzed are in close proximity to the mines, no major cost anticipated with water transport are foreseen.

Thus, dewatering water is included as available water resource in the water balance in this study, rather than a solution to close the gap in the cost curve. [19]

Re-use of recycled water

In Tavan Tolgoi region, Energy Resources operates two wastewater treatment plants. The treated wastewater from the suom center and the camp at which the employees of Energy Resources live, is treated and used for dust suppression at the Ukhaa Khudag mine. Total recycled water, i.e. treated wastewater, amounts to 5.71 /sec (0.8 mn m^3/yr).

[19] As no concrete environmental and social costs to the usage of dewatering water were identified, dewatering water is not included in the cost curves.

3.2.2. Total current water availability

Please see considered water availability – including groundwater and dewatering water - for both regions in Table 8 and Table 9 below.

Table 8 Considered Approved Groundwater Reserves in Nyalga Shivee Ovoo region

Water Source	Water availability	
	mn m^3/year	l/sec
Groundwater Cat-A	0.44	13.93
Groundwater Cat -B	5.92	186.55
Groundwater Cat-C	12.67	399.44
Dewatering Water	17.34	546.99
Total	36.37	1,146.91

Table 9 Considered Approved Groundwater Reserves in Tavan Tolgoi region

Water Source	Water availability	
	mn m^3/year	l/sec
Groundwater Cat-A	1.61	50.72
Groundwater Cat -B	10.13	319.59
Dewatering & Recycled Water	0.72	22.58
Total	12.46	392.89

Note: Please note that these are estimates only. The exact water availability needs to be verified in additional studies.

Table 23 and Table 24 in Appendix A.3 provide an overview of water availability per aquifer and aquifer category for Nyalga Shivee Ovoo and Tavan Tolgoi.

Please note that additional water reserves are available of which the exact quantities will be known following verification and validation (see section 3.2.1). The potentially available water amounts to 20.46 mn m^3/year for Tavan Tolgoi (C1/C and C2/P aquifers in the region) and to 8.79 mn m^3/year for Nyalga Shivee Ovoo (C2 aquifers in the study region).

Please consult Annex A.3 for a detailed description of assumptions, data sources and methodologies.

3.3. Water Balances: Identifying the water gap

To gain an understanding on the overall water supply and demand situation in the study regions, overall water demand is compared with available water resources. Overall water demand includes agriculture, livestock, domestic, mining and other industries – in addition to water demand from (planned) developments (see section 3.1 for more information).

This analysis sheds light on whether all planned investments can be done within the given water resources, while considering all other water demand, or whether measures are required to close the gap.

3.4. Nyalga Shivee Ovoo brown coal region

When contrasting current and future water demand with available water resources[20], it becomes clear that water demand in the high demand scenario cannot be met with established and Government approved groundwater reserves considered in this study and dewatering water alone in 2040.

Water demand in 2040, without any of the planned projects being executed, can be met by available water resources in all scenarios. In the case, however, that all planned projects are implemented, there will be water gap by 2030 in all scenarios, even if dewatering water is used for planned project demand (see Figure 11 and Table 10).

[20] Available water resources consist of groundwater and dewatering water. Given hydrogeological characteristics, groundwater categories A, B and C1 are considered in Nyalga Shivee Ovoo region.

Table 10 Overview of water supply and water demand across scenarios in Nyalga Shivee Ovoo region

mn m3/yr	Baseline	Low demand scenario		Medium demand scenario		High demand scenario	
	2015	2030	2040	2030	2040	2030	2040
Water Resources	36.37	36.37	36.37	36.37	36.37	36.37	36.37
Water demand (without planned projects)	8.49	11.76	14.08	13.17	15.82	23.30	27.12
Water demand (with planned projects)	8.49	55.25	57.58	56.66	59.32	66.79	70.62
Gap (without planned projects)	3.97	0.70	(1.62)	(0.71)	(3.37)	(10.84)	(14.66)
Gap (with planned projects)	3.97	(42.79)	(45.12)	(44.21)	(46.86)	(54.33)	(58.16)

Figure 11 Water Balances for Nyalga Shivee Ovoo - All water demand scenarios, assuming all planned projects are being executed

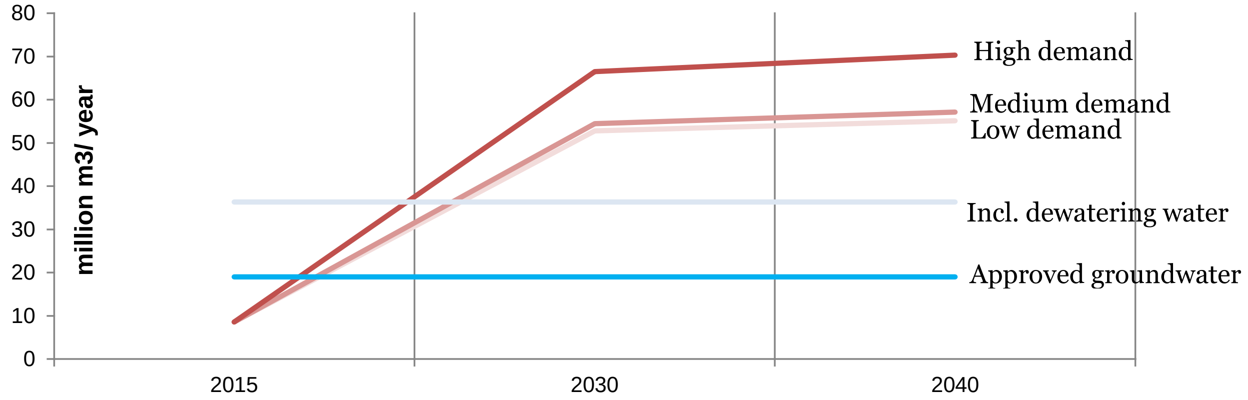
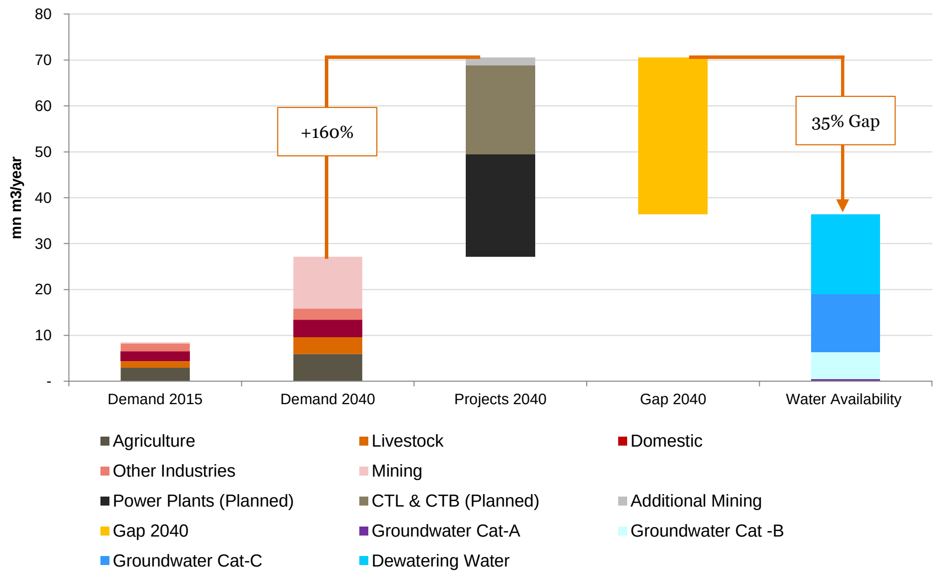


Figure 12 shows a more detailed view of the high scenario, in which additional water requirements from planned projects amount to 160% of the water demand in 2040. The high water demand from the planned projects stems nearly to two equal parts from power plants and Coal to Liquid plants. Additional mine water demand, including e.g. dust suppression and water for the worker, required to produce the coal requirements for these planned projects – is a comparatively small share.

Figure 12 Water Balance for Nyalga Shivee Ovoo Region (High demand scenario, incl. execution of planned projects)



Additional graphs for low and medium demand scenarios can be found in Annex A.1.

If left unaddressed, the water supply-demand gap for the high scenario, assuming all planned projects will be executed, will amount to 35% (34.25 mn m3/yr). In the low and medium demand scenarios, 30% and 31% of total demand will remain unmet by available water resources, respectively.

3.5. Tavan Tolgoi

In the Tavan Tolgoi study area, available water supply including groundwater, recycled water and dewatering[21] is sufficient to meet baseline water demand (i.e. excluding planned projects) until 2040 in the low and medium water demand scenarios. However, available water supplies are expected to be insufficient to meet water demand in the high scenario by 2030 (gap of 4.97 mn m3/year in 2030 and 8.82 mn m3/year in 2040).

When adding water demand from planned projects (see section 3.1), it becomes apparent that available water resources are insufficient to meet water demand by 2030 in the medium and high water demand scenarios. In the low water demand scenario, available water is sufficient to meet all demand (see

Figure 13). The gap amounts to 4.29 mn m3/year in 2030 and 6.21 mn m3/year in 2040 in the medium scenario and to 15 mn m3/year in 2030 and 18.85 mn m3/year in 2040 in the high demand scenario. Please see Table 11 for an overview.

Table 11 Overview of water supply and water demand across scenarios in Tavan Tolgoi

mn m3/yr	Baseline	Low demand scenario		Medium demand scenario		High demand scenario	
	2015	203 0	2040	2030	2040	2030	2040
Water Resources	12.46	12.46	12.46	12.46	12.46	12.46	12.46
Water demand (without planned projects)	4.55	6.87	8.38	10.46	12.38	17.43	21.28
Water demand (with planned projects)	4.55	7.76	9.27	16.75	18.66	27.46	31.31
Gap (without planned projects)	7.91	5.59	4.08	2.00	0.08	(4.97)	(8.82)

[21] Given hydrogeological characteristics, only groundwater categories A and B are considered in Tavan Tolgoi region.

Gap (with planned projects)	7.91	4.70	3.19	(4.29)	(6.21)	(15.00)	(18.85)

Figure 13 Water Balances for Tavan Tolgoi - All scenarios, assuming all planned projects are being executed

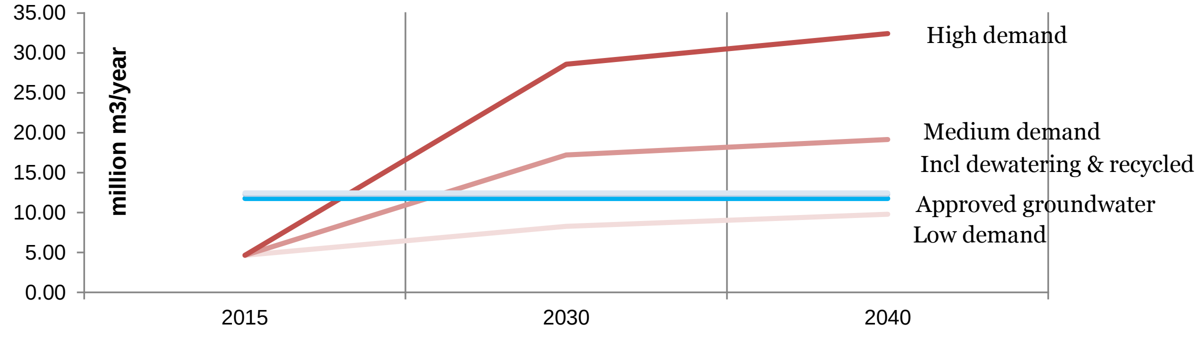
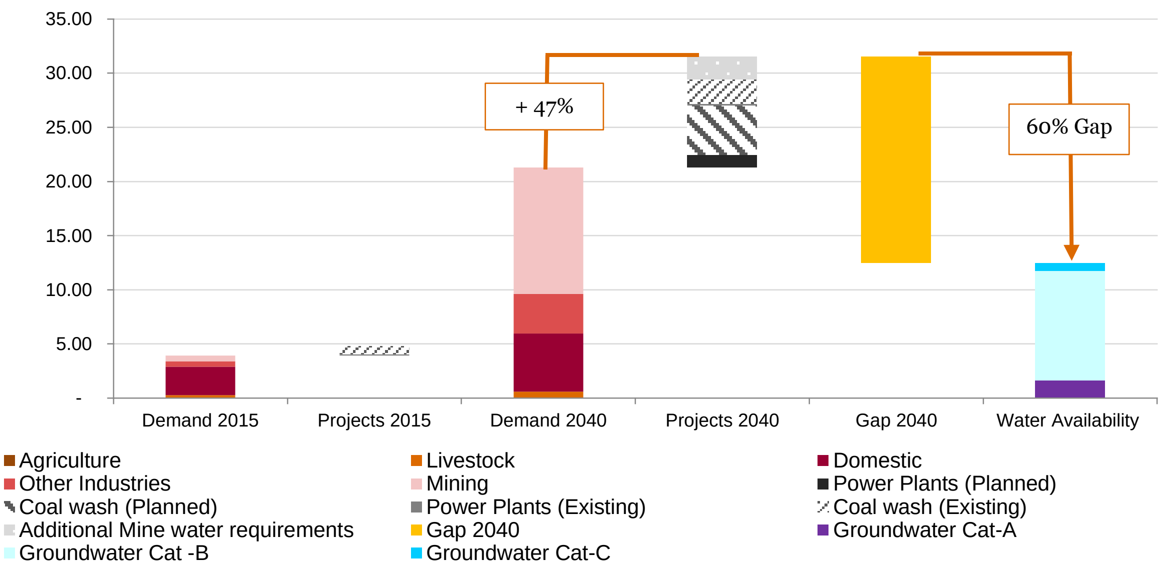


Figure 14 presents a more detailed view of the water balance in the high water demand scenario. It becomes apparent that mine water demand is the highest water demand category in Tavan Tolgoi in 2040. Water demand from additional projects add 47% to water demand in 2040. Usage of dewatering water is not sufficient to close the gap. Without further measures, 60% of water demand (18.85 mn m³/yr) will remain unmet in 2040.

Figure 14 Water Balance for Tavan Tolgoi Region (High demand scenario, incl. execution of planned projects)



Additional graphs for low and medium demand scenarios can be found in Annex A.1.

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

4.1. Solutions – Water demand reduction

This section focuses on the potential technical options that could be implemented to reduce water demand at existing projects and planned projects within the study area in the coal mining regions of Tavan Tolgoi and Nyalga Shivee Ovoo. The identification of water demand reduction solutions focuses on all types of development projects, i.e. thermal power, coal-to-liquid, coal-to-briquette and coal to washing plants, as well as coal mining operations.

The current (planned) technologies and technical specifications used for existing and planned investment projects were identified and used as baseline, from which potential water demand reduction solutions were identified. For an overview of all considered investment projects, please consult Table 1 Overview of planned developments in Nyalga Shivee Ovoo region and Table 2 Overview of existing and planned developments in Tavan Tolgoi region.

Information on existing and planned investments and projects in these regions has been received from responsible Ministries (Ministry of Energy, Ministry of Mining, Ministry of Environment, Green Development and Tourism), from River Basin Administrations and the (state) companies owning or planning these projects. For most projects, estimates for baseline annual water requirements were obtained or were derived from the data that was collected. However, data on exact technical specifications was very limited. To validate these water demand data, comparisons of the theoretical water demand for different technical specifications were made in order to determine an assumed baseline specification. Information on best practices are based on the project team's experience and best practice applications reported in the literature.

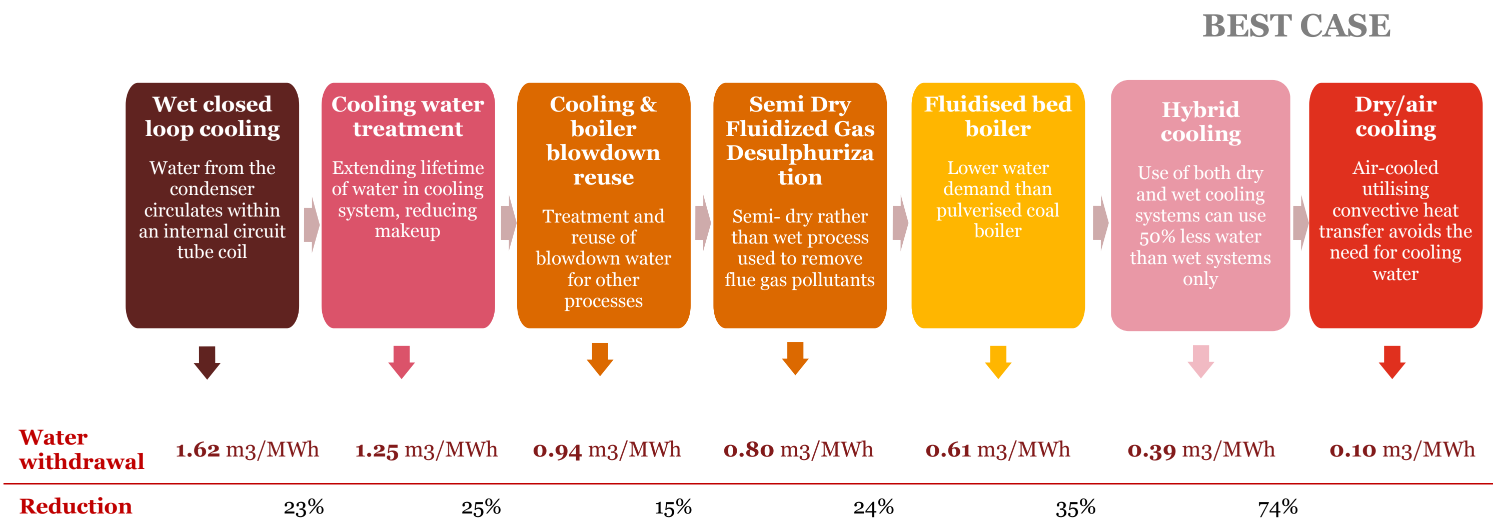
Below a brief summary of solutions, including water demand reduction potential, is provided for all analysed projects. More detailed information, incl. the particular baseline and water demand reduction potential for concrete projects, can be found in Appendix.

4.1.1. Thermal Power Plants (TPP) and Coal-to-Liquid Plants (CTL)

Thermal power generation requires reliable access to large volumes of water. Traditionally, the largest single demand for water is associated with the cooling system for the steam turbine, followed by boiler make-up and removal of SO_2 from flue gases. Coal-to-liquid facilities also require high volumes of water with key processes matching those for thermal power plants.

Figure 15 outlines the general technical options for water demand reduction at TPP and CTL plants. Each box illustrates technological options, which can be further improved by the measures to the right of each box. The existing baseline for TPP and CTL plants will determine the additional options that can be potentially added. Dry/ air cooling (with circulating fluidized bed boilers and boiler blowdown reuse) on the far right illustrate the best case, with respect to water usage.

Figure 15 Technical options for water demand reduction at TTP and CTL plants

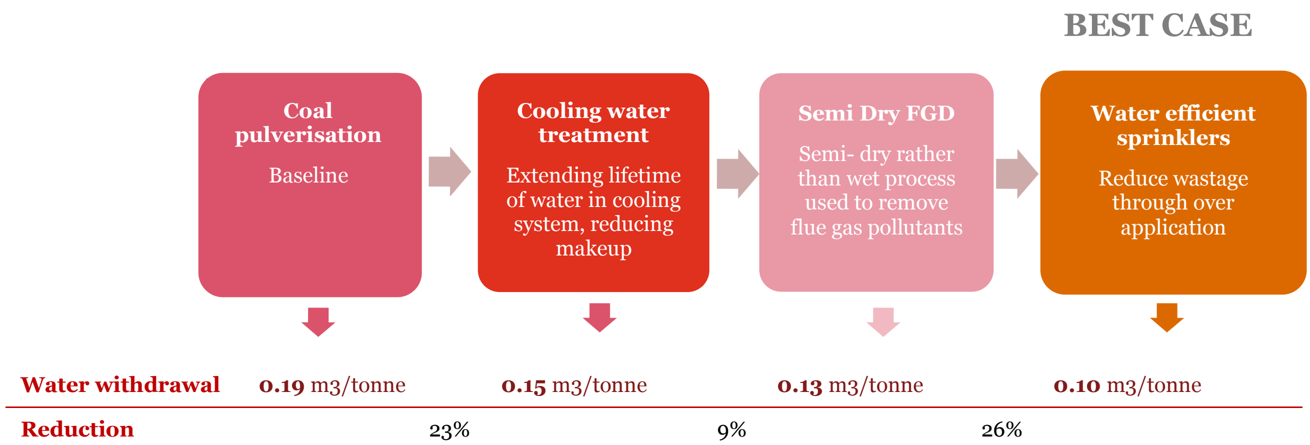


Note: *% reductions illustrate the cumulative improvement that can be made through the implementation of each option*

4.1.2. Coal to Briquette Plants

Coal briquetting is a value-adding process by which low grade coal is converted into a higher grade, uniform, hard and impact resistance agglomeration with increased calorific value. This coal can then be used for domestic and industrial purposes. Water is typically used for cooling purposes and can form part of the binder. Figure 16 provides a summary of the technical options and the water saving potential.

Figure 16 Technical options for water demand reduction at coal to briquette plants

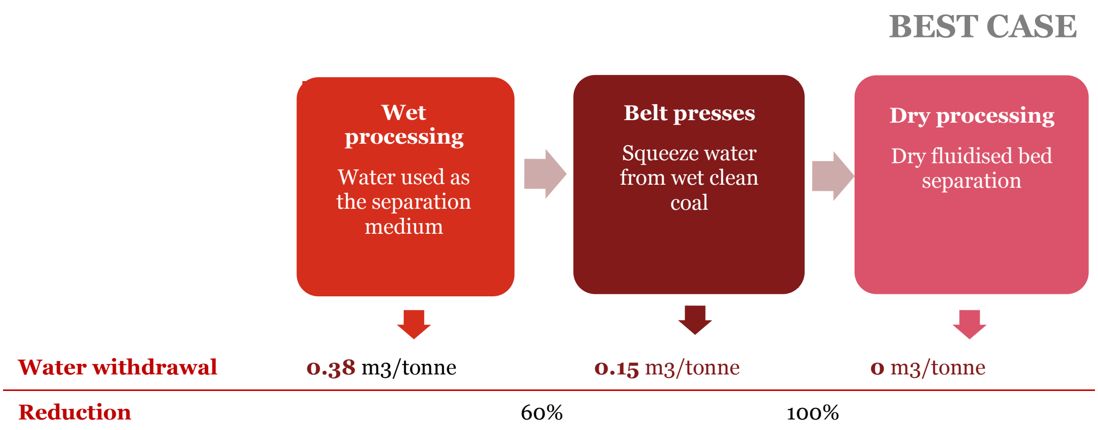


4.1.3. Coal Washing Plants

Coal washing is a process whereby impurities (e.g. ash, rock and sulfur) are removed from the coal, improving its combustion efficiency, which therefore increase its value. Physical cleaning processes are most commonly used, which involves the mechanical separation of the contaminants from the coal using gravity separation processes. Coal washing is most commonly undertaken, using water as the separation medium.

Figure 17 provides details of general technical options that can be applied to reduce water requirements.

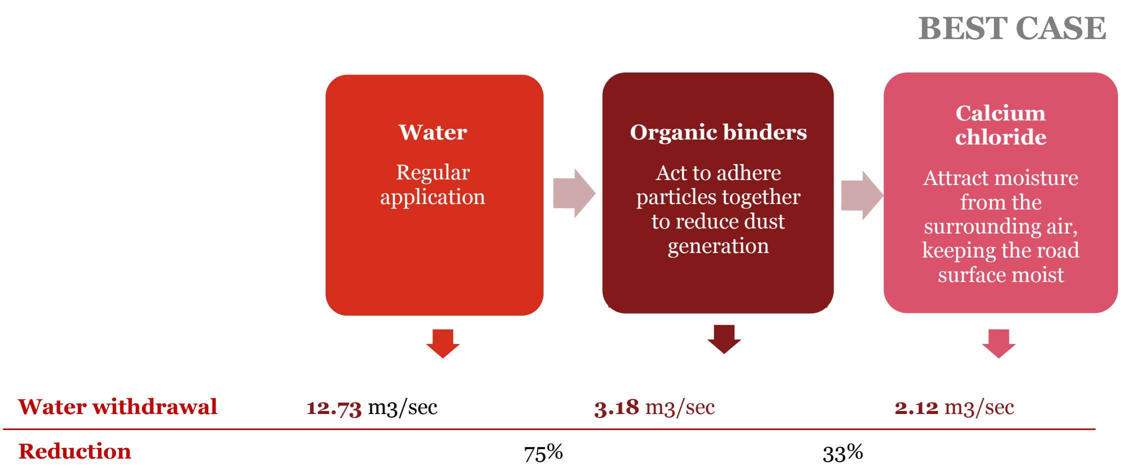
Figure 17 Technical options for water demand reduction at coal wash plants



4.1.4. Coal mining

The main water demand at the mines in the Nyalga Shivee Ovoo and Tavan Tolgoi regions is for suppressing dust associated with haul roads and stock piles. The exact volume of water required for water-spray based dust suppression varies depending upon the climatic conditions, area of coal stockpile and the area of active roads. In addition to regular water only applications, chemical dust suppressants are key alternatives which reduce water use as presented in Figure 18.

Figure 18 Technical options for water demand reduction for dust suppression at mining sites



4.2. Solutions – Water supply augmentation

This study analyses water supplies being augmented via re-use of dewatering water from coal mines, identification of additional groundwater development areas and construction of planned surface water transfers.

4.2.1. Identification of additional groundwater development areas

This study identifies potential target groundwater development areas in each study region beyond the already existing government approved reserves introduced in section 3.2.

Similar to the current water availability assessment in section 3.2, shallow aquifers are not included in the assessment. Given that deep aquifers are mostly non-renewable, calculations of the potential to develop groundwater resources are made over the next 25 years in order to meet water demand over the entire planned project lifetime.

The underlying methodology uses a modification of the established Balance Method, which is used by the Ministry of Environment, Green Development and Tourism. The modifications, based on findings from past (on field) water resource assessments involved re-definition of aquifer thickness (to take into account the entire saturated sequence that will contribute to yields) and exclusion of recharge (to provide highly conservative numbers). The water availability estimates of the assessed target borefields, which include a recovery factor, take physical, regulatory and technical constraints into account, i.e. only the actually exploitable water resources, also considering environmental water requirements, are illustrated.

In addition, the costs of each borefield are estimated to allow for the identification of the most cost effective solution. Total estimated costs cover capital and operational costs for borefield schemes to deliver water to site (without storage reservoir) for over 25 years. Capital costs for each bore include an allowance for a building, switchboard, pump, pipes to the mine site, bore column, headworks and instrumentation, low voltage lighting, heating and other items as required. A separate allowance was made for stepdown transformer. Operating costs include maintenance costs for the water supply and pipe systems, energy costs (mostly for pumping) and replacement costs.

More information, including sources, study area description and maps, are provided in Annex A.5.2. To allow for transparency, all background documents detailing the data, methodology, etc., are available as supplemental reports to this study (see Annex A.1).

Please note that while a conservative approach was chosen to establish potential, more detailed in-field investigations are required to prove reserves with certainty.

4.2.1.1. Groundwater development potential in Nyalga Shivee Ovoo region

In the Nyalga Shivoo Ovoo study area, ten borefields in addition to the already established reserves, were identified. Due to the study area's hydrogeology, sufficient reserves were identified in the 50km radius alone to close the gap. Thus no further investigations were undertaken for the remaining areas under the 100km radius.

Details on the identified target borefields, including Table 12 Details on target borefields in Nyalga Shivee Ovoo information on mine to be supplied, distance to mine, capital and operational costs can be seen in Table 12.

The total yield of target borefields have the potential to increase overall water availability by 1000 l/s (excluding dewatering water) at the cost of 210.6 mn USD for capital expenditure and 10.9 mn USD annually for operational expenditure.

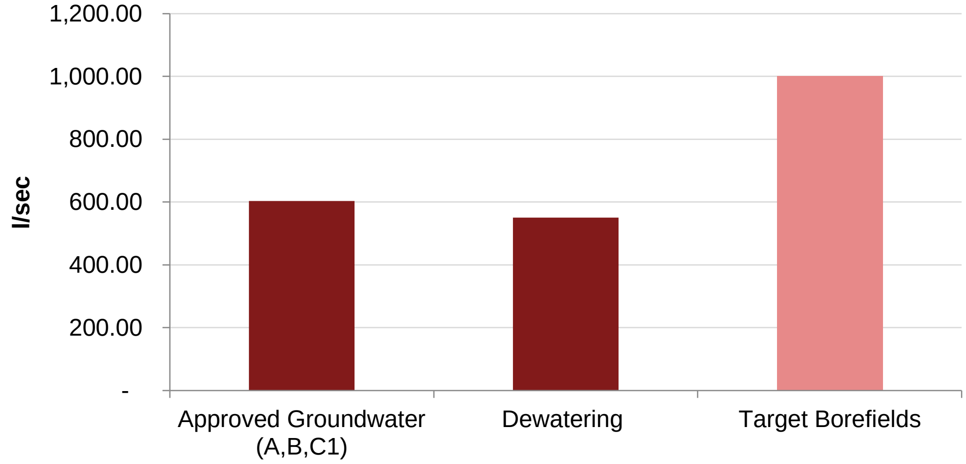
Table 12 Details on target borefields in Nyalga Shivee Ovoo

Borefield	Potential Borefield Yield (l/sec)	Delivery to	Approx. distance (km)	Capital Costs (USD mn)	Annual Operating Costs (USD mn)
Borefield B	100	ShiveeOvoo	26	29.7	1.4
Borefield C	150	ShiveeOvoo	31	33.2	1.8
Borefield E	100	TurugNuur	0	20.7	1
Borefield F	150	TurugNuur	0	21.5	1.1
Borefield G	100	TurugNuur	27	30.7	1.7
Borefield H	100	TurugNuur	16	26.3	1.3
Borefield I	150	Buuruljuutiin Tal	0	21.4	1.1
Borefield J	150	Buuruljuutiin Tal	16	27.1	1.5
Total	**1,000**	**-**	**-**	**210.6**	**10.9**

Note: Borefields A and D are not included in further analysis. While they are not part of the established reserves by the Government, these have been registered in the area and thus are potentially committed. Without further information, a conservative approach is chosen leading to the exclusion of these borefields in this analysis.

Figure 19 presents that the yield of target borefields have the potential to **increase overall water availability by 1000 l/ sec (87%),** when comparing currently available groundwater (600 l/sec) and dewatering water (550 l/sec).

Figure 19 Relative additional yield from target borefields



4.2.1.2. Groundwater development potential in Tavan Tolgoi

With similar conditions assumed in other local basins, i.e. within the study area, nine sites for potential borefield development have been identified. Nearby in the Dundgobi Brown Coal area, i.e. just outside the study area, two additional potential development sites have also been identified.

More detailed information on the identified target borefields, incl. mine to be supplied, distance to mine, capital and operational costs can be seen in Table 13.

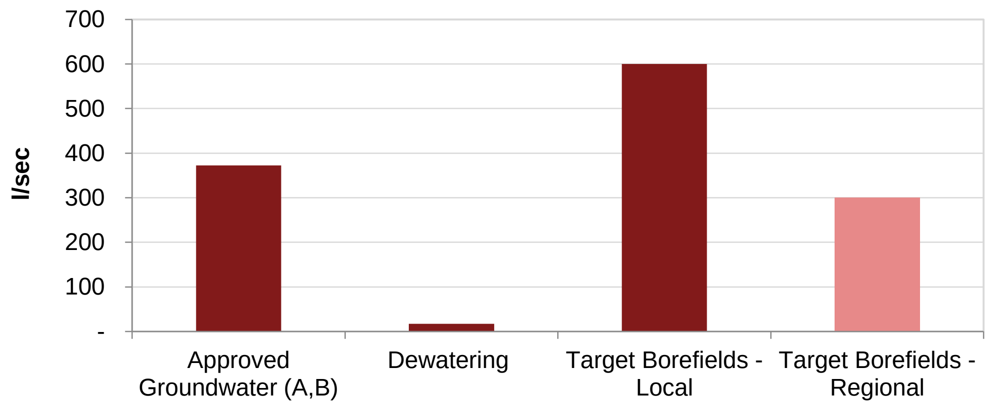
The local and regional borefields have the potential to increase water availability by 600l/ sec and 300 l/ sec respectively. Total costs for all borefields amount to 580.44 mn USD of capital expenditure and to 37.1 mn USD of annual operation expenditure.

Table 13 Details on target borefields in Tavan Tolgoi

Borefield	Potential Borefield Yield (l/s)	Approx. distance (km)	Capital Costs (USD mn)	Annual Operating Costs (USD mn)
Borefield A	50	90	54	4.3
Borefield B	50	80	49.7	3.8
Borefield C	100	84	58.1	3
Borefield D	50	39	34	2.5
Borefield E	50	111	61.5	4.7
Borefield F	100	90	62.1	3.2
Borefield G	50	33	32	2.4
Borefield H	100	102	66.6	3.4
Borefield I	50	78	49.1	3.8
Borefields J1+J2	300	141	113.3	6.9
Total	**900**	**-**	**580.44**	**37.1**

Figure 20 shows the total water availability from different water supply options. When comparing currently available groundwater (370 l/ sec) and dewatering water (17 l/sec), the yield of local target borefields have the potential to increase overall water availability by 600 l/ sec (154%). In addition, the yield of the regional target borefields increases overall water availability by an additional 300 l/sec (30%).

Figure 20 Relative additional yield from regional target borefields



4.2.2. Surface water transfers

The Orkhon-Gobi water transfer scheme was identified as a potential project that could provide significant additional water supply to the Tavan Tolgoi region in the Southern Gobi. The surface water transfer element would divert approximately 216,000 m^3/day of water from the Orkhon River to be used for agriculture and urban demand along its route and deliver ~100,000 m^3/day for mining and industry into the Southern-Gobi region. It is estimated that ~47,000 m^3/day would reach the Tavan Tolgoi region.

The scheme comprises a dam across the Orkhon River and related reservoir and intake structure, located approximately 250km northwest of Ulaanbaatar. A pipeline and associated pumping stations and infrastructure would be built to transmit the water through a 740km long pipeline to Tavan Tolgoi and Oyo Tolgoi, with side branches to Mandalgobi and Dalanzadgad.

This new major diversion scheme has received varying views from different stakeholder groups within Mongolia in terms of its overall cost effectiveness. Due to concerns over the uncertainty of data relating to the scheme, an additional study has been conducted to provide a high level peer review of existing information to enable the scheme to be included within the prioritization framework.[22] The evaluation focused on water availability, costing and economic, environmental and social impacts of the scheme. [23]

The evaluation of information on the Orkhon-Gobi water transfer scheme has resulted in a revised cost estimate of USD1, 295 mn at the upper confidence level. An offtake flow of 2.5m^3/s for the surface water transfer is viable but dependent upon the proportion of flow regulated for environmental flow purposes. Information on economic, environmental and social impacts was also collated, allowing the water transfer scheme to be included within the hydro-economic framework.

It should be noted that data availability on the scheme reflects the early 'scoping' stage of the project in its lifecycle. There is limited information on the hydrology and exact design and related assumptions. The cost estimate reflects these uncertainties which would be further refined at pre-feasibility and feasibility stage. Further it needs to be noted that the water demand in Tavan Tolgoi region, and the requirement of this water transfer, depends on whether planned projects will be implemented.

Additional information can be found in AnnexA.5.4 and A.5.5, as well as in the accompanying report supplement (see Annex A.1).

[22] 2030 Water Resources Group, Amec Foster Wheeler and Groundwater Management Solutions (2016) "Peer Review of Orkhon-Gobi Water Transfer".
[23] Information used for the evaluation came from a Screening Report namely "Prestige (2014). Report on Initial Economic, Financial, Environmental and Social Screening. Preparation of Terms of Reference for Feasibility Studies on Flow Regulation of Orkhon River and Construction of Water Reservoir Complex Project" and accompanying data, supplemented by responses to two clarification requests.

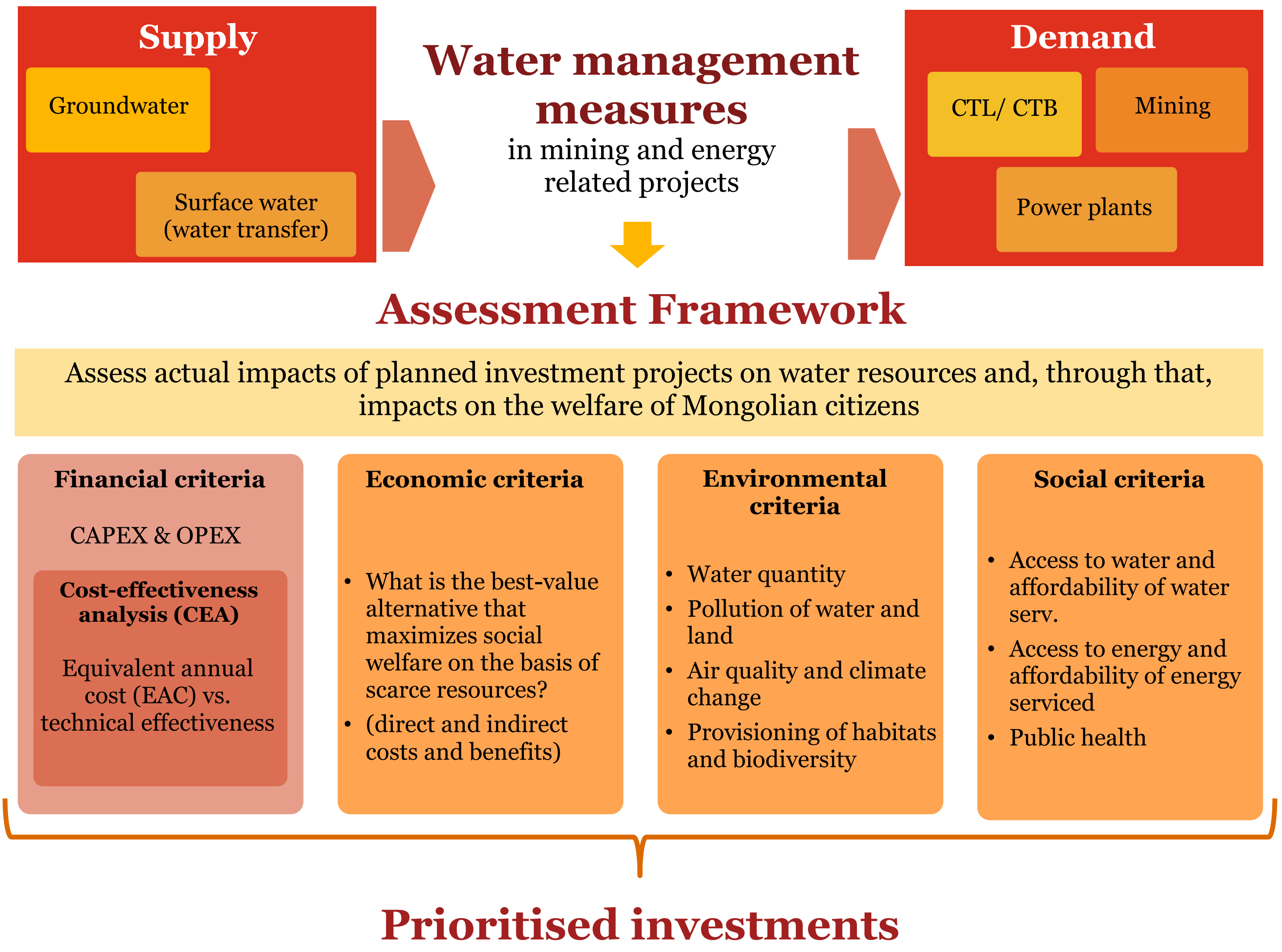
5. Prioritising and choosing solutions to close the water gap

5.1. Assessment Framework

As presented in the previous chapters, total increase in water availability from water demand reduction and water supply augmentation exceed the water required to close the gap in the high water demand scenario for 2040. Joint measures increase water availability by 55.64 mn m³/year against the baselined (gap: 34.25 mn m³/year) in Nyalga Shivee Ovoo and by 57.12 mn m³/year against the baseline (gap: 18.85 mn m³/year) in Tavan Tolgoi. [24]

Thus, different project alternatives presented in Section 4 have been assessed against financial, economic, environmental and social criteria in order to identify cost-effective and best-value alternatives to close the anticipated water gap in Nyalga Shivee Ovoo and Tavan Tolgoi in 2040. Figure 21 provides an overview of the Assessment Framework.

Figure 21 Assessment Framework to prioritize solutions to close the water gap



[24] A detailed overview of incremental water availability against the baseline of all solutions can be seen in Appendix A.8.1 and A.8.2.

A summary description of the criteria applied during the assessment of different project alternatives and the way these were assessed are presented in Table 14 below. In general terms, the assessment framework includes:

- **Quantitative criteria** for which there was actual quantitative information or it was possible to estimate a value on the basis of benchmark figures. These criteria have been used to develop financial and holistic[25] cost curves;
- **Semi-qualitative criteria** for which there was no quantitative information available or estimations could not be performed based on the literature review, but values were assigned focusing on presenting available evidence on the impacts and using the outcomes of consultation activities;
- **Qualitative criteria** for which there was neither quantitative information nor enough detailed information to assign quantitative values. The assessment was focused on presenting diverging and limited evidence on the impacts on other water users.

Table 14 Criteria within the Assessment Framework

	Criteria	Quant.	Semi-Qual.	Qual.
Financial criteria	Financial costs of the project alternatives (capex and opex)	★		
	Technical effectiveness (water saving or water supply Aug.)	★		
	Cost- effectiveness ratio	★		
	Potential impact of an increase in the Water Abstraction Fee			★
Economic criteria	Impacts on recreation and (eco-) tourism			★
	Reduced human health risks	★		
	Employment		★[26]	
	Induced investment and growth			★
Environmental criteria	Impact on available water quantity		★	
	Chemical pollution of water and land		★	
	Thermal pollution of water and land		★	
	Air quality and climate change	★		
	Impacts on habitats and biodiversity	★		
Social criteria	Access to and affordability of water services			★
	Access to and affordability of energy services			★
	Impacts on human health from improved access to water and electricity			★

[25] Holistic cost curves in addition to financial costs also account for economic and environmental impacts of different project alternatives

[26] For water efficiency measures only

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

2. Holistic cost curves: Prioritisation of investment options is based on financial criteria, in addition to economic and environmental criteria. Social criteria have not been included in quantitative or semi-quantitative assessments, given the lack of numerical evidence.

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

5.2. 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 development of new groundwater abstraction boreholes, installation of dry coal washing technology or dry/air cooled systems at Thermal Power Plants and Coal-to-Liquid Plants among others; 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, are frequently inter-connected or mutually exclusive (e.g. using organic binders for dust suppression or calcium chloride etc.) 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 annual 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 Thermal Power Plants as an example, the analysed measure may only require an upgrade of the existing technology rather than the complete investment for the measure. Furthermore, in some cases the projects are at a conceptual stage. For projects with multiple technological alternatives, such as water efficiency measures at TPPs, CTLs, CTB and mining site (dust suppression), 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 TPP) is used to construct cost curves. In some cases, multiple measures are suggested for the same (planned) project, e.g. cooling measures for hybrid thermal power 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 thermal power plant but would also require a switch to a dry cooled thermal power plant 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 5.1). For each technological alternative, (IC) against previous alternative were used to develop cost curves.

- **Technical effectiveness** (mn m^3/ year) of different project alternatives in the Nyalga Shivee Ovoo and Tavan Tolgoi regions reflected 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 m^3 per year) were calculated for different project alternatives in the Nyalga Shivee Ovoo and Tavan Tolgoi regions 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 TPP from wet closed cycle recirculating to hybrid (dry/wet) would result in reducing water demand from 1.1 m^3/MWh to 0.78 m^3/MWh. Furthermore, installing a dry/air cooled cooling system would result in 0 m^3/MWh water demand. Calculating incremental water availability against baseline would result in a 0.32 m^3/MWh reduction for installing hybrid cooling system and a 1.1 m^3/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 m^3/MWh reduction for installing hybrid cooling system and 0.78 m^3/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 22 How to interpret a cost curve

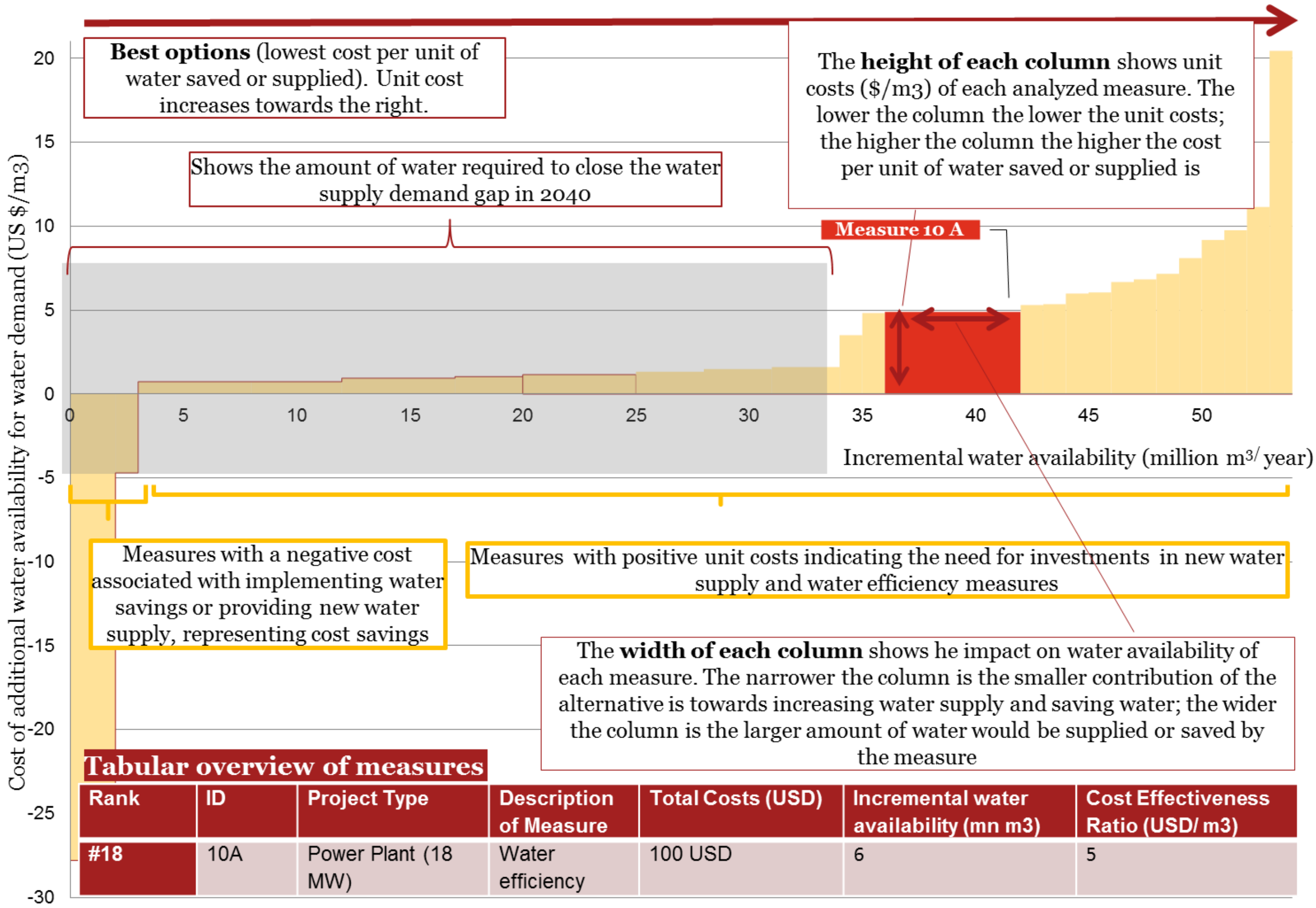


Figure 22 provides an example on how to read a cost curve. As mentioned above, the horizontal axis reflects incremental water availability (in this assessment, each project alternative, i.e. each column shows additional water availability in comparison to the previous technological alternative). The 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 thermal power plants or the use of calcium chloride for dust suppression at mine sites. 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.

5.3. Cost curves

Financial as well as holistic cost curves were derived for Nyalga Shivee Ovoo and Tavan Tolgoi regions. The financial cost curves can be seen in Annex A.1, while the holistic cost curves are illustrated in the following chapter. A comparative analysis between the financial and holistic cost curves can also be found in Annex A.7.3.

All eligible project alternatives in the Nyalga Shivee Ovoo and Tavan Tolgoi regions 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 Thermal Power Plants)

- Project alternatives resulting in negative water savings, in other words relatively more water intensive options in comparison to the previous alternative

- Dewatering water, as costs for its development are considered as sunk costs, as dewatering is required for coal extraction. Further, when assessing the water gap, dewatering water was considered as an available water resource. The inclusion in cost curves would result in double counting.

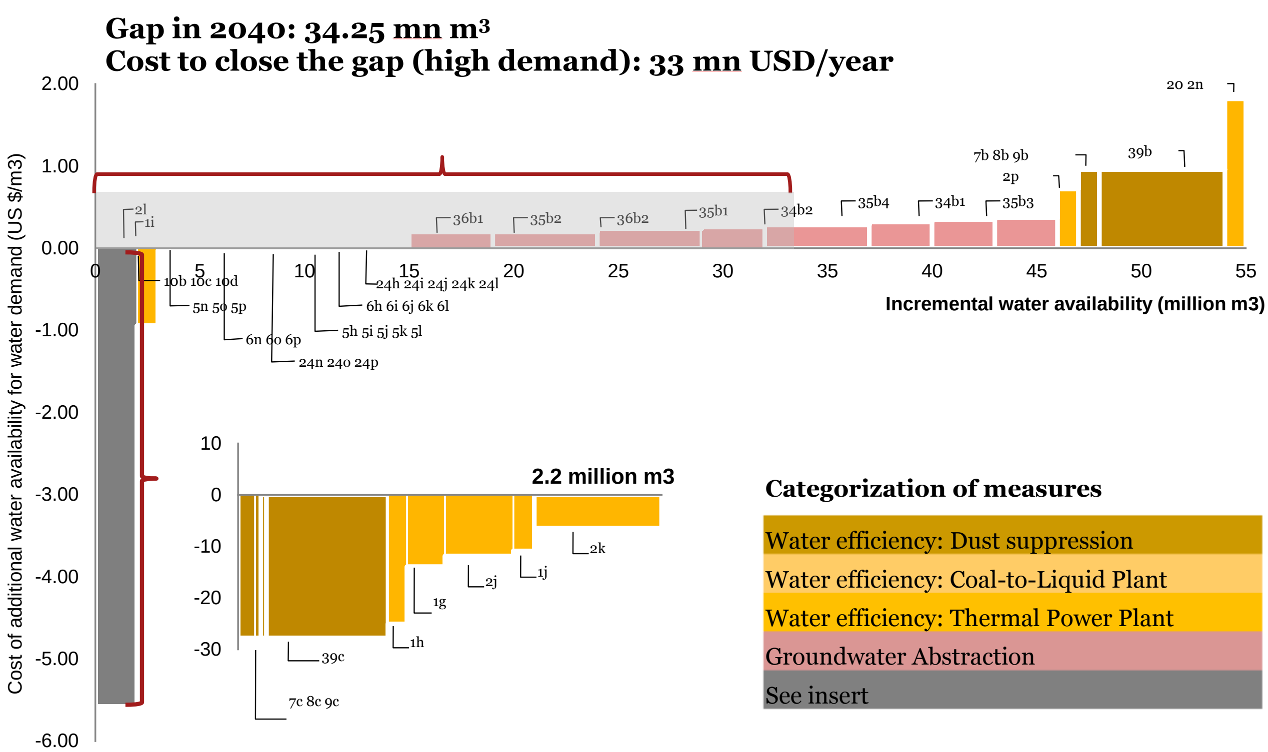
For easy cross-reference, the numbering of the measures on the cost curves relate to the ID for analysis, mentioned in previous tables.

5.3.1. Holistic cost curves – Nyalga Shivee Ovoo region

The Incremental costs of closing low and medium water demand scenario gap in Nyalga Shivee Ovoo are about 23 mn USD/year and about 33 mn USD/year for closing high water demand scenario gap in 2040. In the low and medium scenario, 25 mn m3/yr of water is made available to close the low gap of 21.2 mn m3/yr and medium gap of 23 mn m3/yr. In the high scenario, 35 mn m3/yr of water are made available to close the gap of 34.25 mn m3/yr in 2040.

Figure 23 below shows the holistic cost curves, i.e. considering financial, economic and environmental criteria, for Nyalga Shivee Ovoo region.

Figure 23 Nyalga Shivee Ovoo – Holistic cost curve



Once the holistic 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. Looking at the cost curve above, it becomes evident that a number of cost-effective technological alternatives relate to the same plant or sites. For instance, four technological alternatives for the Thermal Power Plant 270 MW (ID #1) are ranking high in terms of their cost-effectiveness including 1h, 1g, 1i and 1j 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 Circulating fluidised bed (CFB) boilers, Cooling Water Treatment, Cooling Water and Boiler Water Blowdown Reuse (baseline) to dry/air cooled cooling system with CFB boilers and Boiler Water Blowdown Reuse (alternative 1j). 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 incremental costs and incremental water availability of 1j alternative against the baseline (as opposed to its previous alternative, 1i). Therefore, Table 15 that lists prioritised solutions accounts for such *step changes* in technologies and presents incremental costs and incremental water availability for each technological alternative considered in comparison to baseline (i.e. the starting point). This results in the need to implement fewer measures than the curve would suggest in order to close the gap. A detailed list of all measures underlying the cost curve can be found in Annex A.8.3. [27]

Table 15 Nyalga Shivee Ovoo – Prioritised list of solutions (holistic cost curve)

Rank	ID	Name - Project title	Baseline technology	Complete Technology Description	Total cost (USD, EAC)	Incremental costs (USD, EAC against baseline)	Incremental water availability (mn m3/year, against baseline)	Cost Effectiveness Ratio (USD/ m3)
1	7c	Shivee Ovoo Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,551,076	1,542,661	0.95	-5.58
2	8c	Tugrug Nuur Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	517,026	514,221	0.32	-5.58
3	9c	Booroljuutiin Tal Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	517,026	514,221	0.32	-5.58
4	39c	Other Mines NSO	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	10,340,502	10,284,405	6.32	-5.58
5,6,8, 11	1 g, h, i, j	Thermal Power Plant (270 MW) - Shivee Ovoo	Wet Closed Cycle Recirculating, Circulating fluidised bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Dry/Air Cooled, Circulating Fluidized Bed Boilers, Boiler Water Blowdown Reuse	5,439,601	-3,918,516	0.71	-5.02 to -0.77
7,9,10	2j, k, l	Thermal Power Plant (750 MW) - Shivee Ovoo	Wet Closed Cycle Recirculating, Wet Flue Gas Desulphurisation, Cooling Water Treatment, Cooling Water	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse,	18,405,625	-4,292,083	2.95	-2.38 to -0.94

[27] Please also see more details on the usage of calcium chloride for dust suppression in Annex A 5.1.4.

Rank	ID	Name - Project title	Baseline technology	Complete Technology Description	Total cost (USD, EAC)	Incremental costs (USD, EAC against baseline)	Incremental water availability (mn m3/year, against baseline)	Cost Effectiveness Ratio (USD/ m3)
			Blowdown Reuse	Circulating Fluidised Bed Boilers, dry Flue Gas Desulphurisation				
12,13, 14	10b, c, d	Coal to Briquette- Tugrug Nuur	Wet closed circuit cooling	Cooling Water Treatment, Dry Flue Gas Desulphurisation and Efficient Sprinklers	513,952	513,952	0.03	-0.05
15-17, 24-28	5h, i, j, k, l, n, o, p	Coal to Liquid - Tugrug Nuur	Wet Closed Cycle Recirculating, Wet Flue Gas Desulphurisation	Dry/Air Cooled, Dry Flue Gas Desulphurization, Boiler Water Blowdown Reuse, Circulating Fluidised Bed Boilers	16,453,389	12,308,578	9.52	-0.03 to -0.01
18-20, 29-33	6h, i, j, k, l, n, o, p	Coal to Liquid - Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet Flue Gas Desulphurisation	Dry/Air Cooled, Dry Flue Gas Desulphurisation, Boiler Water Blowdown Reuse, Circulating Fluidised Bed Boilers	7,478,813	5,594,808	4.28	-0.03 to -0.01
Sub-total -low (21.2 mn m3) and medium (23 mn m3) gaps					61,217,010	23,062,247	25	
21-23, 34-38	24h, i, j, k, l, n, o, p	Coal to Liquid - Shivee Ovoo	Wet Closed Cycle Recirculating, Wet Flue Gas Desulphurisation	Dry/Air Cooled, Dry Flue Gas Desulphurisation, Boiler Water Blowdown Reuse, Circulating Fluidised Bed Boilers	8,974,576	6,713,770	4.55	-0.03 to -0.01
39	36b1	Borefield in Target I - Booroljuutiin	NA	Development of Remote borefields in Target Areas (without storage reservoir) delivered to Booroljuutiin Taal	3,457,597	3,457,597	4.73	0.20
Total (high gap – 34.25 mn m3)					**73,649,183**	**33,233,614**	**35**	

In addition to considering incremental costs of implementing these technological alternatives (i.e. in comparison to their baseline technologies), one may also consider the total costs of implementing these measures (which will be higher than incremental costs). In particular, total equivalent annual costs of implementing these measures in Nyalga Shivee Ovoo region (i.e. disregarding the costs of baseline project alternatives) are about 61 mn USD/year for low and medium water demand scenarios and 74 mn USD/year for high water demand scenario.

Considering the results of holistic analysis in Nyalga Shivee Ovoo region, key highlights include:

- **Dust suppression with calcium chloride** in Nyalga Shivee Ovoo region is the best value alternative with the total cumulative water availability (assessed against baseline dust suppression technology employed at each mine) of 7.9 mn m^3/year and a negative ratio of -5.58 USD/m^3.
- Alternatives related to installation of **hybrid and dry/air cooled cooling systems for TPPs** are the next best value alternatives with the ratios ranging from -5.02 to 0.94 USD/m^3 and cumulative water availability of 3.7 mn m^3.
- Implementation of water efficiency measures at **Tugrug Nuur CTB plant** has cumulative water availability generation potential of 0.03 mn m^3 at -0.05 USD/m^3 ratio.
- **Water efficiency measures** at CTL plants show relatively poorer value ranging from -0.03 USD/m^3 to -0.01 USD/m^3 and cumulatively generating 18.4 mn m^3 of water.
- Development of new **groundwater abstraction** has significant water augmenting potential and is vital for closing the gap, starting with most cost-effective borefields (showing the ratio of 0.20 USD/m^3).

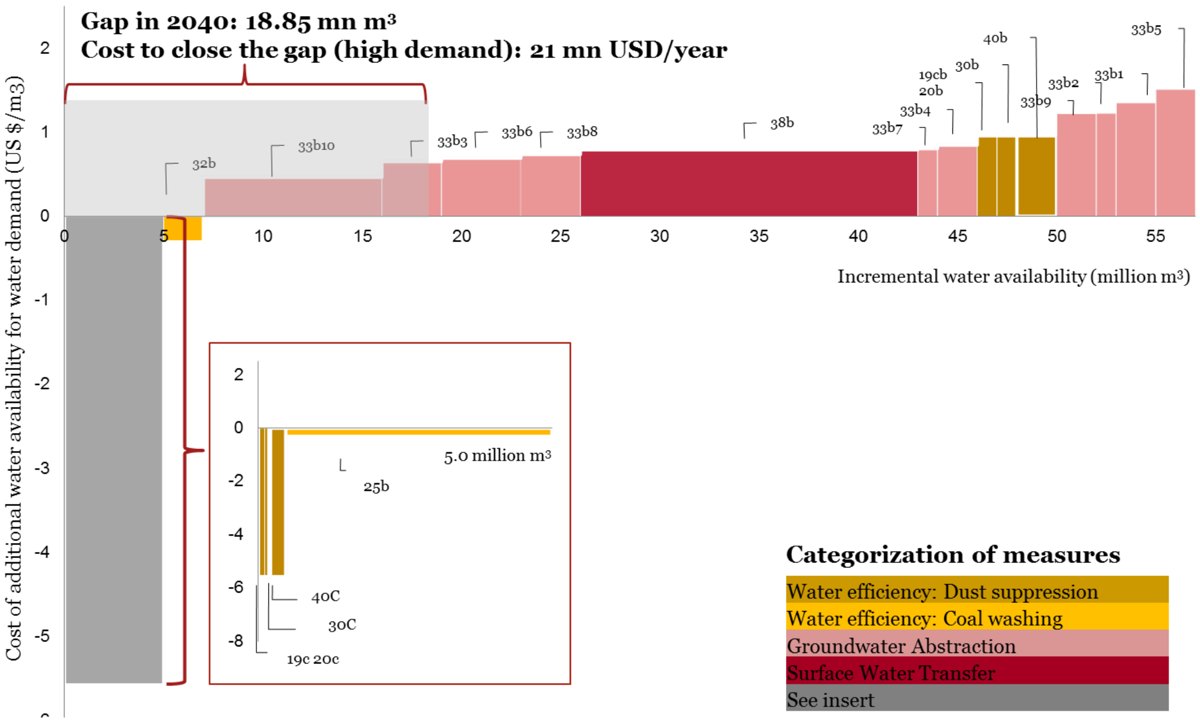
The results of the analysis suggest that implementation of a combination of water efficiency and water augmentation projects in Nyalga Shivee Ovoo regions would be sufficient to close the 2040 gap under both low, medium and high scenarios.

5.3.2. Holistic cost curves – Tavan Tolgoi region

There is no gap anticipated under the low water demand scenario. The Incremental costs of closing medium and high water demand scenario gap in Tavan Tolgoi region are about 4 mn USD/year and 21 mn USD/year respectively. In the medium scenario, 9.3 mn m^3 of water are made available to close the gap of 6.21 mn m^3. In the high scenario, 21 mn m^3 of water are made available to close the gap of 18.85 mn m^3 in 2040.

Figure 24 below shows the holistic cost curves, i.e. considering financial, economic and environmental criteria, for Tavan Tolgoi region.

Figure 24 Tavan Tolgoi – Holistic cost curve



Looking at the cost curve above, a number of cost-effective technological alternatives relate to the same sites. For instance, four top cost-effective technological alternatives (19c, 20c, 30c and 40c) relate to the use of calcium chloride for dust suppression in comparison to the use of organic binders. In practice, one would not first invest in using organic binders for dust suppression to then switch to using calcium chloride. A step change would be implemented going from using water for dust suppression (baseline) to using calcium chloride (options c) instead. 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 incremental costs and incremental water availability of 19c, 20c, 30c and 40c alternatives against the baseline (as opposed to their previous alternative, 19b, 20b, 30b and 40b). Therefore, Table 16 that lists prioritized solutions accounts for such *step changes* in technologies and presents incremental costs and incremental water availability for each technological alternative considered in comparison to baseline (i.e. the starting point). This results in the need to implement fewer measures than the curve would suggest in order to close the gap. . A detailed list of all measures underlying the cost curve can be found in Annex A.8.4.[28]

Table 16 Tavan Tolgoi – Prioritised list of solutions (holistic cost curve)

Rank	ID	Name - Project title	Baseline technology	Complete Technology Description	Total cost (USD, EAC)	Incremental costs (USD, EAC against baseline)	Incremental water availability (mn m³/year, baseline	Cost Effectiveness Ratio (USD/ m³)
1	19c	Erdenes Tavan Tolgoi Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,874,243	1,864,075	1.15	-5.58
2	20c	Ukhaa Khudag Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,185,022	1,178,593	0.72	-5.58
3	30c	Tavan Tolgoi JSC Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	530,911	528,031	0.32	-5.58
4	40c	Other Mines Tavan Tolgoi	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	4,142,551	4,120,078	2.53	-5.58

[28] Please also see more details on the usage of calcium chloride for dust suppression in Annex A 5.1.4.

5	25b	Coal Washing - Erdenes Tavan Tolgoi	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	3,674,368	-4,034,498	4.54	-0.30
Sub-total (medium gap – 6.21 mn m³)					**11,407,095**	**3,656,279**	**9.3**	
6	32b	Coal Washing - Mongolian Mining Co.	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	1,837,184	-2,017,249	2.27	-0.30
7	33b 10	Borefield in Target J1+J2 – Tavan Tolgoi	NA	Development of Remote Borefields in Target Areas (without storage reservoir) delivered to Talvan Tolgoi	19,382,043	19,382,043	9.46	0.46
Total (high gap – 18.85 mn m³)					**32,626,322**	**21,021,073**	**21**	

Total equivalent annual costs of implementing these measures in Tavan Tolgoi region (i.e. disregarding the costs of baseline project alternatives) are about 11 mn USD/ year and 33 mn USD/year for medium and high water demand scenarios respectively.

In Tavan Tolgoi region, key solution highlights include:

- **Dust suppression with calcium chloride** in Tavan Tolgoi and Ukhaa Khudag mines is the best value alternative (with a ratio of -5.5.8 USD/m³, i.e. suggesting financial savings alongside water savings) and total increased water availability (assessed against baseline dust suppression technology employed at each mine) of 4.7 mn m³ per year.

- The use of **dry coal cleaning technology** for all coal washing plants is the next best value alternative demonstrating the ratio of -0.30 USD/m³ and total cumulative water availability of 6.8 mn m³ per year.

- **Development of new groundwater abstraction boreholes** shows significant water augmenting potential and is vital for closing the gap, starting with most cost-effective borefields (showing the ratio of 0.46 USD/m³).

- **Orkhon-Gobi water transfer scheme** has a water augmentation potential of 17.2 mn m³. However, implementation of relatively better value alternatives (water efficiency measures and new groundwater borefields) is sufficient to close the gap in Tavan Tolgoi region and Orkhon-Gobi water transfer project is not required for closing the gap effort in the Tavan Tolgoi.

The results of the analysis suggest that implementation of a combination of water efficiency and water augmentation projects in Tavan Tolgoi regions would be sufficient to close the 2040 gap under low, medium and high scenarios.

5.3.3. Consideration of semi-qualitative and qualitative criteria

The assessment framework introduced in Chapter 5.1 also includes criteria, for which no quantitative data is available to date. Data/ information was not available for all projects and technological alternatives but as the criteria are deemed to be of importance, further research on semi-qualitative and qualitative assessment criteria is recommended, in the hope that future data availability will allow their full inclusion in the cost curves.

Furthermore, a number of assessment criteria remained qualitative as there was neither quantitative information nor enough detailed information to assign quantitative values.

A number of observations regarding **social impacts** associated with the project alternatives considered in this assessment are of relevance:

- **Access to Water Resources For Local Communities**:

- Access to water resources for local communities is an important issue (as argued, for instance, in the Tsogttsetsii soum, Umnugovi aimag). However, establishing conclusively the anticipated impact (positive or negative) of the investments considered on access to water for local communities cannot be done in the absence of both accurate data and ad-hoc studies on shallow aquifers in the region.

- **Access to Water Resources For Herders:**

  - Animal watering is perceived as the most challenging task in rural livelihoods[29]. According to ADB (2013)[30], in Gobi, herder families move 6 to 7 times a year and travel up to 90 km as part of their nomadic movements. Yet, it is not just the loss of access to water resources that affects livestock husbandry but also the loss of access to grazing reserves and seasonal pastures, which clearly affects pastoral practices.

  - In the specific case of mining sites, impacts on herder livelihoods also potentially include relocation of local populations and a decrease in income for those herders unable to migrate or diversify their income opportunities[31] . As per relocation, dedicated support and development programmes from mining companies seem a common claim.

  - Part of these social concerns are reflected in the IRIM Baseline Perception Survey (2014)[32], which shows a rather pessimistic attitude towards the current status of quantity and quality of local water, showing a perceived downward trend. However, these are based on perceptions only.

- **Affordability of Water and Energy Services:**

  - Affordability of water and energy services are important social considerations. While not much evidence is available regarding the reliability and affordability of energy services as a result of the energy projects at stake, the increases in power demand that would be expected for the future will be partially offset by the impacts of large tariff increases. As a matter of fact, these increases (as in ECA, 2008[33]) have been long expected to ensure sufficient resources are available for new installed capacity, system rehabilitation or improved efficiency.

  - Financing new investments may require a rise in water and electricity tariffs. Some of the cost recovery calculations available suggest that financing this new infrastructure may lead to increases of 230% for drinking water and 350% for electricity tariffs when compared to 2010 levels (McGrath et al., 2011)[34]. However, this would require a further in-depth analysis.

  - An illustration of this challenge (both for water and energy services) is reflected in the subsidisation by ER to Tsogttsetsii inhabitants back in 2011. No evidence has been provided of whether this practice is an ongoing one.

5.3.4. Focusing on water demand reduction measures

The deep aquifers in the Gobi Region receive little to no recharge; as such, they are a non-renewable resource with a finite life. The large areal extent and thickness of these aquifers however provide significant groundwater storage that can sustain development for many years. The reserves that have been established as water supply augmentation solutions are based on prescribed water level drawdown criteria and typically provide surety of supply for a minimum of 25 years. In order to meet water demand over the entire planned

[29] Batimaa P., Myagmarjav B., Batnasan N., Jadambaa N., Khishigsuren P., 2010. Urban water vulnerability to climate change in Mongolia. UNEP
[30] ADB, 2013. Making Grasslands Sustainable in Mongolia. Adapting to Climate and Environmental Change.
[31] Warlters, M., 2009. Southern Mongolia Infrastructure strategy. Washington, DC: World Bank
[32] IRIM, 2014. Baseline community perceptions survey for International Finance Corporation. Final Report (May 2014). IRIM (Independent Research Institute of Mongolia), Mongolia.
[33] ECA, 2008. Mongolia: Power Sector Development and South Gobi Development. Draft Report (September 2008) submitted to the World Bank. ECA (Economic Consulting Associates), UK.
[34] McGrath et al., 2011. McGrath F., Martsynkevych V., Hoffman D., Richter R., Dugersuren S., Yaylymova A., 2011. Spirited away – Mongolia's mining boom and the people that development left behind. CEE Bankwatch Network, Urgewald, Bank Information Center, Oyu Tolgoi Watch

project lifetime. While additional groundwater sources can be explored once the most cost-effective ones which were suggested as solutions in this report, preference may be given to water demand side solutions despite less favourable cost-effectiveness ratios. In Nyalaga Shivee Ovoo, 31.3 mn m^3/year can be saved by introducing water demand reduction measures at an incremental cost of 33.0 mn USD/year. The remaining gap of 2.95 mn m^3/year can be closed by local groundwater abstraction at a cost of 3.5 mn USD/year leading to an incremental cost of 36.5 mn USD/year as compared to incremental cost of 33.2 mn USD/year as the most cost-effective solution (see section 5.3.1).

In Tavan Tolgoi, 11.5 mn m^3/year can be saved by implementing all identified water demand reduction measures at an incremental cost of 1.6 mn USD/year. The remaining gap of 7.4 mn m^3/year can be most economically closed by local groundwater abstraction (19.4 mn USD/year). The gap could also be closed by construction of the Orkhon-Gobi Water Transfer, which, however, would result in much higher costs (212 mn USD in total) and is linked to risks related to uncertainties of future demand (see section 5.3.2).

Where non-renewable resources are being developed, such as is the case in the Southern Gobi region, artificial recharge of the source aquifers may be considered to maintain aquifer water levels and/or extend duration of supply. This practice demands a local water surplus which notionally may exist in the form of excess mine inflows, surface water run-off or treated wastewater. Surface water run-off may seasonally provide significant quantities of water. It is this water however that sustains shallow aquifers and associated local use and ecosystems; opportunities to divert for any purpose will be extremely limited anywhere in the study area and in the Gobi Region as a whole. Relatively smaller quantities of water may, at some sites, become available from mine operations and/or waste water treatment which could be diverted for artificial recharge. In most if not all cases however any such water would typically be used for other purposes with a view to reducing the quantity and cost of groundwater withdrawn from the deep aquifers.

6. Conclusions and recommendations

6.1. The challenge

Mining is the backbone of Mongolia's economy. Mongolia's key coal mining reserves – Tavan Tolgoi and Shivee Ovoo - are located in the Gobi desert. In these regions, many investments in coal value adding technologies, including power plants, coal washing, coal-to-liquid and coal-to-briquette are planned. Water is a key criterion to these new developments.

In Nyalga Shivee Ovoo region, water demand, without any of the planned projects, such as Coal to Liquid and Coal-to-Briquette Plants as well as Power Plants, being executed, can be met by available water resources, i.e. established government approved groundwater resources and dewatering water, in all scenarios[35]. In the case, however, that all planned projects are implemented, there will be water gap by 2030 in all scenarios, even if dewatering water is used for planned project demand. If left unaddressed, the water supply demand gap will amount to 35% (34.25 mn m^3/yr) in the high water demand scenario and 30% and 31% in the low and medium demand scenarios respectively.

In Tavan Tolgoi area, water demand without any of the planned projects being executed can be met by available water resources, i.e. established government approved groundwater resources, recycled and dewatering water in the low and medium water demand scenario. In the high water demand scenario, however, a gap of 41% (8.82 mn m^3/year) in 2040 is estimated. In case planned projects are executed, 33% (6.21 mn m^3/year) and 60% (18.85 mn m^3/year) of water demand cannot be met with available water resources in the medium and high demand scenario respectively.

All analysed (planned) projects are related to coal. However several factors lead to high uncertainties around the (financial) feasibility and profitability of the analysed projects. These factors include a volatile coal market with currently low coal prices, climate change discussions leading to potentially moving away from coal as key energy source and the economic situation in Mongolia.. In Tavan Tolgoi specifically, the implementation of value adding projects depend on the formation of the international Erdenes Tavan Tolgoi consortium. This high uncertainty on future water demand calls for flexible water management solutions to respond to changing dynamics. While the uncertainty of which projects will be completed is quite high, it is recommended to decide on flexible solutions for the high water demand scenario in any case. Certainty on future water supply is expected to lead to higher investor trust and thus - potentially - to higher inclusive economic growth.

6.2. Identified priority solutions

Based on the holistic hydro-economic analysis, the most cost effective solution to close the gap of 34.25 mn m^3 in the high demand scenario in Nyalga Shivee Ovoo would have incremental costs 33.2 mn USD/year when compared to the baseline technology alternatives. Most of the gap (86%) can be closed by water demand reduction measures, such as:

1. Dust suppression using calcium chloride in Shivee Ovoo, Tugrug Nuur, Booroljuutiin Tal and other mines (7.9 mn m^3/year);
2. Installation of dry/ air cooled cooling systems at planned 270 MW and 750 MW thermal power plants at Shivee Ovoo (3.7 mn m^3/year);
3. Installation of cooling water treatment, dry FGD and efficient sprinklers at Coal to Briquette plant (0.03 mn m^3);
4. Installation of dry/ air cooling system at planned Tugrug Nuur and Booroljuutiin Tal Coal to Liquid plants (13.8 mn m^3/year); and
5. Installation of dry/ air cooling system at the planned Shivee Ovoo Coal to Liquid plant (4.5 mn m^3/year).

The remaining gap (4.7 mn m^3/year) can be closed by developing selected new groundwater boreholes.

[35] Given hydrogeological characteristics, groundwater categories A, B and C1 are considered in Nyalga Shivee Ovoo region.

In Tavan Tolgoi, the holistic hydro-economic analysis suggests that the most cost effective solutions to close the gap of 18.85 mn m^3/year in the high demand scenario would have incremental costs of 21.0 mn USD/year when compared to the baseline technology alternatives. Most cost-effective water demand reduction measures can close 50% of the gap, including:

1. Dust suppression using calcium chloride (4.7 mn m3/year), and
2. Implementation of dry coal cleaning technology at existing and planned coal washing plants (6.8 mn m3/year).

The remaining gap can be closed most cost-effectively by development of selected new groundwater boreholes (9.5 mn m^3/year).

Considering that groundwater reserves in the Gobi are mostly non-renewable, preference may be given to water demand reduction measures, even if some of these may result in higher costs.

In Nyalaga Shivee Ovoo, 31.3 mn m^3/year can be saved by introducing water demand reduction measures at an incremental cost of 33.0 mn USD/year. The remaining gap of 2.95 mn m^3/year can be closed by local groundwater abstraction at a cost of 3.5 mn USD/ year, leading to an incremental cost of 36.5 mn USD/year as compared to incremental costs of 33.2mn USD/year as the most cost-effective solution.

In Tavan Tolgoi, 11.5 mn m^3/year can be saved by implementing all identified water demand reduction measures at an incremental cost of 1.6 mn USD/year. The remaining gap of 7.4 mn m^3/year can be most economically closed by local groundwater abstraction (19.4 mn USD/ year). The gap could also be closed by construction of the Orkhon-Gobi Water Transfer, which, however, would result in much higher costs (212 mn USD/year in total) and is linked to risks related to uncertainties of future demand.

Additional research and validation is required to confirm water availability of government approved aquifers, especially with respect to environmental impacts, to confirm newly identified borefields in this study, to confirm total costs and water augmentation capacity, as well as social and environmental impacts of the Orkhon Gobi water transfer, and to develop detailed feasibility studies for water saving potential and costs of planned 5,280 MW and 600 MW thermal power plants in Nyalga Shivee Ovoo region.

6.3. Next steps

Fundamental decision on use of groundwater

Groundwater resources are mostly non-renewable in the Gobi. Thus, a fundamental decision needs to be made on whether it shall be used, and if so, for which uses, or not.

The inclusion of public and private sector, as well as civil society to this decision-making process is essential. To gain an understanding of the broad level of stakeholders, it is suggested to engage in information campaigns and allow for written comments from informed stakeholders. For this stakeholder engagement process, clear communication on alternatives and costs (including opportunity and generational costs) needs to be conveyed.

Action driven from Government

Discussions on future action should be structured around the Water-Energy Nexus. The planned projects, all related to producing energy in one form or another, require water. Priorities need to be made on trade-offs of water usage and energy generation. High level policy and strategic documents on Energy and Water should be coordinated and integrated by the MEDGT, Ministry of Energy, Ministry of Mining and Ministry of Industry.

Decisions need to be made on which areas should managed with regulations or with incentives.

- **Regulatory measures:** Ideas for regulatory measures include making water permits conditional to usage of most water efficient technologies (BAT) and/ or not providing construction permits for technologies wasting water, such as water-cooled power plants.

- **Creating incentives:** Ideas for incentives include setting the water price at a level which incentivizes investment in most water efficient technologies, providing financial support and preferred conditions in cooperation with leading (Mongolian) banks, emphasizing/ implementing rebates on recycled water, promoting reduction of import taxes on water efficient technologies etc.

Close links can be made to the parallel 2030 WRG Work Stream on Water Valuation and Incentives.

Action driven from Companies/ Investors

All water demand reduction measures need to be implemented by the operating companies/ investors. Support needs to be provided to them in order to understand the necessity of such investments, identify the required solutions, as well as sourcing and implementing these in their respective operations.

Knowledge transfer between companies within Mongolia and abroad, as well as capacity building shall support the companies/ investors in identifying and implementing the optimal and most cost effective solution. For this, a voluntary mining group with water focus could be set up. Close links can be made to the IFC Mining Roundtable.

Importance of multi-stakeholder consultations

Identified best value projects require multiple stakeholders to take action to ensure that no water supply-demand gap will occur. This adds complexity to the implementation.

Two different approaches are suggested to overcome this complexity: 1) Regulatory-based approach, in which water permits are only provided when best available technologies with respect to water efficiency are used, and 2) Stakeholder-based approach, in which investors are required to agree on water saving measures to be executed across the region, for which costs will be shed, to allow for sufficient resources for all projects. Further, incentives for sustainable water resource management can be explored – either in combination with the two above mentioned approaches or as a separate approach. However, it needs to be noted that the result of the behavioural change induced by the incentives is less certain than when following the first two approaches.

Given that these decisions have the potential to affect all Mongolians, directly or indirectly, a multi-stakeholder consultation process is of great importance.

Based on the analysis, following stakeholders are suggested to be part of the implementation of concrete action. Please see Table 17 for Nyalga Shivee Ovoo Region and Table 18 for Tavan Tolgoi region.

Table 17 Suggested stakeholders to be involved in action in Nyalga Shivee Ovoo region

Private Sector/ Investors	Public Sector	Civil Society
One Power Global Limited	Ministry of Environment, Green Development and Tourism	Mongolian Environmental Civil Council
IM Power Plc	Ministry of Mining	WWF Mongolia Program Office
State Grid Corporation of China	Ministry of Energy	MINIS
Tsetsens Mining and Energy	National Water Committee	Rivers Without Boundaries
Germon Gas LLC	Ministry of Industry	Mongolian National Mining Association
CTL Mongolia LLC	River Basin Administrations	The Nature Conservancy (TNC)l
Tsetsens Mining and Energy	Affected soum & bag governors	Water Supply Institute of Geo-ecology
Camex LLC		
Key financing institutions, such as Khan Bank etc.		

Table 18 Suggested stakeholders to be involved in action in Tavan Tolgoi region

Private Sector/ Investors	Public Sector	Civil Society
Mongolian Mining Corporation	Ministry of Environment, Green Development and Tourism	Mongolian Environmental Civil Council
Consortium in discussion for Power Plant 450 Mw/ Lead MCS Energy	Ministry of Mining	Mongolian United Herders Association
Mongolian Mining Corporation	Ministry of Energy	WWF Mongolia Program Office
Tavan Tolgoi JSC	National Water Committee	IFC Mining Roundtable
Consortium in discussion for coal washing/ Lead MMC	River Basin Administrations	MINIS
Consortium in discussion for coal washing/ Lead Erdenes Tavan Tolgoi	Affected soum & bag governors	Rivers Without Boundaries
Erdenes Tavan Tolgoi		Mongolian National Mining Association
Oyu Tolgoi		Water Supply Institute of Geo-ecology
Key financing institutions, such as Khan Bank etc.		The Nature Conservancy (TNC)

7. Roadmap to implement concrete actions

Action 1: Gain certainty on investment implementation status

Action 2: Convene stakeholders to decide on which suggested solutions are most fitting for the context

- Usage of non-renewable groundwater reserves and preference for demand side or supply side solutions
- Options around solutions being implemented by government (surface water transfer) or private sector/ investors (value adding projects, groundwater abstraction)
- All stakeholders should be invited to provide written comments to government/ work stream members
- Consideration of all factors (feasibility, costs, impact on water resources, impact on society/ environment/ economic development)
- Consideration of past, ongoing and future initiatives in Mongolia related to coal and water management in the Gobi region

Action 3: Initiate more in-depth investigations on solutions

- Confirm water availability of government approved aquifers, especially with respect to environmental impacts
- Confirm newly identified borefields in this study
- Confirm total costs, water augmentation capacity, as well as social and environmental impacts of surface water transfers and
- Develop detailed feasibility studies of all suggested demand side reduction solutions
- Develop detailed feasibility studies for water saving potential and costs of planned 5,280 MW and 600 MW thermal power plants in Nyalga Shivee Ovoo region

Action 4: Identify financing solutions

- Connect with key national and international financial institutions to create financing solutions for value added projects following best practices, e.g. specially designed bank loans for companies using best available technology w.r.t. water efficiency

Action 5: Identify required regulatory/ incentive frameworks and

- Water permits only to be provided to companies if best available technology is being used w.r.t. water efficiency
- (Import) tax incentives for technologies

Action 6: Move towards restoring international investor trust

- Provide evidence of potential solutions to water being a key constraint
- Wider initiatives required to restore investor trust (outside of scope, but crucial for future developments)

Appendix A. - Appendices

A.1. Overview of additional report supplements

Care was taken to ensure that all underlying information of the analysis will be transparent and readily available for public usage. Due to the size of the reports, these could not be annexed but are rather available upon demand. Please see a list of report supplements below:

- Report supplement #1: Water Demand Estimation Methodology
- Report supplement #2: Groundwater Assessment Methodology and Groundwater Abstraction Solutions, consisting of the following:
  - RS #2.1 Overview of groundwater occurrence in the Gobi region
  - RS # 2.2 Comparison of previous resource estimation studies
  - RS # 2.3 and RS #2.4 Detailed assessment of target borefield assessment in Nyalga Shivee Ovoo and Tavan Tolgoi, respectively
  - RS # 2.5 Comparison and discussion of formal reserve determination and the approach adopted for this study
- Report Supplement #3 Water demand reduction solutions
- Report Supplement # 4 Peer Review of Orkhon Gobi Water Transfer Scheme
- Report Supplement #5 Assessment Framework

These reports are available upon request.

A.2. Participant lists (Interviews, Focus Group Discussions and Workshops)

Table 19 Stakeholder list of interviews conducted

#	Name	Organization	Organization type	Position
1	Ankhbat	UB Mayor's Office	Government	Senior officer, Policy Strategy Planning Division
2	Erdene	Mongolian Environmental Civil Council	NGO	Executive Director
3	Baldan-Ochir	Mongolian United Herders Association	NGO	Director
4	Basandorj	Mongolian Environmental Civil Council	NGO	Head of the land, underground, soil and water division
5	Bayarmaa	Mongolian Environmental Civil Council	NGO	Founder & Head, Environmental protection citizen's partnership
6	Chimed-Ochir	WWF Mongolia Program Office	NGO	Director
7	Nergui	Ministry of Mining	Government	Head of Mining Policy Department
8	Tovuudorj	Ministry of Energy	Government	Director General Strategic Policy and Planning Department

#	Name	Organization	Organization type	Position
9	Badamdorj	National Water Committee, Government of Mongolia	Government	Deputy director
10	Enkhbaatar	MINIS	International org.	PIU Director
11	Nergui	MINIS	International org.	Contract management & monitoring specialist
12	Bat-erdene	MINIS	International org.	Environmental and Ecological Management specialist
13	Dulguun	United Nations: International Think Tank for Landlocked Developing Countries	International org.	Research coordinator
14	Gansukh	RBA: Galba-Uush Dolood Region Basin Authority	Government	Senior specialist
15	Enkhbayar	RBA: Altain Ovor Govi	Government	Senior specialist
16	Jargaltsengel	RBA: North Govi Guveet-Khalkha Dundad	Government	Director
17	Sukhgerel	Rivers Without Boundaries	NGO	Mongolia Coordinator
18	Chuluuntsetseg	CAMEX Tugrug Nuuriin Energy	Private	Project coordinator
19	Sumiya	CAMEX Tugrug Nuuriin Energy	Private	Hydrogeologist
20	Tserennorov	Ministry of Industry	Government	Natural Resource Management Advisor
21	Temuujin	Ministry of Industry	Government	Senior specialist
22	Dalai	Prestige Group	Private	President & Managing Director
23	Saranmandal	Prestige Group	Private	Project and Finance Manager
24	Batdelger	Prestige Group	Private	Chief Executive Officer
25	Bat-erdene	Shiveegovi soum governor's office	Government	Soum Governor
26	Namuuntsetseg	Shiveegovi soum governor's office	Government	Environmental Officer
27	Shinegerel	Bayan soum (Tuv aimag) governor's office	Government	Soum Governor
28	Buyandelger	Resident of Tsogttsetsii soum	Local resident	Herder in Tsagaan-Ovoo bag
29	Tuya	Resident of Tsogttsetsii soum	Local resident	Herder in Tsagaan-Ovoo bag
30	Natsagdash	Erdenes Tavan Tolgoi JSC	Private	Mining Manager
31	Bayarsaikhan Tsagaankhuu	Tsagaan Ovoo bag	Government	Bag Governor
32	Sharkhuu	Bilegt bag governor	Government	Bag Governor
33	Norovsuren	Tsagaan Ovoo bag	Government	Social Worker
34	Munkh-Erdene	Tsetsii Nutag NGO	NGO	Specialist
35	Battogtokh	Tsagaan Ovoo bag	Government	Head of citizens representative meeting
36	Ardtumen	Siirst Bag	Government	Head of citizens representative meeting
37	Soyolbadrakh	Resident of Tsogttsetsii soum	Local resident	Herder
38	Otgonbayar	Tsogtsetsii soum	Government	Environmental Officer
39	Odgerel	Tsogtsetsii soum	Local resident	School teacher

#	Name	Organization	Organization type	Position
40	Munkhdelger	Tsogtsetsii soum	Government	Head of citizens representative meeting
41	Baasandorj	Mongolian Mining Corporation	Private	VP & Head of Site Infrastructure Project
42	Munkhtur	MCS Energy	Private	CEO
43	Bayasgalan	Mongolian Mining Corporation	Private	Executive General Manager Processing division (Coal processing, water supply, power generation & distribution)
44	Batsukh	Erdenes Tavan Tolgoi JSC	Private	Water supply project leader
45	Mark Newby	Oyu Tolgoi LLC	Private	Environmental manager
46	Ankh-Od	Erdenes Tavan Tolgoi JSC	Private	Coal handling and preparation plant project manager
47	Munkhbaatar	Shivee Ovoo JSC	Private	Deputy Director

Table 20 Stakeholder list of participants of first Focus Group Discussion

#	Name	Organization	Organization type	Position
1	G.Munkh-Erdem	MEGDT	Government	Department of Land Management and Water Integrated Policy MEGDT
2	Enkhtaivan	Ministry of Energy	Government	Senior officer
3	Nergui	Ministry of Mining	Government	Head of Mining policy dept.
4	Jargaltsengel	RBA Umard Govi	Government	RBA Head
5	Bazarragchaa	Tavan Tolgoi Power Plant (Ministry of Energy)	Government	Project Implementation Unit (PIU is under the Ministry of Energy and responsible for TTPP from GoM side)
6	D.Ankhbat	UB city Governor's Office	Government	Senior officer, Policy Strategy Planning Division
7	Enkhbaatar	MINIS Project	International org.	PIU Director
8	Altangerel	MINIS Project	International org.	GWMIU
9	Anarmaa	GGGI	International org.	Project Manager
10	Byambatseren	NAMAC/ Herders' Association	NGO	Head of international cooperation and Legal Advisor
11	Mrs. O.Enkhtuya	The Nature Conservancy	NGO	Head
12	Battseren	ACF - Wash Action	NGO	Director
13	Enkhbold.D	Mongolian Mining Association	NGO	Foreign relations manager, interpreter
14	Basandorj	Mongolian Water Partnership	NGO	Head
15	Erdene	Environmental Citizens Council	NGO	Executive Director
16	Otgon-Erdene	Economic Policy and Competitiveness Research Center	NGO	Researcher
17	Batbayar	Erdenes MGL JSC	Private	Director of Mining Department
18	Batsukh	Erdenes TT JSC	Private	Water supply project Leader
19	Dima	Erdenes TT JSC	Private	Relations manager

#	Name	Organization	Organization type	Position
20	Saranmandal	Prestige engineering LLC	Private	Project and Finance Manager
21	Dalaitseren	Prestige engineering LLC	Private	
22	Baasandorj	Energy Resources LLC	Private	VP & Head of Site Infrastructure Project
23	L.Myagmarjav	MCS LTD	Private	Director
24	Mark Newby	Oyu Tolgoi LLC	Private	Environmental manager
25	Zolbayar	MCS Energy LLC	Private	

Table 21 Stakeholder list of participants of second Focus Group Discussion

#	Name	Organization	Organization type	Position
1	G.Munkh-Erdem	MEGDT	Government	Department of Land Management and Water Integrated Policy MEGDT
2	Enkhtaivan	Ministry of Energy	Government	Senior officer
3	Nergui	Ministry of Mining	Government	Head of Mining policy dept.
4	Jargaltsengel	RBA Umard Govi	Government	RBA Head
5	Bazarragchaa	Tavan Tolgoi Power Plant (Ministry of Energy)	Government	Project Implementation Unit (PIU is under the Ministry of Energy and responsible for TTPP from GoM side)
6	D.Ankhbat	UB city Governor's Office	Government	Senior officer, Policy Strategy Planning Division
7	Enkhbaatar	MINIS Project	International org.	PIU Director
8	Altangerel	MINIS Project	International org.	GWMIU
9	Anarmaa	GGGI	International org.	Project Manager
10	Byambatseren	NAMAC/ Herders' Association	NGO	Head of international cooperation and Legal Advisor
11	Mrs. O.Enkhtuya	The Nature Conservancy	NGO	Head
12	Battseren	ACF - Wash Action	NGO	Director
13	Enkhbold.D	Mongolian Mining Association	NGO	Foreign relations manager, interpreter
14	Basandorj	Mongolian Water Partnership	NGO	Head
15	Erdene	Environmental Citizens Council	NGO	Executive Director
16	Otgon-Erdene	Economic Policy and Competitiveness Research Center	NGO	Researcher
17	Batbayar	Erdenes MGL JSC	Private	Director of Mining Department
18	Batsukh	Erdenes TT JSC	Private	Water supply project Leader
19	Dima	Erdenes TT JSC	Private	Relations manager
20	Saranmandal	Prestige engineering LLC	Private	Project and Finance Manager
21	Dalaitseren	Prestige engineering LLC	Private	
22	Baasandorj	Energy Resources LLC	Private	VP & Head of Site Infrastructure Project
23	L.Myagmarjav	MCS LTD	Private	Director

#	Name	Organization	Organization type	Position
24	Mark Newby	Oyu Tolgoi LLC	Private	Environmental manager
25	Zolbayar	MCS Energy LLC	Private	
1	G.Munkh-Erdem	MEGDT	Government	Director, Department of Land Management and Water Integrated Policy
2	A.Oyunsuvd	MEGDT	Government	Director, Water Resources Division
3	P.Badamdorj	MEGDT	Government	Water Resources Division
4	Davaasuren	MEGDT	Government	Water Resources Division
5	Otgonbayar	MEGDT	Government	Water Resources Division
6	Chuluunkhuu	MEGDT	Government	RBA Management Division
7	Darkhanchimeg	MEGDT	Government	Water Resources Division
8	D.Saikhanjargal	MEGDT	Government	Water Resources Division
9	B.Sarantsetseg	MEGDT	Government	Department of Land Management and Water Integrated Policy
10	G.Tamir	Ministry of Mining	Government	Water Specialist
11	S.Purevdorj	WWF	NGO	Freshwater & Climate Change Officer
12	Janchivdorj	Institute of Geo-Ecology	NGO	Head of Water Supply Division
13	L.Maygmarjav	MCS LTD	Private	Director

Table 22 Stakeholder list of participants of IFC Mining Round Table workshop (presentation and discussion of interim results)

#	Name	Organization	Organization type	Position
1	Ts.Delgerbat	Terra Energy	Private	Environmental Specialist at the site
2	D.Nemekhbat	Terra Energy	Private	Sustainable development director,
3	D.Ariunbileg	Hunnu Coal	Private	Community Relations
4	B.Lkhagvajargal	Hunnu Coal	Private	
5	P.Erdenebileg	Erdene Resources	Private	Community Officer
6	Oljmedekh.D	OT	Private	DZ office manager
7	N. Munkhbayar	OT	Private	Community Relations Officer
8	S. Otgonbaatar	OT	Private	Water management senior officer
9	O. Tseesuren	OT	Private	Environmental assistant officer
10	Dorjsuren	Energy Resources	Private	Community Relations Officer
11	Badraltkhuu	SGS	Private	DZ representative
12	Bolor	E-TT	Private	Environmental specialist
13	Unenkhuu	E-TT	Private	Environmental specialist
14	Altangerel	E-TT	Private	Lawyer
15	D.Chandmani	RBA: Ongi	Government	Director
16	D.Amarjargal	RBA: Ongi	Government	Social-economic, communications specialist
17	Ts.Enkhtuya	RBA: Ongi	Government	Water tariff, price specialist
18	O.Enkhtuya	RBA: Ongi	Government	Financial specialist

#	Name	Organization	Organization type	Position
19	D.Jargaltsengel	RBA: Umard Gobyn Guvet - Khalkhyn Dundad Tal	Government	Director
20	Batsengel	RBA: Umard Gobyn Guvet - Khalkhyn Dundad Tal	Government	
21	Boldsaikhan B.	RBA: Umard Gobyn Guvet - Khalkhyn Dundad Tal	Government	Specialist in charge of water quality and ecological issues
22	Purevsuren	RBA: Umard Gobyn Guvet - Khalkhyn Dundad Tal	Government	
23	O.Azbayar	Sainshand RBA	Government	Water monitoring specialist
24	B.Yalaltbayar	Sainshand RBA	Government	Water management training specialist
25	Ts.Ulziidari	Sainshand RBA	Government	Water
26	S.Purevdorj	Sainshand RBA	Government	Water tariff, price specialist
27	D.Enkhbold	Mongolian National Mining Association	NGO	Executive Director
28	D.Jamyan	Mongolian National Mining Association	NGO	Umnugobi representative
29	Enkhjin	Mongolian National Mining Association	NGO	HSE Manager
30	Enkhbaatar	PIU/MINIS	Int. org.	Coordinator
31	Bat-Erdene	PIU/MINIS	Int. org.	Monitoring Specialist
32	Tsetsgee	PIU/MINIS	Int. org.	Environment safeguards and Water management specialist
33	B.Ariunchimeg	PIU/MINIS	Int. org.	FMS
34	B.Altangerel	GWMIU/MINIS	Int. org.	Team leader, hydrogeologist
35	P.Nansal	GWMIU/MINIS	Int. org.	Ecological specialist
36	G.Zolzaya	GWMIU/MINIS	Int. org.	Specialist

A.3. Established groundwater reserves

Table 23 Established Groundwater Reserves in Nyalga Shivee Ovoo Region

№	Name of Reserve Area	Location	Reserve Category / Amount						Year of Approval (if known)
			A (measured / proven)	B (indicated / possible)	C1/C (inferred/ potential)	C2/P (probable/ predicted)	Total	Total	
			m^3/day	m^3/day	m^3/Day	m^3/day	m^3/day	L/s	
1	TsagaanChuluut	DornogobiAi r agsoum		1,752	379	3,444	5,575	65	2011
2	Choir free Economic Zone	Govisumber				767	767	9	2008

№	Name of Reserve Area	Location	Reserve Category / Amount						Year of Approval (if known)
3	JargalantNuur	DundgobiBa y anjargalan			11,232		11,232	130	2008
4	NogoonToirom	Gobisumber S hivee-Ovoo	605	3,672	3,560	1,037	8,874	102.71	2013
5	TevshynKhundii	Gobisumber S umber			1,203	600	1,803	21	2009
6	TsagaanUndur	KhentiyDark h an			994		994	12	2011
7	IkhTalynkhotgor	DundgobiTs a gaan-Delger			5,280	2,230	7,510	87	2011
8	ZosynBulag/Kuu vriinbuuts/Darav gai	Darkhansou m , Khentii province			994		994	12	2014
9	North Choir/Bayan Tal	47km NNW of SO mine	173	3,456	1,296	6,584	11,508	133	
10	TeregtiinKhotgo r	23km NNW of SO mine		864	778		1,642	19	
11	KhukhTsav	43,8 km East of SO mine			1,296		1,296	15	
12	IkhNart	63,0 km South of SO mine				475	475	6	
13	IkhUlaanNuur	71,8km SW of SO mine				6,350	6,350	74	
14	Sairga	69,7km SW of SO mine				1,313	1,313	75	
15	Zaraa	61,7km SW of SO mine				78	78	1	
16	KhalzanOvoot	41,0km South of SO mine				1,201	1,201	14	
17	Shivee-Ovoo	ShiveeOvoo	432	6,463	7,517		14,412	16	
18	GoviUgtaal	83,7km West of SO mine			173		173	2	
			1,210	**16,207**	**34,700**	**24,079**	**76,19 7**	**793.71**	

Table 24 Established Groundwater Reserves in Tavan Tolgoi region

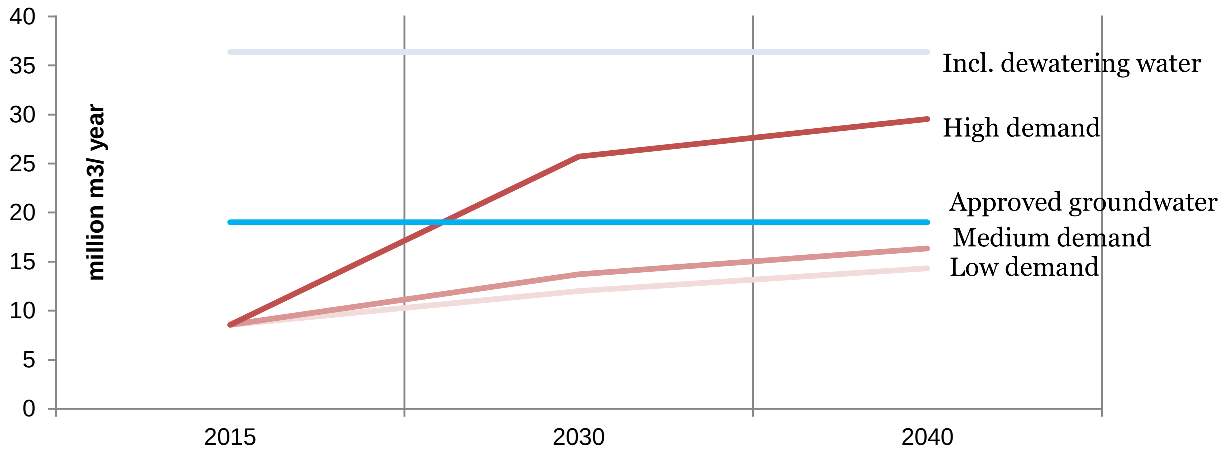
№	Name of Reserve Area	Location	Reserve Category / Amount						Year Approved (if known)
			A (measured / proven)	B (indicated/ possible)	C1/C (inferred/ potential)	C2/P (probable/ predicted)	Total	Total	

№	Name of Reserve Area	Location	Reserve Category / Amount						Year Approved (if known)
			m3/ day	m3/ day	m3/ day	m3/ day	m3/ day	L/s	
1	Balgasiin Ulaan Nuur	62km from TT		11,737	23,185		34,922	404	2014
2	Naimdain Khundii	60km north of TT				9,720	9,720	113	2012
3	Naimant Depression	15km North of TT		5,357	4,752		10,109	117	2010
4	Zairmagtai	62km SE of TT		1,322	657		1,979	23	1987
5	Bayan-Ovoo	94km SE of TT			86		86	1	1988
6	NariinZag				6,480		6,480	75	1988
7	Kharmagtai	83km NE of TT		3,776	2,195		5,970	69	2013
8	Dalanzadgad	80km of WSW of TT	2,592	1,469			4,061	47.00	1982
9	Mandakh	94km WNW of MM	1,814	778	933		3,525	41	1985
10	Nomgonsoum - Guramsangiin Hooloi	98km South of TT							1991
11	TavanAld			3,326	8,052		11,379	132	2014
	Total		**4,406**	**27,764**	**46,341**	**9,720**	**88,231**	**1,022**	

A.4. Additional water balances

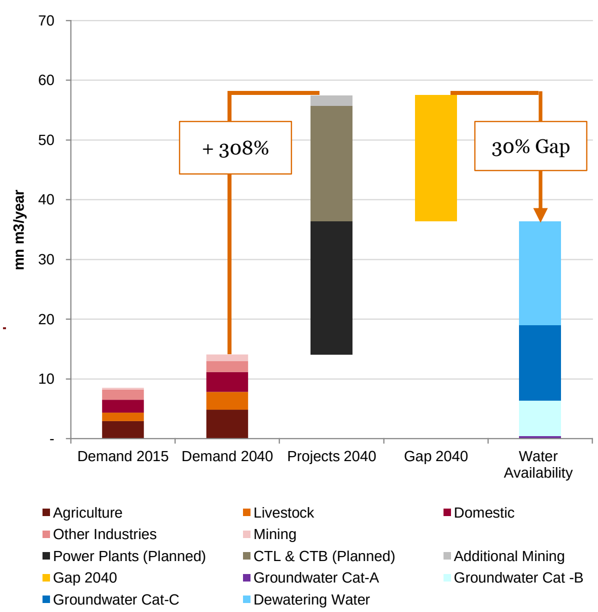
Water Balances baseline, i.e. excluding water demand from planned investments (2015, 2030 & 2040) Nyalga Shivee Ovoo

Baseline

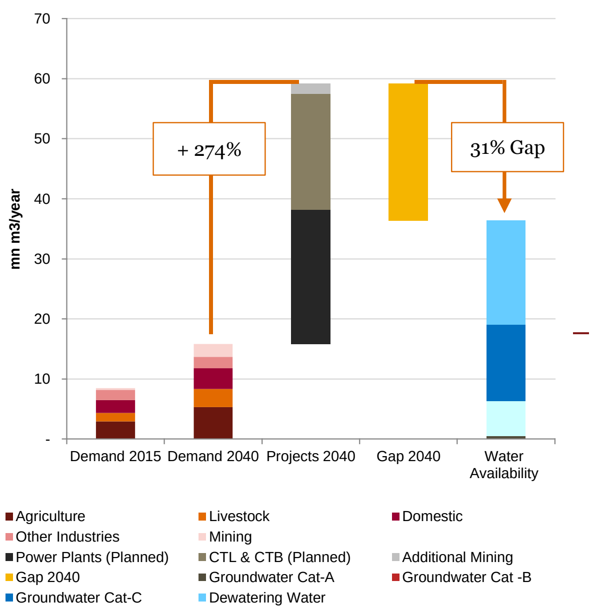


Water Balances incl. planned investments (2015, 2030 & 2040) Nyalga Shivee Ovo

Low scenario

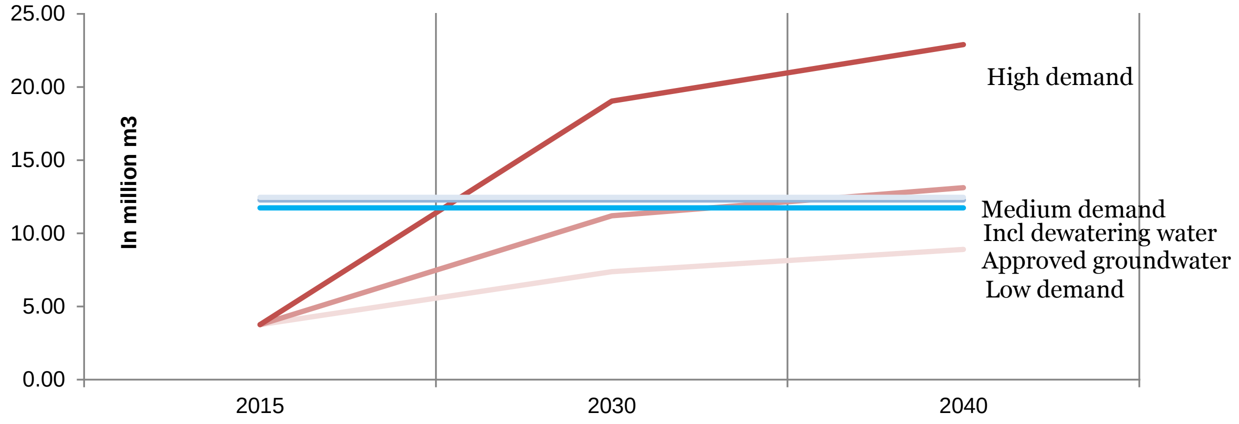


Medium scenario



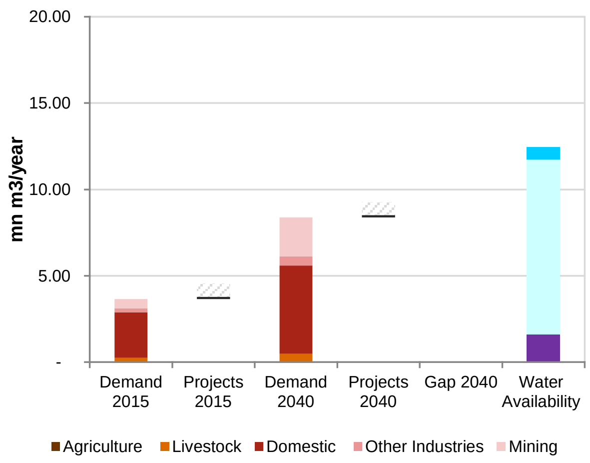
Water Balances baseline, i.e. excluding water demand from planned investments (2015, 2030 & 2040)- Tavan Tolgoi

Baseline

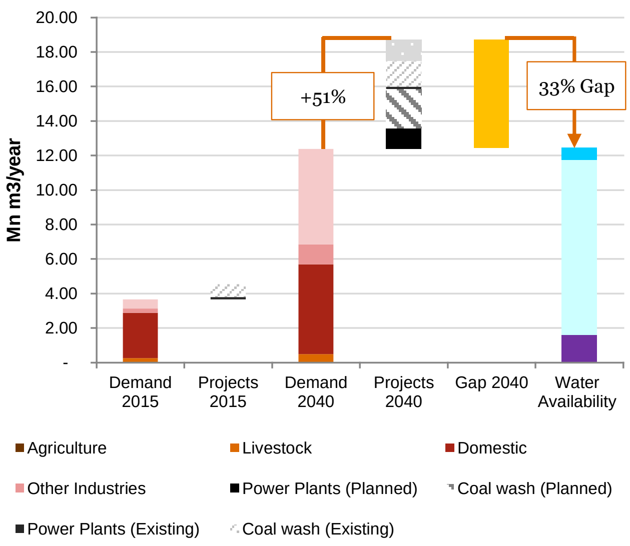


Water Balances incl. planned investments (2015, 2030 and 2040) Tavan Tolgoi

Low scenario



Medium scenario



A.5. Identifying a wide range of potential solutions to close the water gap

A.5.1. Solutions – Water demand reduction

This section focuses on the potential technical options that could be implemented to reduce water demand at existing projects and planned projects within the study area in the coal mining regions of Tavan Tolgoi and Nyalga Shivee Ovoo. The identification of water demand reduction solutions focuses on all types of development projects, i.e. thermal power, coal-to-liquid, coal-to-briquette and coal to washing plants, as well as
coal mining operations.

The current (planned) technologies and technical specifications used for existing and planned investment projects were identified and used as baseline, from which potential water demand reduction solutions were identified. For an overview of all considered investment projects, please consult Table 1 and Table 2.

Information on existing and planned investments and projects in these regions has been received from responsible Ministries (Ministry of Energy, Ministry of Mining, Ministry of Environment, Green Development and Tourism), from River Basin Administrations and the (state) companies owning or planning these projects. For most projects, estimates for baseline annual water requirements were obtained or were derived from the data that was collected. However, data on exact technical specifications was very limited. To validate these water demand data, comparisons of the theoretical water demand for different technical specifications were made in order to determine an assumed baseline specification. Information on best practices are based on the project team's experience and best practice applications reported in the literature.

A brief summary of each of the technical options and the total water demand reduction potential is outlined below, with further information provided in Appendix A.5.2. Details of the total water savings that could be potentially achieved are also highlighted.

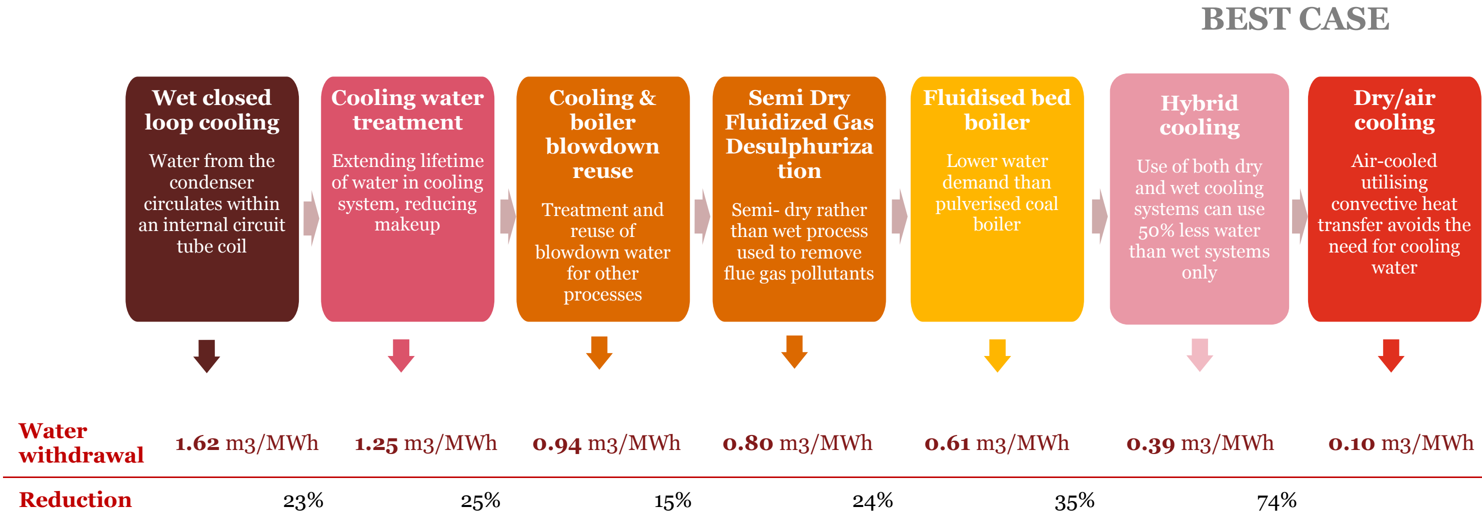
The "ID for analysis", mentioned in the tables below provides for a cross-reference of (planned) projects across chapters.

A.5.1.1. Thermal Power Plants (TPP) and Coal-to-Liquid Plants (CTL)

Thermal power generation requires reliable access to large volumes of water. Traditionally, the largest single demand for water is associated with the cooling system for the steam turbine, followed by boiler make-up and removal of SO_2 from flue gases. Coal-to-liquid facilities also require high volumes of water with key processes matching those for thermal power plants.

Figure 15 outlines the general technical options for water demand reduction at TPP and CTL plants. Each box illustrates technological options, which can be further improved by the measures to the right of each box. The existing baseline for TPP and CTL plants will determine the additional options that can be potentially added. Dry/ air cooling (with circulating fluidized bed boilers and boiler blowdown reuse) on the far right illustrate the best case, with respect to water usage.

Figure 25 Technical options for water demand reduction at TTP and CTL plants



Note: *% reductions illustrate the cumulative improvement that can be made through the implementation of each option*

Table 25 presents the total water reduction potential for the one existing and one planned TPP in Tavan Tolgoi and four planned TPPs in Nyalga Shivee Ovoo. The total potential water reduction is based on the improvement from the baseline (current/ planned technology) to the best practice technology. TPPs in Tavan Tolgoi already use best practice technologies, thus there is no water demand reduction potential. In Nyalgo Shivee Ovoo, on the other hand, water saving of 18.43 mn m3/year could be potentially achieved when shifting to best practice technologies.

Table 25 Identified water demand reduction potential for TPP's at Tavan Tolgoi and Nyalga Shivee Ovoo for baseline and best case

Region	TPP	ID for analysis	Inferred baseline specification	Water withdrawal (mn m3/year)	Best case specification	% Reduction over baseline	Water withdrawal (mn m3/year)	Potential water saving (mn m3/year)
NSO	270 MW	1	WCCC, CFBB, CWT, CWBR, BWBR	0.86	DAC, CFBB, BWBR	83%	0.15	0.71
NSO	750 MW	2	WCCC, WFGD, CWT, CWBR	4.79	DAC, WFGD, BWBR, CFBB	90%	0.49	4.31
NSO	5280 MW	3	DAC, WFGD	15.70	DAC, BWBR, CFBB	80%	3.15	12.55
NSO	600 MW	4	DAC, CFBB	2.00	DAC, CFBB, BWBR	43%	1.15	0.85
	Sub Total			**23.35**			**4.92**	**18.43**
TT	18 MW	17	DAC, CFBB, BWBR	0.13	DAC, CFBB, BWBR	0	0.13	0.00
TT	450 MW	18	DAC, CFBB, BWBR	1.20	DAC, CFBB, BWBR	0	1.20	0.00
	Sub Total			1.33			**1.33**	**0.00**
	Total			**24.69**			**6.26**	**18.43**

Key: WCCC = Wet Closed Cycle Cooling; DAC = Dry/Air Cooled; CFBB = Circulating Fluidized Bed Boilers; CWT = Cooling Water Treatment; CWBR = Cooling Water Blowdown Reuse; BWBR = Boiler Water Blowdown Reuse; WFGD = Wet FGD; NSO = Nyalga Shivee Ovoo; TT = Tavan Tolgoi

Similarly, Table 26 Identified water demand reduction potential for CTL plants at Nyalga Shivee Ovoo for baseline and best case presents the water reduction potential for the three planned CTL plants in Nyalga Shivee Ovoo. When improving the technologies from the currently planned technological specifications (baseline) to best practice, total water saving of 18.35 mn m^3/year could be potentially achieved.

Table 26 Identified water demand reduction potential for CTL plants at Nyalga Shivee Ovoo for baseline and best case

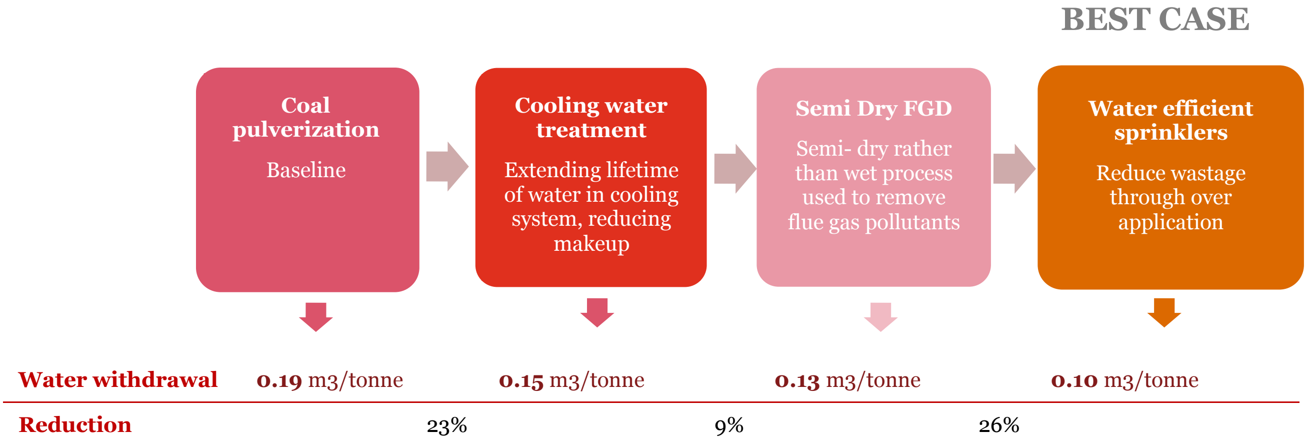
Region	CTL Plant	ID for analysis	Inferred baseline specification	Water withdrawal (mn m^3/year)	Best case specification	% Reduction	Water withdrawal (mn m^3/year)	Potential water saving (mn m^3/year)
NSO	Tugrug Nuur	5	WCCC, WFGD	10.00	DAC, BWRR, CFBB	95%	0.48	9.52
NSO	Buuruljuut yn Tal	6	WCCC, WFGD	4.50	DAC, BWRR, CFBB	95%	0.22	4.28
NSO	Shivee Ovoo	24	WCCC, WFGD	4.78	DAC, BWRR, CFBB	95%	0.23	4.55
	Total			**19.28**			**0.93**	**18.35**

Key: WCCC = Wet Closed Cycle Cooling; DAC = Dry/Air Cooled; CFBB = Circulating fluidized bed boilers; BWBR = Boiler Water Blowdown Reuse; WFGD = Wet FGD; NSO = Nyalga Shivee Ovoo

A.5.1.2. Coal to Briquette Plants

Coal briquetting is a value-adding process by which low grade coal is converted into a higher grade, uniform, hard and impact resistance agglomeration with increased calorific value. This coal can then be used for domestic and industrial purposes. Water is typically used for cooling purposes and can form part of the binder. Figure 16 provides a summary of the technical options and the water saving potential.

Figure 26 Technical options for water demand reduction at coal to briquette plants



There is one coal to briquette plant planned for the Nyalga Shivee Ovoo region. The baseline water withdrawal demand is estimated as 0.058 mn m^3/year. Making all technical improvements illustrated in Figure 16 from the baseline to the best case (water efficient sprinklers), total potential water saving of 0.030 mn m^3/year could be achieved.

A.5.1.3. Coal Washing Plants

Coal washing is a process whereby impurities (e.g. ash, rock and sulfur) are removed from the coal, improving its combustion efficiency, which therefore increase its value. Physical cleaning processes are most commonly used, which involves the mechanical separation of the contaminants from the coal using gravity separation processes. Coal washing is most commonly undertaken, using water as the separation medium.

Figure 27 provides details of general technical options that can be applied to reduce water requirements.

Figure 27 Technical options for water demand reduction at coal wash plants

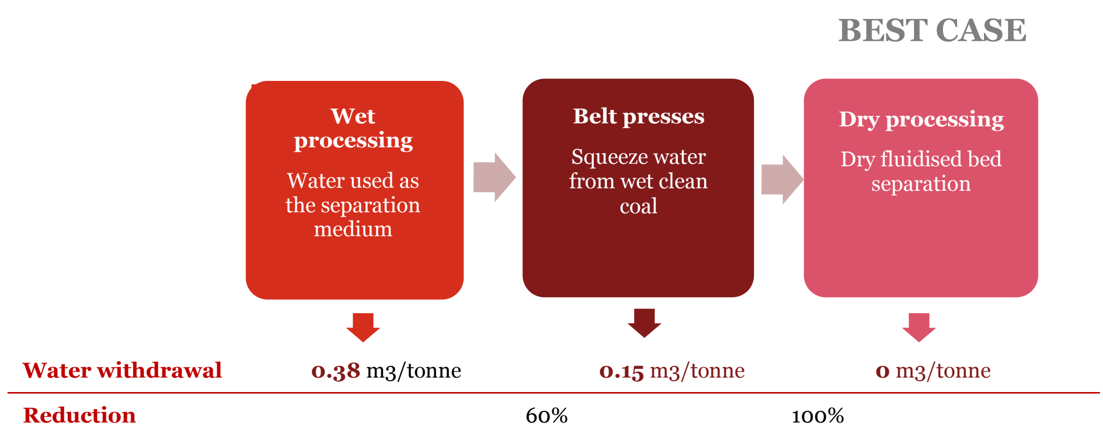


Table 27 Identified water demand reduction potential for coal washing plants under the high growth scenario - Table 27 highlights, under the high growth scenario, the water withdrawal demand for the existing and planned coal washing plants in Tavan Tolgoi. The existing and planned coal washing plants in Tavan Tolgoi using dry processing are already following best practice and thus no water savings can be made for these technologies. While the remaining existing and planned coal washing plants already use belt presses (baseline), the implementation of dry processing can potentially reduce water demand at each plant to zero. Thus, in total, potential overall saving of 6.853 mn m^3/year can be achieved in Tavan Tolgoi.

Table 27 Identified water demand reduction potential for coal washing plants under the high growth scenario

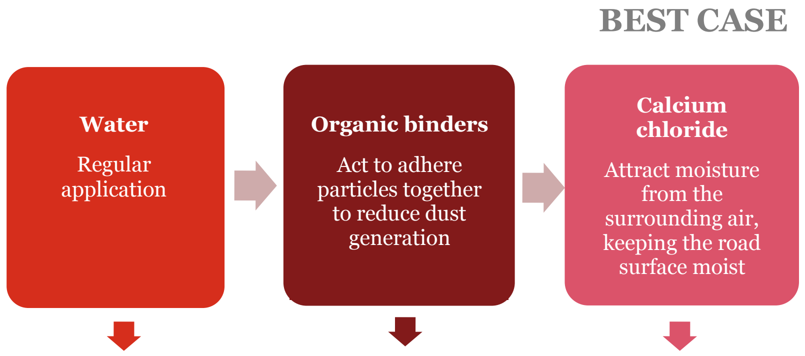
Region	Mine	ID for analysis	Baseline	Water withdrawal (mn m^3/year)	Best case	% Reduction	Water withdrawal (mn m^3/year)	Potential water saving (mn m^3/year)
TT	Energy Resources	32	Water separation	2,272	Dry separation	100%	0	2,272
TT	Erdenes TT	25	Water separation	4.541	Dry separation	100%	0	4.541
	Total							**6.853**

Key: TT = Tavan Tolgoi

A.5.1.4. Coal mining

The main water demand at the mines in the Nyalga Shivee Ovoo and Tavan Tolgoi regions is for suppressing dust associated with haul roads and stock piles. The exact volume of water required for water-spray based dust suppression varies depending upon the climatic conditions, area of coal stockpile and the area of active roads. In addition to regular water only applications, chemical dust suppressants are key alternatives which reduce water use as presented inFigure 28.

Figure 28 Technical options for water demand reduction for dust suppression at mining sites



Water withdrawal	**12.73** m3/sec		**3.18** m3/sec		**2.12** m3/sec
Reduction		75%		33%	

Table 28 Identified water demand reduction potential for dust suppression under the high water demand scenario shows the associated water demand for key mines in the two regions based on dust suppression undertaken by water only applications and best case option, and potential water savings achieved for the high growth scenario. When shifting from the baseline of water only applications to the best case of using the binder calcium chloride, total potential water saving of 7.904 mn m^3/yr in Nyalga Shivee Ovoo and 4.729 mn m^3/year in Tavan Tolgoi could be achieved.

The main potential environmental impact from the use of calcium chloride as a dust suppressant are on quality of surface and ground waters through runoff and infiltration and on soils and plants. The chloride concentrations in ground and surface waters depend upon application rates, composition and type of soil and rock, intensity and amount of rainfall, the drainage system of the road surface and wider dilution from water from other sources. There is however, limited quantitative information available, and most studies that have been undertaken relate to the use of calcium chloride as de-icers. Studies have shown very low levels chlorides in downstream runoff and groundwater whilst others have seen high levels.

Exposure to extended high levels of chloride in water can impact on the abundance and reproduction of fish and other aquatic organisms. Chloride in drinking water is not generally considered harmful to human health and whilst the EPA has a maximum chloride concentration of 250mg/l this is based solely on taste and palatability rather than health impacts. In contrast, livestock are more tolerant to water with high salinity than humans. The accumulation of salts in soils can adversely affect plant physiology and morphology.

The use of best management practices and carefully following manufactures recommended application rates will limit potential runoff.

Table 28 Identified water demand reduction potential for dust suppression under the high water demand scenario

Region	Mine	ID for analysis	Baseline dust suppression	Water withdrawal (mn m^3/year)	Best case dust suppression	% Reduction	Water withdrawal (mn m^3/year)	Potential water saving (mn m^3/year)
NSO	Tugrug Nuur	8	Water only	0.379	Calcium Chloride	83%	0.063	0.316
NSO	Shivee Ovoo JSC	7	Water only	1.138	Calcium Chloride	83%	0.190	0.948
NSO	Buuruljuutyn Tal	9	Water only	0.379	Calcium Chloride	83%	0.063	0.316
NSO	Other mines	39	Water only	7.588	Calcium Chloride	83%	1.264	6.324

NSO Total								**7.904**
TT	Erdenes TT	19	Water only	1.375	Calcium Chloride	83%	0.229	1.146
TT	Energy Resources	20	Water only	0.869	Calcium Chloride	83%	0.145	0.724
TT	TT JSC	30	Water only	0.389	Calcium Chloride	83%	0.064	0.325
TT	Other mines	40	Water only	3.040	Calcium Chloride	83%	0.506	2.534
TT Total								**4.729**

Key: TT = Tavan Tolgoi; NSO = Nyalga Shivee Ovoo

A.5.2. Methodology details on water demand reduction

Table 29 Calculated water withdrawals with the application of technological alternatives for thermal power plants in Nyalga-Shivee Ovoo and Tavan Tolgoi.

ID	Thermal Power Plant	Operator	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m³/MWh)	Derived water withdrawals (m³/year)	Estimate Water withdrawals (m³/year)
Nyalga Shivee Ovoo								
1a	270 MW	One Power Global Limited	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Baseline	1,655,640	0.606	1,002,954	860,000
1g	270 MW	One Power Global Limited	Hybrid (Dry/Wet) Cooling, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	1,655,640	0.468	774,533	664,137
1h	270 MW	One Power Global Limited	Hybrid (Dry/Wet) Cooling, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,655,640	0.391	647,347	555,079
1i	270 MW	One Power Global Limited	Dry/Air Cooled, Circulating fluidized bed boilers,	Dry/Air Cooled	1,655,640	0.180	298,015	255,538
1j	270 MW	One Power Global Limited	Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,655,640	0.103	170,829	146,480
2q	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Wet FGD,	Baseline	4,599,000	1.018	4,679,942	4,793,472

ID	Thermal Power Plant	Operator	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m³/MWh)	Derived water withdrawals (m³/year)	Estimate Water withdrawals (m³/year)
			Cooling Water Treatment, Cooling Water Blowdown Reuse					
2r	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	4,599,000	0.941	4,326,647	4,431,606
2a	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	4,599,000	0.800	3,678,188	3,767,417
2b	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	4,599,000	0.606	2,785,982	2,853,567
2k	750 MW	IM Power Plc	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	4,599,000	0.585	2,690,392	2,755,658
2l	750 MW	IM Power Plc	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown	Circulating fluidized bed boilers	4,599,000	0.391	1,798,186	1,841,808

ID	Thermal Power Plant	Operator	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m3/MWh)	Derived water withdrawals (m3/year)	Estimate Water withdrawals (m3/year)
			Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers					
2m	750 MW	IM Power Plc	Dry/Air Cooled, Wet FGD	Dry/Air Cooled	4,599,000	0.515	2,368,485	2,425,942
2n	750 MW	IM Power Plc	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	4,599,000	0.438	2,015,190	2,064,076
2o	750 MW	IM Power Plc	Dry/Air Cooled, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	4,599,000	0.297	1,366,731	1,399,886
2p	750 MW	IM Power Plc	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	4,599,000	0.103	474,525	486,036
3a	5280 MW	State Grid Corporation of China	Dry/Air Cooled, Wet FGD	Baseline	32,376,960	0.515	16,674,134	15,700,000
3b	5280 MW	State Grid Corporation of China	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	32,376,960	0.438	14,186,936	13,358,109
3c	5280 MW	State Grid Corporation of China	Dry/Air Cooled, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	32,376,960	0.297	9,621,785	9,059,662
3d	5280 MW	IM Power Plc	Dry/Air Cooled, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	32,376,960	0.103	3,340,655	3,145,487
4a	600 MW	Tsetsens Mining and Energy LLC	Dry/Air Cooled, Circulating fluidized bed boilers	Baseline	3,679,200	0.180	662,256	2,000,000
4b	600 MW	Tsetsens mining and Energy LLC	Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	3,679,200	0.103	379,620	1,146,444

ID	Thermal Power Plant	Operator	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m^3/MWh)	Derived water withdrawals (m^3/year)	Estimate Water withdrawals (m^3/year)
Tavan Tolgoi								
17a	18 MW	MMC	Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	Baseline	110,376	0.180	19,868	132,000
18 a	450 MW	MCS	Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	Baseline	2,759,400	0.274	756,076	1,200,000

Table 30 Calculated water withdrawals with the application of technological alternatives for planned CTL plants in Nyalga-Shivee Ovoo.

ID	Location	Operator	Process Configuration	Added Technological Alternative	Fuel Production Volume (m3/year)	Water to fuel ratio	Derived water withdrawals (m3/year)	Estimate Water withdrawals (m3/year)
5a	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD	Baseline: Wet Closed Cycle Recirculating, Wet FGD	1,311,200	6.680	8,758,816	10,000,000
5b	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment,	Cooling Water Treatment	1,311,200	5.160	6,766,253	7,725,077
5c	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	1,311,200	4.209	5,518,868	6,300,929
5d	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,311,200	3.891	5,102,241	5,825,263
5e	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	1,311,200	3.308	4,337,539	4,952,198
5f	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	1,311,200	2.506	3,285,397	3,750,960
5i	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	1,311,200	2.435	3,192,566	3,644,975
5j	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,311,200	2.202	2,887,075	3,296,193

ID	Location	Operator	Process Configuration	Added Technological Alternative	Fuel Production Volume (m3/year)	Water to fuel ratio	Derived water withdrawals (m3/year)	Estimate Water withdrawals (m3/year)
5k	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	1,311,200	1.774	2,326,358	2,656,019
5l	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	1,311,200	1.186	1,554,876	1,775,212
5m	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD	Dry/Air Cooled, Wet FGD	1,311,200	1.610	2,111,032	2,410,180
5n	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,311,200	1.370	1,796,140	2,050,665
5o	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	1,311,200	0.929	1,218,168	1,390,791
5p	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	1,311,200	0.323	422,944	482,878
6a	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD	Baseline: Wet Closed Cycle Recirculating, Wet FGD	596,000	6.680	3,981,280	4,500,000
6b	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment,	Cooling Water Treatment	596,000	5.160	3,075,570	3,476,285
6c	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	596,000	4.209	2,508,576	2,835,418
6d	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	596,000	3.891	2,319,200	2,621,368

ID	Location	Operator	Process Configuration	Added Technological Alternative	Fuel Production Volume (m^3/year)	Water to fuel ratio	Derived water withdrawals (m^3/year)	Estimate Water withdrawals (m^3/year)
6e	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	596,000	3.308	1,971,609	2,228,489
6f	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	596,000	2.506	1,493,362	1,687,932
6i	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	596,000	2.435	1,451,167	1,640,239
6j	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	596,000	2.202	1,312,307	1,483,287
6k	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	596,000	1.774	1,057,436	1,195,209
6l	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	596,000	1.186	706,762	798,845
6m	Buuruljuutyn Tal	Tsetsens Mining and Energy	Dry/Air Cooled, Wet FGD	Dry/Air Cooled, Wet FGD	596,000	1.610	959,560	1,084,581
6n	Buuruljuutyn Tal	Tsetsens Mining	Dry/Air Cooled, Wet FGD, Boiler	Boiler Water Blowdown Reuse	596,000	1.370	816,427	922,799

ID	Location	Operator	Process Configuration	Added Technological Alternative	Fuel Production Volume (m3/year)	Water to fuel ratio	Derived water withdrawals (m3/year)	Estimate Water withdrawals (m3/year)
		and Energy	Water Blowdown Reuse					
6o	Buuruljuutyn Tal	Tsetsens Mining and Energy	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	596,000	0.929	553,713	625,856
6p	Buuruljuutyn Tal	Tsetsens Mining and Energy	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	596,000	0.323	192,247	217,295
24a	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Wet FGD	Baseline: Wet Closed Cycle Recirculating, Wet FGD	715,200	6.680	4,777,536	4,777,536
24b	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment,	Cooling Water Treatment	715,200	5.160	3,690,684	3,690,684
24c	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	715,200	4.209	3,010,291	3,010,291
24d	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	715,200	3.891	2,783,040	2,783,040
24e	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	715,200	3.308	2,365,930	2,365,930
24f	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	715,200	2.506	1,792,035	1,792,035
24i	Shivee Ovoo	Germon Gas LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment,	Cooling Water Blowdown Reuse	715,200	2.435	1,741,400	1,741,400

ID	Location	Operator	Process Configuration	Added Technological Alternative	Fuel Production Volume (m3/year)	Water to fuel ratio	Derived water withdrawals (m3/year)	Estimate Water withdrawals (m3/year)
			Cooling Water Blowdown Reuse					
24j	Shivee Ovoo	Germon Gas LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	715,200	2.202	1,574,768	1,574,768
24k	Shivee Ovoo	Germon Gas LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	715,200	1.774	1,268,923	1,268,923
24l	Shivee Ovoo	Germon Gas LLC	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	715,200	1.186	848,114	848,114
24m	Shivee Ovoo	Germon Gas LLC	Dry/Air Cooled, Wet FGD	Dry/Air Cooled, Wet FGD	715,200	1.610	1,151,472	1,151,472
24n	Shivee Ovoo	Germon Gas LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	715,200	1.370	979,713	979,713
24o	Shivee Ovoo	Germon Gas LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	715,200	0.929	664,455	664,455
24p	Shivee Ovoo	Germon Gas LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	Circulating fluidized bed boilers	715,200	0.323	230,697	230,697

Table 31 Calculated water withdrawals with the application of technological alternatives for planned coal to briquette plant.

ID	Process Configuration	Added Alternative	Technological	Derived water withdrawals (m3/year)	Estimated water withdrawals (m3/year)
10a	Wet closed circuit cooling, binding, wet FGD	Baseline		27,360	57,600

ID	Process Configuration	Added Technological Alternative	Derived water withdrawals (m³/year)	Estimated water withdrawals (m³/year)
10b	Wet closed circuit cooling, binding, wet FGD, cooling water treatment	Cooling water treatment	21,123	44,470
10c	Wet closed circuit cooling, binding, semi-dry FGD, cooling water treatment,	Semi-dry FGD	19,314	40,662
10d	Wet closed circuit cooling, semi-dry FGD, cooling water treatment, efficient sprinklers	Efficient sprinklers	14,274	30,052

Table 32 Calculated water withdrawals with the application of technological alternatives for planned coal washing plants in Tavan Tolgoi region

ID	Coal Wash Plant	Scenario	Production (Mt/year)	Added Technological Alternative	Water Requirement (l/sec)	Estimated water withdrawals (m³/year)
28a	Energy Resources	Baseline/Low	5	Belt Presses	24	756,864
28b	Energy Resources	Baseline/Low	5	Dry Cleaning	0	0
31a	Energy Resources	Medium	10	Belt Presses	48	1,513,728
31b	Energy Resources	Medium	10	Dry Cleaning	0	0
32a	Energy Resources	High	15	Belt Presses	72	2,270,592
32b	Energy Resources	High	15	Dry Cleaning	0	0
27a	ETT	Low	5	Dry Cleaning	0	0
15a	ETT	Medium	15	Belt Presses	72	2,270,592
15b	ETT	Medium	15	Dry Cleaning	0	0
25a	ETT	High	30	Belt Presses	144	4,54,184
25b	ETT	High	30	Dry Cleaning	0	0

Table 33 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining (high scenario)

ID	Mine	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m³/year)
7a	Shivee Ovoo JSC	Water	52.50	1,138,253
7b	Shivee Ovoo JSC	Organic Binders	13.13	284,563
7c	Shivee Ovoo JSC	Calcium Chloride	8.75	189,709
8a	Tugrug Nuur	Water	17.50	379,418
8b	Tugrug Nuur	Organic Binders	4.38	94,854
8c	Tugrug Nuur	Calcium Chloride	2.92	63,236
9a	Buuruljuutyn Tal	Water	17.50	379,418
9b	Buuruljuutyn Tal	Organic Binders	4.38	94,854
9c	Buuruljuutyn Tal	Calcium Chloride	2.92	63,236
39a	Other mines	Water	17.50	7,588,350
39b	Other mines	Organic Binders	4.38	1,897,088
39c	Other mines	Calcium Chloride	2.92	1,264,725

ID	Mine	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m^3/year)
19a	Erdenes TT	Water	63.44	1,375,408
19b	Erdenes TT	Organic Binders	15.86	343,852
19c	Erdenes TT	Calcium Chloride	10.57	229,235
20a	Energy Resources	Water	40.11	869,625
20b	Energy Resources	Organic Binders	10.03	217,406
20c	Energy Resources	Calcium Chloride	6.69	144,937
30a	TT JSC	Water	17.97	389,608
30b	TT JSC	Organic Binders	4.49	97,402
30c	TT JSC	Calcium Chloride	3.00	64,935
40a	Other mines	Water	17.50	3,040,000
40b	Other mines	Organic Binders	4.38	760,000
40c	Other mines	Calcium Chloride	2.92	506,667

A.5.3. Solutions – Water supply augmentation

This study analyses water supplies being augmented via re-use of dewatering water from coal mines, identification of additional groundwater development areas and construction of planned surface water transfers.

A.5.3.1. Identification of additional groundwater development areas

This study identifies potential target groundwater development areas in each study region beyond the already existing government approved reserves introduced in section 3.2.

Similar to the current water availability assessment in section 3.2, shallow aquifers are not included in the assessment. Given that deep aquifers are mostly non-renewable, calculations of the potential to develop groundwater resources are made over the next 25 years in order to meet water demand over the entire planned project lifetime.

The methodology adopted for this study has been extensively used by GWMS for strategic resource planning and for prioritizing groundwater exploration programmes in the Gobi region. The underlying methodology uses a modification of the established Balance Method, which is used by the MEGDT. The modifications, based on findings from past (on field) water resource assessments involved re-definition of aquifer thickness (to take into account the entire saturated sequence that will contribute to yields) and exclusion of recharge (to provide and additional of conservatism). The water availability estimates of the assessed target borefields, which include a recovery factor, take physical, regulatory and technical constraints into account, i.e. only the actually exploitable water resources, also considering environmental water requirements, are illustrated.

In addition, the costs of each borefield are estimated to allow for the identification of the most cost effective solution. Total estimated costs cover capital and operational costs for borefield schemes to deliver water to site (without storage reservoir) for over 25 years. Capital costs for each bore include an allowance for a building, switchboard, pump, pipes to the mine site, bore column, headworks and instrumentation, low voltage lighting, heating and other items as required. A separate allowance was made for stepdown transformer. Operating costs include maintenance costs for the water supply and pipe systems, energy costs (mostly for pumping) and replacement costs.

The study has considered all key resource estimation studies, in addition to the formal groundwater reserve determination, in Mongolia's Gobi region. Key studies include:

- Tunhof and Buyanhising (2010) – Groundwater Assessment in the Gobi Region of Mongolia
- World Bank (2010) – Southern Gobi Regional Environmental Assessment

- IBRD & World Bank (2009) – Southern Mongolia Infrastructure Study
- Integrated Water Management Plan Mongolia (2013)
- Prestige Co Ltd, MINIS, MEGDT, World Bank (2014) – Report on initial economic, financial, environmental and social screening: Preparation of Terms of Reference for feasibility studies on flow regulation of Orkhon River and construction of water reservoir complex
- PwC & Deltares (2014) – Targeted analysis on water resource management issues in Mongolia (2030 WRG)

To allow for transparency, all background documents detailing the data, methodology, etc., are available as supplemental reports to this study (see Section 1).

Please note that while a conservative approach was chosen to establish potential, more detailed in-field investigations are required to prove reserves with certainty.

A.5.3.2. Groundwater development potential in Nyalga Shivee Ovoo region

The brown coal (lignite) mined at Shivee Ovoo occurs within the upper and lower stratums of the Tevshiin Gobi Formation. A Lower Cretaceous water-bearing complex comprising weakly cemented sandstone, brown coal, siltstone, and gravel stone with rare conglomerate extending from near-surface to 260 meters below ground level has been described in local studies. The significant water-bearing potential of the brown coal has been demonstrated through actual dewatering and field investigations at several sites.

In the Nyalga Shivoo Ovoo study area, ten borefields in addition to the already established reserves, were identified. Due to the study area's hydrogeology, sufficient reserves were identified in the 50km radius alone to close the gap. Thus no further investigations were undertaken for the remaining areas under the 100km radius.

The location of the identified target borefields with supplementary information on mine to be supplied, distance to mine, capital and operational costs can be seen inTable 34. Please note that borefields A and D, marked in Table 34 Details on target borefields in Nyalga Shivee Ovoo are not included in further analysis. While they are not part of the established reserves by the Government, these have been registered in the area and thus are potentially committed. Without further information, a conservative approach is chosen leading to the exclusion of these borefields in this analysis.

The total yield of target borefields have the potential to increase overall water availability by 1000 l/s (excluding dewatering water) at the cost of 210.6 mn USD for capital expenditure and 10.9 mn USD annually for operational expenditure.

Figure 29 Identified target borefields in Nyalga Shivee Ovoo region

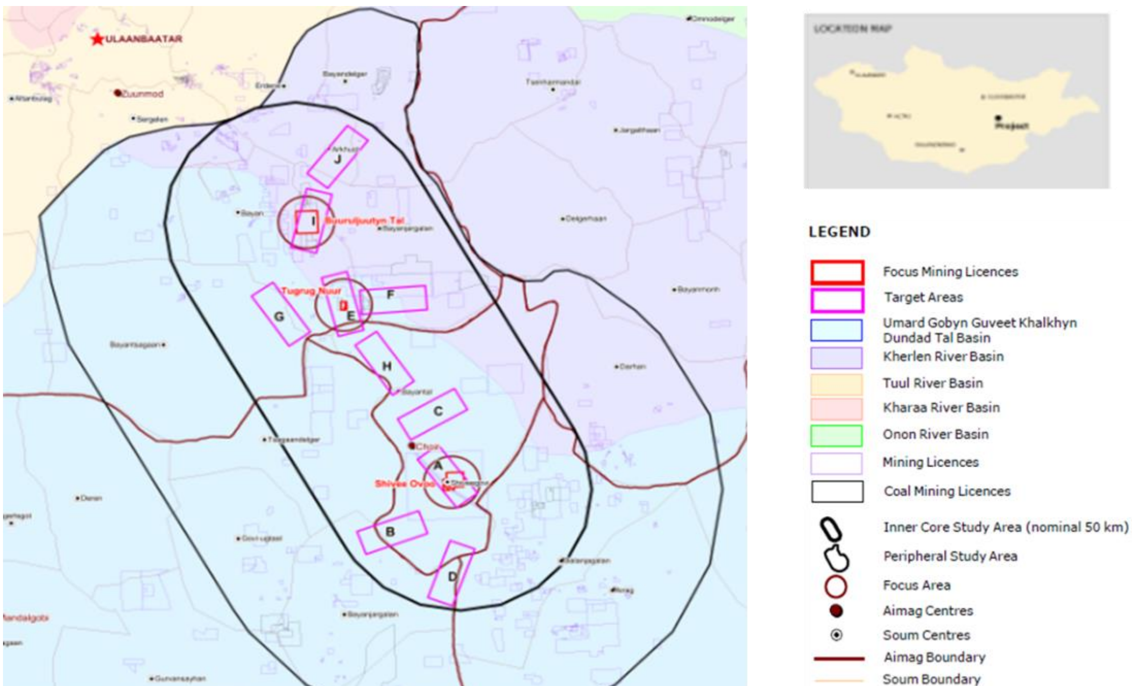
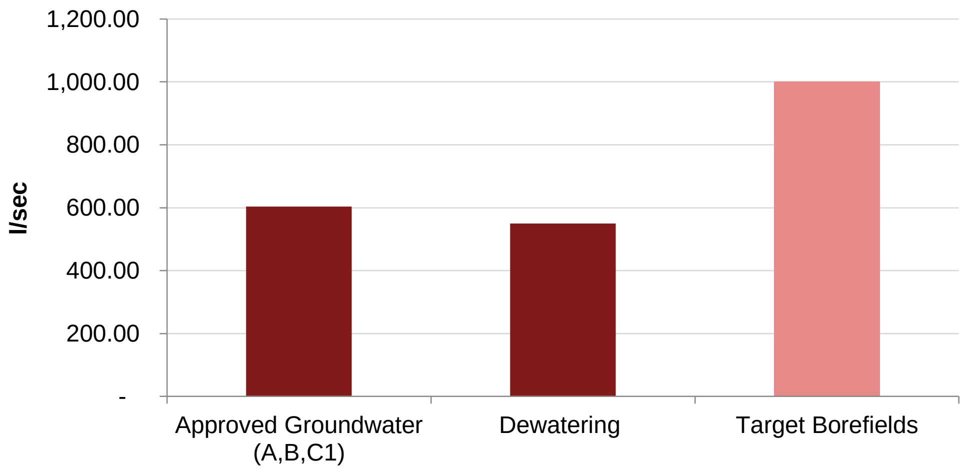


Table 34 Details on target borefields in Nyalga Shivee Ovoo

Borefield	Potential Borefield Yield (l/sec)	Delivery to	Approx. distance (km)	Capital Costs (USD mn)	Annual Operating Costs (USD mn)
Borefield B	100	ShiveeOvoo	26	29.7	1.4
Borefield C	150	ShiveeOvoo	31	33.2	1.8
Borefield E	100	TurugNuur	0	20.7	1
Borefield F	150	TurugNuur	0	21.5	1.1
Borefield G	100	TurugNuur	27	30.7	1.7
Borefield H	100	TurugNuur	16	26.3	1.3
Borefield I	150	Buuruljuutiin Tal	0	21.4	1.1
Borefield J	150	Buuruljuutiin Tal	16	27.1	1.5
Total	**1000**	-	-	**210.6**	**10.9**

Figure 19 presents that the yield of target borefields have the potential to **increase overall water availability by 1000 l/ sec (87%),** when comparing currently available groundwater (600 l/sec) and dewatering water (550 l/sec).

Figure 30 Relative additional yield from target borefields



A.5.3.3. Groundwater development potential in Tavan Tolgoi

The region is characterized by east-west trending ridges of Carboniferous/Permian strata with intervening basins with Cretaceous sediment infill. The Permian Tavan Tolgoi Formation is a thick sequence of siltstone, mudstone, coal, conglomerate, siderite, and felsic tuff that has been subject to folding and faulting. Multiple bituminous coal seams have been identified and outcrops occur. Unlike the younger lignites at Shivee Ovoo, the primary permeability of the Permian sequences is low with groundwater flow typically limited to fracture/fault zones. The Cretaceous sedimentary deposits are typically identified as Ulaangobi Formation and Sainshand Formation typified by red sandstone, clay and unsorted conglomerate sandstones with interbedded clays respectively. Aquifers have been identified to depths in the order of 250m, reserves in the order of 100L/s approved and borefields established in two of the basins north of Tavan Tolgoi (Naimant Depression and Naindaim Khundii).

With similar conditions assumed in other local basins, i.e. within the study area, nine sites for potential borefield development have been identified. Nearby in the Dundgobi Brown Coal area, i.e. just outside the study area, two additional potential development sites have also been identified.

The location of the identified target borefields and Figure 31 Identified local target borefields in Tavan Tolgoi region supplementary information on mine to be supplied, distance to mine, capital and operational costs can be seen in Figure 31 and Figure 32.

The local and regional borefields have the potential to increase water availability by 600l/ sec and 300 l/ sec respectively. Total costs for all borefields amount to 580.44 mn USD of capital expenditure and to 37.1 mn USD of annual operation expenditure.

Figure 31 Identified local target borefields in Tavan Tolgoi region

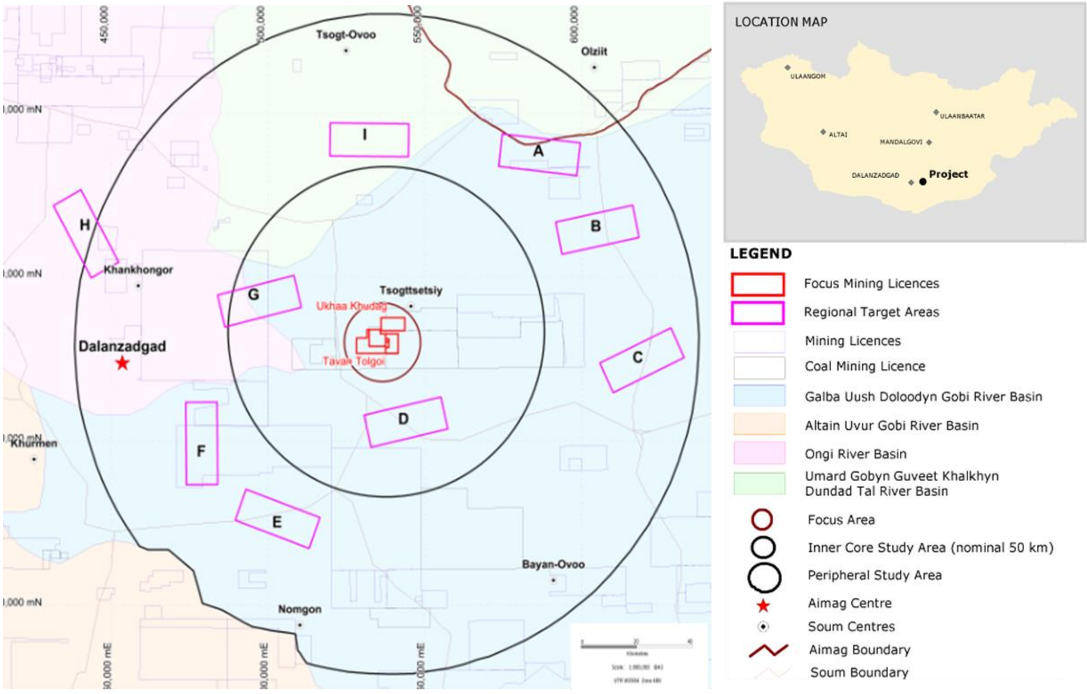


Figure 32 Identified regional target borefields in the Brown Coal area adjacent to Tavan Tolgoi

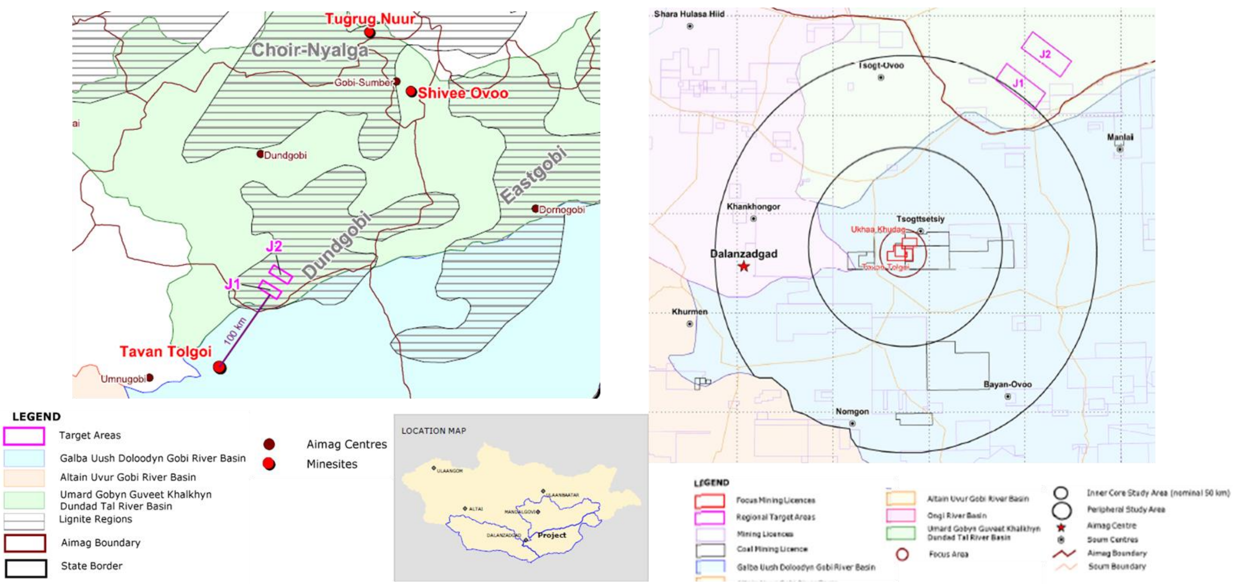
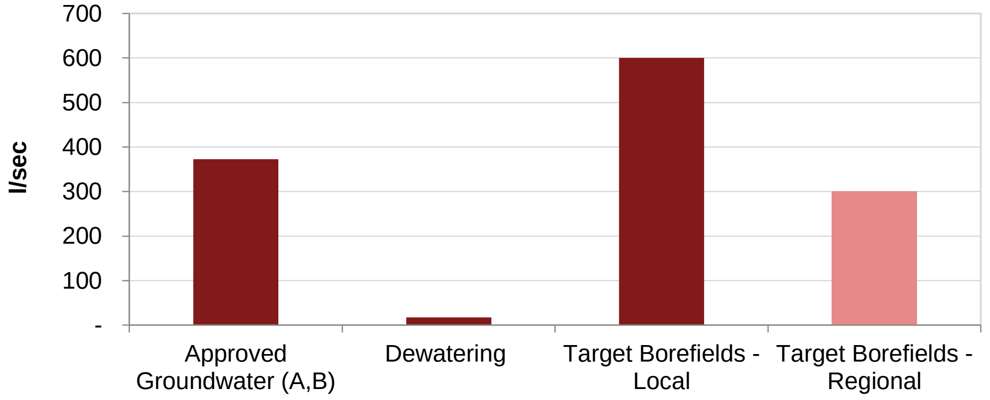


Table 35 Details on target borefields in Tavan Tolgoi

Borefield	Potential Borefield Yield (l/s)	Approx. distance (km)	Capital Costs (USD mn)	Annual Operating Costs (USD mn)
Borefield A	50	90	54	4.3
Borefield B	50	80	49.7	3.8
Borefield C	100	84	58.1	3
Borefield D	50	39	34	2.5
Borefield E	50	111	61.5	4.7
Borefield F	100	90	62.1	3.2
Borefield G	50	33	32	2.4
Borefield H	100	102	66.6	3.4
Borefield I	50	78	49.1	3.8
Borefields J1+J2	300	141	113.3	6.9
Total	**900**	**-**	**580.44**	**37.1**

Figure 33 shows the total water availability from different water supply options. When comparing currently available groundwater (370 l/ sec) and dewatering water (17 l/sec), the yield of local target borefields have the potential to increase overall water availability by 600 l/ sec (154%). In addition, the yield of the regional target borefields increases overall water availability by an additional 300 l/sec (30%).

Figure 33 Relative additional yield from regional target borefields



A.5.4. Surface water transfers

The Orkhon-Gobi water transfer scheme was identified as a potential project that could provide significant additional water supply to the Tavan Tolgoi region in the Southern Gobi. This new major diversion scheme has received varying views from different stakeholder groups within Mongolia in terms of its overall cost effectiveness. Due to concerns over the uncertainty of data relating to the scheme, an additional study has been conducted to provide a high level peer review of existing information to enable the scheme to be included within the prioritization framework.[36] The evaluation focused on water availability, costing and economic, environmental and social impacts of the scheme.

[36] 2030 Water Resources Group, Amec Foster Wheeler and Groundwater Management Solutions (2016) " Peer Review of Orkhon-Gobi Water Transfer".

Information used for the evaluation came from a Screening Report prepared by Prestige in 2014[37] and accompanying data, supplemented by responses to two clarification requests.

A.5.4.1. Orkhon-Gobi water transfer scheme

The surface water element of Alternative C, an integrated surface water and groundwater scheme, was evaluated, which is one of four possible solutions to meet future water demand in the Southern-Gobi outlined in the Prestige Screening Report.

The surface water transfer element would divert approximately 216,000 m^3/day of water from the Orkhon River to be used for agriculture and urban demand along its route and deliver ~100,000 m^3/day for mining and industry into the Southern-Gobi region. It is estimated that ~47,000 m^3/day would reach the Tavan Tolgoi region.

The scheme comprises a dam across the Orkhon River and related reservoir and intake structure, located approximately 250km northwest of Ulaanbaatar. A pipeline and associated pumping stations and infrastructure would be built to transmit the water through a 740km long pipeline to Tavan Tolgoi and Oyo Tolgoi, with side branches to Mandalgobi and Dalanzadgad.

Additional information can be found in AnnexA.5.5

A.5.4.2. Water availability evaluation

The Orkhon River is the most affected river basin in terms of human influences from agriculture, mining, deforestation and urbanization in Mongolia and is also being impacted by global warming. The observed natural flow regime in the river is decreasing as seen by the mean annual flow of 13.4m^3/s in the 10 year period from 2000-2009 being well below 50% of the long term mean (1945-2008) of 41.5m^3/s[38].

With the decline in flow observed, the viability of an off-take of 2.5m^3/s for the surface water transfer is largely dependent upon the proportion of flow regulated for environmental flow purposes. Where this is established at the desirable norms of at least 80% of the natural river flow[39], the planned reservoir capacity would be adequate to sustain the off-take (but could have periods of some years where only partial re-filling occurs). A previous study[40] has identified an environmental flow rate for the Orkhon of 88% of the mean monthly flow. In order for this to maintained, a required storage volume would exceed 300mn m^3 and that of the planned reservoir capacity, and in simulations undertaken the reservoir did not refill from year 2000 onwards. In summary, the level of flow maintenance regulated for environmental flow purposes, will determine the viability of scheme.

It is recognized that the scheme is still at scoping stage and further definition and assessment of the proposed water use is required.

A.5.4.3. Cost evaluation

The first stage of the cost evaluation looked at the design principles and assumptions associated with this scheme and it was considered that at this screening stage, they have not yet been developed sufficiently to provide confidence in the overall design or costs. The design strategy should be agreed and the basis of the design confirmed to enable a more robust cost estimate with an increased confidence. For a scheme of this scale, with the design at this level of detail, it is important to highlight that there will be changes that could significantly impact the current cost estimate.

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[37] Prestige (2014). Report on Initial Economic, Financial, Environmental and Social Screening. Preparation of Terms of Reference for Feasibility Studies on Flow Regulation of Orkhon River and Construction of Water Reservoir Complex Project.
[38] Khishigsuren, P., Tsogzolmaa, Kh.,and Ts.Baldandorj. (2012). Orkhon River Basin Integrated Water Resources Management Assessment Report, Part 1. Natural Condition and Land Use.
[39] Richter, B.D., Davis, M.M., Apse, C. and C. Konrad. (2011).A presumptive standard for environmental flow protection River Research and Applications 28(8): 1312-1321.
[40] Davaa, G., Oyunbaatar, D., Tumurchudur, S., Wim van der Linden, and Z. Munkhtsetseg. (2012). Orkhon River Basin Integrated Water Resources Management Assessment Report, Part 2. Surface Water Assessment.

Within the context of the existing proposed design, an evaluation of the initial estimate by Prestige Engineering of the capital and operational expenditure of USD525 mn and USD41.6 mn respectively was undertaken. The review of capital expenditure highlighted the need to make adjustments to provide a consistent base date of 1Q2016 (dates of 2Q2010, 1Q2013 and 1Q2015 were use in the Prestige estimate), to allow for uncertainty and risk through providing a three point estimate (low, median and upper confidence levels), for VAT inclusion, and specific cost elements including for the pipeline and dam. There is particular uncertainty in the costings of the dam related to the size required, which will be determined by environmental flow regulations requirements. The review of operational expenditure highlighted the need to update key areas to provide for a consistent base date of 1Q2016, to reflect the increase in current electricity prices, for maintenance and for depreciation.

As a result of the evaluation, the capital expenditure estimate has risen from USD525 mn to USD1,295 mn (including VAT) and operational expenditure from USD41.6 mn to USD79 mn (excluding VAT) both at the upper confidence level. The total Equivalent Annual Cost (EAC) of constructing the Orkhon-Gobi water transfer amount to USD212 mn, while the apportioned EAC relating to only the water share reaching the Tavan Tolgoi region amount to USD46 mn.

At the scoping stage, there is large uncertainty in the design elements of the water transfer scheme. These changes could considerably impact the associated cost estimate. While the revised cost estimate above addresses some issues, this remaining uncertainty would need to be addressed at the feasibility stage.

A.5.4.4. Financial, economic, environmental and social impacts

The revised capital and operational expenditures were combined with water supply data to calculate the cost-effectiveness ratio resulting in a ratio of 2.68USD/m^3 for the water transfer scheme. Since the evaluation did not extend to a validation exercise, information within the Prestige Screening Report was used to extract the data on key relevant economic, social and environmental impacts for use within the assessment tool. That report highlighted key negative impacts as the reduced surface water resources in the Orkhon catchment and associated land use changes. However, the scheme also has a potential to result in significant positive economic and social impacts and to benefit the regions through the additional water supply which is the intended purpose of the project.

A.5.4.5. Conclusions

The evaluation of information on the Orkhon-Gobi water transfer scheme has resulted in a revised cost estimate of USD 1,295 M at the upper confidence level. An offtake flow of 2.5m^3/s for the surface water transfer is viable but dependent upon the proportion of flow regulated for environmental flow purposes. Information on economic, environmental and social impacts was also collated, allowing the water transfer scheme to be included within the hydro-economic framework.

It should be noted that data availability on the scheme reflects the early 'scoping' stage of the project in its lifecycle. There is limited information on the hydrology and exact design and related assumptions. The cost estimate reflects these uncertainties which would be further refined at pre-feasibility and feasibility stage.

A.5.5. Methodology on surface water transfer assessment (cost differences)

Table 36 Revised capital costs of the Orkhon-Gobi water transfer scheme Alternative C.

Capital expenditure	Confidence level		
	Lower	Medium	Upper
Prestige Estimate May 2014		**$525.5M**	
Ductile Pipe Rates		$43.3M	
Fill material to Dam		$35.2M	
Allowance for temporary roads and easements		$9.0M	
Allowance for Thrust blocks		$8.1M	
Feasibility Study Costs omitted		$5.0M	
Project Management		$1.8M	
Replacement of topsoil and reinstatement		$1.0M	
Topsoil excavation		-$4.1M	
Sub-Total		**$624.8M**	
Adjustment from 1Q13 to 1Q16, 10% per annum		$187.4M	
Sub-Total	**$812.2M**	**$812.2M**	**$812.2M**
Estimate; -15% & +45%	-$121.8M	$0M	+$365.5M
Sub-Total	**$690.4M**	**$812.2M**	**$1,177.7M**
VAT 10.0%	$69.0M	$81.2M	$117.8M
Total (Including VAT)	**$759.4M**	**$893.4M**	**$1,295.5M**

Table 37 Revised operational costs of the Orkhon-Gobi water transfer scheme Alternative C

Operational Cost (annual)	Confidence level		
	Lower	Medium	Upper
Capex (Excluding VAT)	**$690.4M**	**$812.2M**	**$1,177.7M**
Operational Expenditure (annual)			
Salary	$3.3M	$3.3M	$3.3M
Operational Vehicles	$0.3M	$0.3M	$0.3M
Social insurance fee	$0.4M	$0.4M	$0.4M
Electricity	$33.9M	$33.9M	$33.9M
Communication	$0.1M	$0.1M	$0.1M
Maintenance 0.5% of Capex	$3.4M	$4.4M	$5.9M
Other	$2.6M	$2.6M	$2.6M
Water Resource Fee	$3.4M	$3.4M	$3.4M
Sub-Total	**$47.4M**	**$48.1M**	**$49.9M**
Depreciation 2.5% (40years)	$17.3M	$20.3M	$29.4M
Total Operational Cost	**$64.7M**	**$68.4M**	**$79.3M**

A.6. Methodology on assessment framework

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.

- Semi-qualitative criteria: criteria for which there is no quantitative information available or estimations cannot be performed based on literature review, but values are assigned focusing on presenting available evidence on the impacts and using the outcomes of consultation activities.

- Qualitative assessment: there is neither quantitative information nor enough detailed information to assign semi-qualitative values. The assessment is focused on presenting diverging and limited evidence on the impacts on other water users and other recipients.

Criteria	QT	Semi-QL	QL	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 • The CE ratio is then converted into semi-qualitative values to be used in the ranking of technological alternatives. Values have been established from 1 to 4; being 1 the most cost effective option and 4 the less cost effective one. Values: <-14:1; -14-0:2; 0-10:3; >10:4 (if water savings are negative, 4 is assumed for comparison)
Potential impact of an increase in the Water Abstraction Fee			★	• It focuses on presenting available evidence in the report on the impacts of the increase in the water abstraction fee on the planned investments using the outcomes of consultation activities. It is a qualitative assessment not included for assessment purposes.
Impacts on recreation and (eco-) tourism			★	• It focuses on presenting diverging and limited evidence on the impacts on eco-tourism and recreation. Quantitative information is not available at a project level, thus it is a qualitative assessment not included for assessment purposes in a comprehensive way.
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.

Criteria	QT	Semi-QL	QL	Description
				• These damage costs were converted into semi-qualitative values, which were assigned to the reduced health impact of the different technological alternatives. Values have been established from 1 to 4; being 1 the biggest reduction in health impacts and 4 the smallest impact reduction: <-18,500:1; -18,500-0:2; 0-500,000:3; >500,000:4.
Employment		★		• Employment values are either obtained from project specific information or are estimated based on the installed capacity or the investment and employment multipliers for the Mongolian economy. • Values ranging from 1 to 4 are then assigned, being 1 the projects, which are more employment intensive and 4 projects less employment intensive. Values: >2,400:1; 2,400-500:2; 500-400:3; <400:4
Induced investment and growth			★	• Impact of investments associated with different project alternatives on investment and growth should be expressed in monetary terms, per project. However multipliers for most technologies are not available.
Impact on available water quantity		★		• It focuses on presenting available evidence on the impacts of different project alternatives on water availability for environmental needs. • Values are assigned as follows: not relevant, no impact: 1; low relevance; low impact: 2; relevant, medium impact: 3; high relevance high impact: 4
Chemical pollution of water and land		★		• It focuses on presenting available evidence on the impacts of different project alternatives on water quality for environmental needs. It includes chemical and wastes affecting water quality. • Values are assigned as follows: not relevant, no impact: 1; low relevance; low impact: 2; relevant, medium impact: 3; high relevance high impact: 4
Thermal pollution of water and land		★		• Discharges of cooling waters associated with alternative projects are expressed in m^3 of wastewater per year per project alternative. • Values are assigned as follows: not relevant, no impact: 1; low relevance; low impact: 2; relevant, medium impact: 3; high relevance high impact: 4
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 CO2 and N2O of coal normalized to kWh of electricity produced were used, to get a monetised value (USD). • These damage costs were converted into semi-qualitative values, which were assigned to the reduced damages of the different technological alternatives. Values have been established from 1 to 4; being 1 the biggest reduction in damages and 4 the smallest: <-2,250: 1; -2,205-0: 2; 0-69,000: 3; >69,000: 4
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): NH3 (0.0988 g/t), Non-methane Hydrocarbons, including VOCs (0.21 g/t), NOX (3.35 g/t) and SO2 (6.7 g/t). Coefficients of unit-monetized damages on biodiversity (vegetation, fauna) were used for NH3, Non-methane Hydrocarbons, including VOCs, NOX and SO2.

Criteria	QT	Semi-QL	QL	Description
				• These damage costs were converted into semi-qualitative values, which were assigned to the reduced damages of the different technological alternatives. Values have been established from 1 to 4; being 1 the biggest reduction in damages and 4 the smallest: <-11,800: 1; -11,800-0: 2; 0-356,000: 3; >356,000: 4
Access to and affordability of water services			★	• The assessment focuses on presenting available evidence regarding potential contribution of different project alternatives to an improved water access and resulting impact on affordability of these services. It is a qualitative assessment not included for assessment purposes.
Access to and affordability of energy services			★	• The assessment focuses on presenting available evidence regarding potential contribution of different project alternatives to an improved domestic energy supply and resulting impact on affordability of these services due implementation of water related investments. It is a qualitative assessment not included for assessment purposes.
Impacts on human health from improved access to water and electricity			★	• The assessment focuses on presenting available evidence regarding potential contribution of improved water and energy services provision on human health and improved comfort. It is a qualitative assessment not included for assessment purposes.

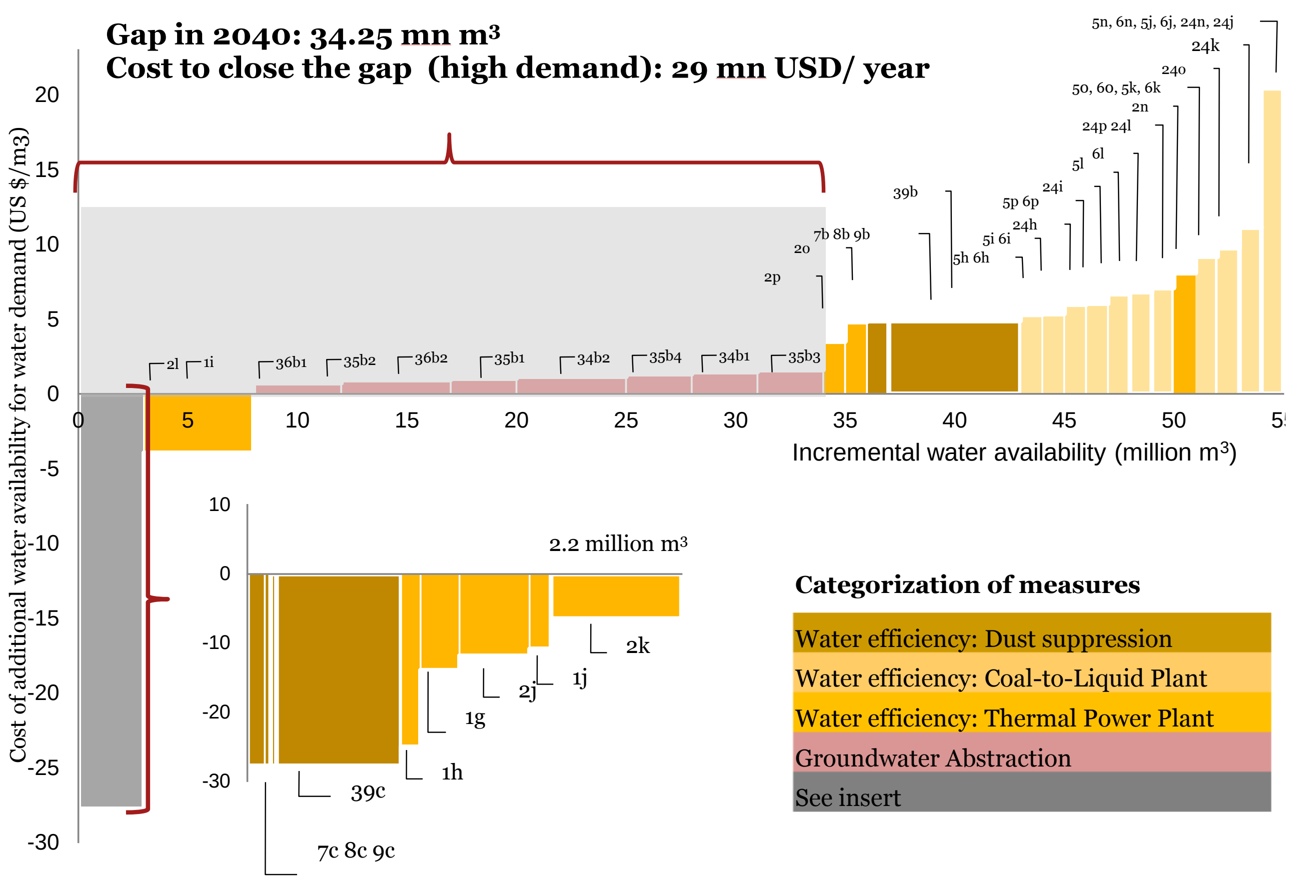
A.7. Financial cost curves

A.7.1. Financial cost curves – Nyalga Shivee Ovoo region

The Incremental costs of closing low and medium water demand scenario gaps in Nyalga Shivee Ovoo are about 16 mn USD/ year and about 29 mn USD/year for closing high water demand scenario gap until 2040. In the low and medium scenario, 26 mn m^3 of water are made available to close the low gap of 21.2 mn m^3 and medium gap of 23 mn m^3. In the high scenario, 37 mn m^3 of water are made available to close the gap of 34.25 mn m^3 in 2040.

Figure 34 below shows the financial cost curve for Nyalga Shivee Ovoo region. A detailed list of all measures underlying the cost curve can be found in *Annex A.8.1*. Please note that in some cases multiple measures are summarized for projects.

Figure 34 Nyalga Shivee Ovoo – 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. Looking at the cost curve above, it becomes evident that a number of cost-effective technological alternatives relate to the same plant or sites. For instance, four technological alternatives for the Thermal Power Plant 270 MW (ID #1) are ranking high in terms of their cost-effectiveness including 1h, 1g, 1i and 1j 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 Circulating fluidised bed (CFB) boilers, Cooling Water Treatment, Cooling Water and Boiler Water Blowdown Reuse (baseline) to dry/air cooled cooling system with CFB boilers and Boiler Water Blowdown Reuse (alternative 1j). 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 1j alternative against the baseline (as opposed to its previous alternative, 1i).

Therefore, *Table 38* 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.8.1.

Table 38 Nyalga Shivee Ovoo - 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)
1	7c	Shivee Ovoo Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,551,076	1,542,661	0.95	-27.80
2	8c	Tugrug Nuur Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	517,026	514,221	0.32	-27.80
3	9c	Booroljuutiin Tal Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	517,026	514,221	0.32	-27.80
4	39c	Other Mines NSO	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	10,340,502	10,284,405	6.32	-27.80
5, 6, 8, 11	1 g, h, i, j	TPP Shivee Ovoo 270 MW	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Dry/Air Cooled, Circulating Fluidized Bed Boilers, Boiler Water Blowdown Reuse	5,439,601	-3,918,516	0.71	-25.05 to – 3.96
8, 9, 10	2j, k, l	TPP Shivee Ovoo 750 MW	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating Fluidized Bed Boilers, dry Flue Gas Desulphurization	18,405,625	-4,292,083	2.95	-11.86 to – 4.70
12	36b1	Borefield in Target I - Booroljuutiin Tal	NA	Development of Remote Borefields in Target Areas (without storage reservoir) delivered to	3,457,597	3,457,597	4.73	0.73

Rank	ID	Name - Project title	Baseline technology	Complete Technology Description	Total cost (USD, EAC)	Incremental costs (USD, EAC against baseline)	Incremental water availability (mn m3/year, against baseline)	Cost Effectiveness Ratio (USD/ m3)
				Booroljuutiin Taal				
13	35b2	Borefield in Target F – Tugrug Nuur	NA	Development of Remote Borefields in Target Areas (without stage reservoir) delivered to Tugrug Nuur	3,468,614	3,468,614	4.73	0.73
14	36b2	Borefield in Target J - Booroljuutiin Tal	NA	Development of Remote Borefields in Target Areas (without storage reservoir) delivered to Booroljuutiin Taal	4,485,555	4,485,555	4.73	0.95
Sub-total - low (21.2 mn m3) and medium (23 mn m3) gaps					**48,182,622**	**16,056,675**	**26**	
15	35b1	Borefield in Target E - TN	NA	Development of Remote Borefields in Target Areas (without stage reservoir) delivered to Tugrug Nuur	3,280,479	3,280,479	3.15	1.04
16	34b2	Borefield in Target C – Shivee Ovoo	NA	Development of Remote Borefields in Target Areas (without storage reservoir) delivered to Shivee Ovoo	5,457,580	5,457,580	4.73	1.15
17	35b4	Borefield in Target H – Tugrug Nuur	NA	Development of Remote Borefields in Target Areas (without stage reservoir) delivered to Tugrug Nuur	4,197,420	4,197,420	3.15	1.33
Total (high gap – 34.25 mn m3)					**61,118,101**	**28,992,154**	**37**	

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 Nyalga Shivee Ovoo region (i.e. disregarding the costs of baseline project alternatives) are about 48 mn USD/ year for low and medium water demand scenarios and 61 mn USD/ year for high water demand scenario.

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

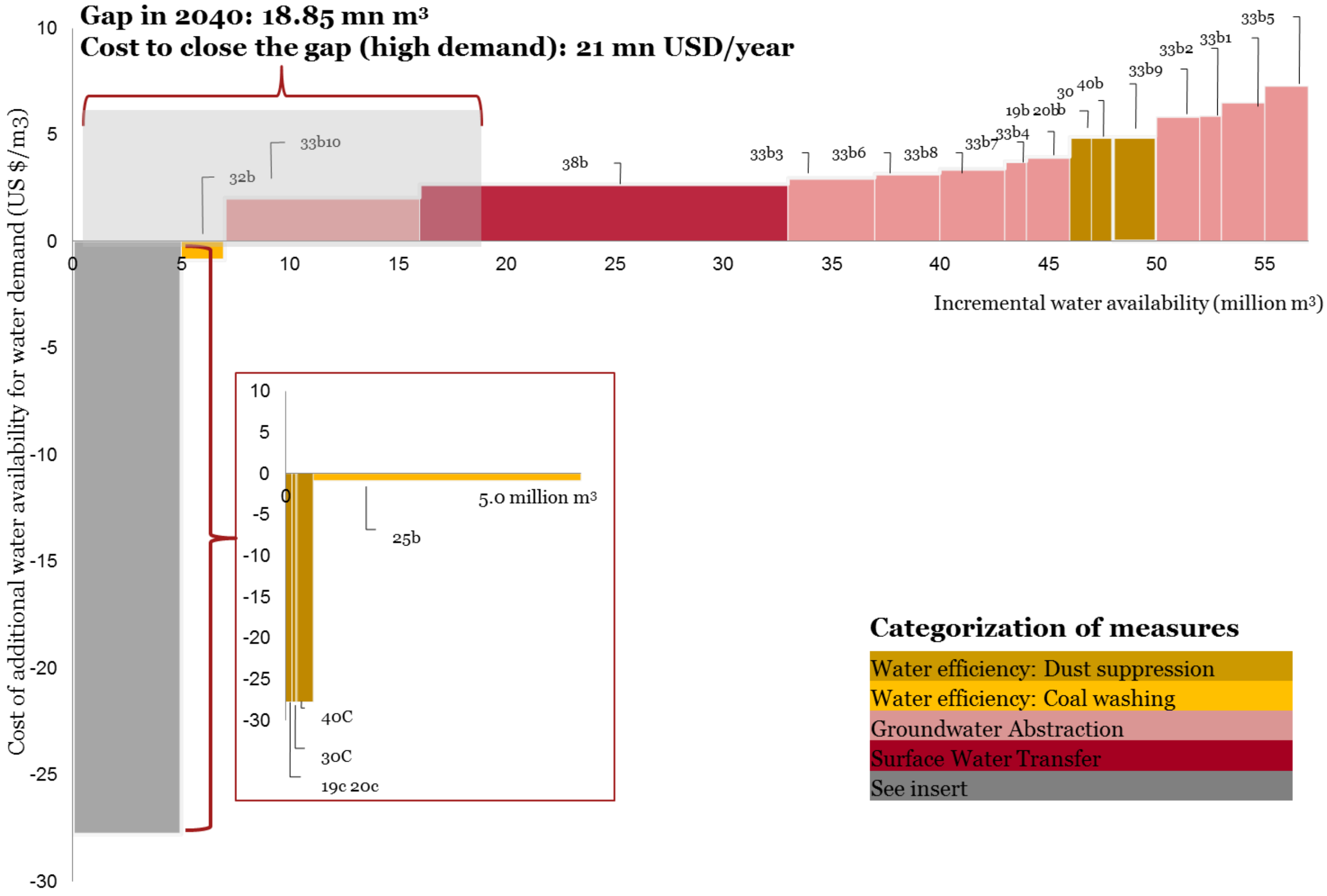
- **Dust suppression with calcium chloride** in Nyalga Shivee Ovoo region is the most cost-effective alternative with a cost-effectiveness ratio of -27.8 USD/m^3 (i.e. suggesting financial savings alongside water savings) and total cumulative water availability (i.e. assessed against baseline dust suppression technology employed at each mine) of 7.9 mn m^3/year.
- Alternatives related to installation of **hybrid and dry/air cooled cooling systems** for TPPs also demonstrate negative cost-effectiveness ratios ranging from -25.05 USD/m^3 to -3.96 USD/m^3. Cumulatively, these measures add 3.7 mn m^3 of water in Nyalga Shivee Ovoo (in comparison to baseline technologies installed at each affected TPP).
- New **groundwater abstraction boreholes** have significant water augmenting potential of 31.5 mn m^3 per year with cost-effectiveness ratios ranging from 0.73 USD/m^3 to 1.61 USD/m^3 (See Appendix A.7.1).
- **Water efficiency measures at CTL plants** show relatively poorer cost-effectiveness ratios ranging from 5.30 USD/m^3 to 20.45 USD/m^3.

A.7.2. Financial cost curves – Tavan Tolgoi region

There is no gap anticipated under the low water demand scenario. The Incremental costs of closing medium and high water demand scenario gaps in Tavan Tolgoi region are about 4 mn USD/year and 21 mn USD/year respectively. In the medium scenario, 9.3 mn m³ of water are made available to close the gap of 6.21 mn m³. In the high scenario, 21 mn m³ of water are made available to close the gap of 18.85 mn m³ in 2040.

Figure 35 below shows the financial cost curve for Tavan Tolgoi region. A detailed list of all measures underlying the cost curve can be found in Annex *A.8.2*. Please note that in some cases multiple measures are summarized for projects.

Figure 35 Tavan Tolgoi – Financial cost curve



Looking at the cost curve above, a number of cost-effective technological alternatives relate to the same sites as relatively less cost-effective. For instance, four top cost-effective technological alternatives (19c, 20c, 30c and 40c) relate to the use of calcium chloride for dust suppression in comparison to the use of organic binders. In practice, one would not first invest in using organic binders for dust suppression to then switch to using calcium chloride. A step change would be implemented going from using water for dust suppression (baseline) to using calcium chloride (options c) instead. 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 19c, 20c, 30c and 40c alternatives against the baseline (as opposed to their previous alternative, 19b, 20b, 30b and 40b).
Therefore, *Table 39* that lists prioritized solutions accounts for such *step changes* in technologies and presents IC 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.8.2.

Table 39 Tavan Tolgoi - Prioritized list of solutions (financial criteria)

Rank	ID	Name - Project title	Baseline technology	Complete Technology Description	Total cost (USD, Equivalent Annual Costs)	Incremental costs (USD, EAC against baseline)	Incremental water availability (mn m³/year, against baseline)	Cost Effectiveness Ratio (USD/ m³)
1	19c	Erdenes Tavan Tolgoi Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,874,243	1,864,075	1.15	-27.80
2	20c	Ukhaa Khudag Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,185,022	1,178,593	0.72	-27.80
3	30c	Tavan Tolgoi JSC Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	530,911	528,031	0.32	-27.80
4	40c	Other Mines TT	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	4,142,551	4,120,078	2.53	-27.80
5	25b	Coal Washing ETT	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	3,674,368	-4,034,498	4.54	-0.89
Sub-total (medium gap – 6.21 mn m³)					**11,407,095**	**3,656,279**	**9.3**	
6	32b	Coal Washing - Mongolian Mining Co.	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	1,837,184	-2,017,249	2.27	-0.89
7	33b 10	Borefield in Target J1+J2 – Tavan Tolgoi	NA	Development of Remote Borefields in Target Areas (without storage reservoir) delivered to Talvan Tolgoi	19,382,043	19,382,043	9.46	2.05
Total **(high gap – 18.85 mn m3)**					**32,626,322**	**21,021,073**	**21**	

Total costs of implementing these measures in Tavan Tolgoi (i.e. disregarding the costs of baseline project alternatives) region to close the gap are about 11 mn USD/year and 33 mn USD/ year for medium and high water demand scenarios respectively.

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

- **Dust suppression with calcium chloride** in Tavan Tolgoi and Ukhaa Khudag mines is the most cost-effective alternative (with a cost-effectiveness ratio of -27.8 USD/m³, i.e. suggesting financial savings alongside water savings) and total increased water availability (i.e. assessed against baseline dust suppression technology employed at each mine) of 4.7 mn m³ per year.

- **Dry coal cleaning technology** for all **coal washing plants** also demonstrates negative cost-effectiveness ratio (i.e. financial savings alongside water savings) of -0.89 USD/m³ and total cumulative water availability (i.e. assessed against baseline coal washing technology employed at each plant) of 6.8 mn m³ per year.

- New **groundwater abstraction boreholes** show significant water augmenting potential to close the gap (total of 28.4 mn m³). As cost-effectiveness ratios range from 2.05 USD/m³ to 7.28 USD/m³ most cost-effective borefields should be preferred, leading to increased water availability of 9.5 mn m³ (See Appendix A.7.2).

- Finally, **Orkhon-Gobi water transfer project** has a water augmentation potential of 17.2 mn m^3 and CE ratio of 2.68 USD/m^3. As implementation of relatively more cost-effective alternatives is sufficient for closing the gap in Tavan Tolgoi region, Orkhon-Gobi water transfer project falls outside the suggested solutions to close the gap in Tavan Tolgoi. The total costs of constructing the Orkhon-Gobi water transfer amount to 212 mn USD/ year, while the apportioned share of the costs only related to the water share for Tavan Tolgoi region amount to 46 mn USD/ year.

A.7.3. Discussion on cost curves: Financial versus holistic cost curves

The integration of economic (human health impacts) and environmental (air quality and climate change, biodiversity and habitats impacts) criteria in the assessment (holistic cost curve) when compared to the purely financial cost curve, has resulted in some changes in the prioritization of measures in both regions.

Most changes relate to a relative lower cost-effectiveness ratio, while only few changes in the sequence of the prioritisation were 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.

In particular:

- The most substantial change associated with the consideration of economic and environmental criteria in addition to financial criteria appeared in Nyalga Shivee Ovoo region, where the implementation of water efficiency measures at **Coal to Liquid Plants** demonstrated significantly reduced cost-effectiveness ratios (from 5.3- 20.5 USD/m^3 to -0.03 -0.01 USD/m^3) after consideration of potential health impacts (estimated on the basis of energy inputs for water supply to the different projects). This change in the ratios resulted in these alternative options shifting down the cost curve in front of new groundwater abstraction.

- Overall, new groundwater abstraction borefields showed significant water augmenting potential with some of the new **groundwater abstraction** projects, such as borefields planned for Tugrug Nuur, Booroljuutiin Tal or Tavan Tolgoi, showing relatively good cost-effectiveness ratios. The financial cost-effectiveness ratios ranged from 0.73USD/m^3 to 1.61 USD/m^3 in Nyalga Shivee Ovoo and from 2.05 USD/m^3 to 7.28 USD/m^3 in Tavan Tolgoi. When economic and environmental criteria have been considered groundwater extraction showed a poorer performance (due to indirect environmental costs associated with energy inputs to make water available). While in absolute terms the ratios did improve (ranging from 0.20 USD/m^3 to 0.38 USD/m^3 in Nyalga Shivee Ovoo), other alternatives such as water efficiency measures at Coal to Liquid Plants ranked relatively higher than new groundwater abstraction projects. However, water augmentation measures remain vital for closing the gaps under high water demand scenarios in both regions as the sole implementation of (relatively better scoring) water efficiency measures would not be sufficient to close the gap.

- **Dust suppression with calcium chloride** in Nyalga Shivee Ovoo and Tavan Tolgoi regions continued to be the best value alternative (with a cost-effectiveness ratio of -27.8 USD/m^3 and total incremental (i.e. against the previous technological alternative) water availability of 0.8 mn m^3/year and 1.0 mn m^3/year respectively. Consideration of human health and environmental impacts results in a decrease of cost effectiveness ratio to -5.6 USD/m^3m. Furthermore, cumulative, i.e. contributing to closing the gap, water availability that is assessed against baseline dust suppression technology employed at each mine is 7.9 mn m^3/year in Nyalga Shivee Ovoo and 4.7 mn m^3/year in Tavan Tolgoi region.

- Water investments for cooling processes in thermal power generation showed a remarkable potential to increase water use efficiency whilst saving money. In Nyalga Shivee Ovoo alternatives related to installation of **hybrid and dry/air cooled cooling systems for Thermal Power Plants** also demonstrated negative cost-effectiveness ratios (i.e. financial savings). Although part of the relative advantage of dry against wet cooling systems (higher upfront capital costs but lower operational costs in the former) is partially outweighed due to their lower energy efficiency, calling for specific analysis of the water-energy nexus informs sound investments. Needless to say that this analysis is contingent on the evolution of the price of inputs (thermal coal) and outputs (power). Cumulative water availability associated with these technological alternatives is 3.7 mn m^3/year in Nyalga Shivee Ovoo (in comparison to baseline technology installed at each affected Thermal Power Plant).

- In Tavan Tolgoi region, moving from coal washing with 60% water reuse to **dry coal cleaning technology** for all **coal washing plants that** demonstrated good levels of cost effectiveness (with a cost-effectiveness ratio decreasing from -0.89 to -0.30 USD/m^3), resulted in cumulative water availability of 6.8 mn m^3/year.

- Furthermore, in Tavan Tolgoi region, **Orkhon-Gobi water transfer project** has a water augmentation potential of 17.2 mn m^3/year. The financial cost effectiveness ratio of 2.68 USD/m^3 changes to 0.79 USD/m^3 when economic and environmental criteria are considered. The results of the assessment suggest that after considering relatively more cost-effective alternatives, Orkhon-Gobi water transfer project falls outside the closing gap effort in Tavan Tolgoi due to the option being relatively less appealing than a number of water efficiency and new groundwater abstraction projects.

- When considering **total and incremental costs** (IC) of closing water supply and demand gaps under low, medium and high water demand scenarios in Nyalga Shivee Ovoo region, the changes to the prioritized list of technological alternatives results in an increase in marginal and total costs of closing the gap package. In particular, ICs of closing high water demand scenario gap increase from 29 mn USD/year to about 33 mn USD/year. Similarly, total costs of implementing of these measures increase from 61 mn USD/year to 74 mn USD/year for high water demand scenario.

- In Tavan Tolgoi, 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 high water demand scenario. In particular, the IC of closing high water demand scenario gap are about 21 mn USD/year while total costs of these measures are about 33 mn USD/year.

A.8. Detailed information on measures illustrated in cost curves

A.8.1. Nyalga Shivee Ovoo – Financial Cost Curves

Table 40 Cost effectiveness of measures to increase water availability in Nyalga Shivee Ovoo (financial, against previous alternative)

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
1	7c	MS	Shivee Ovoo Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,551,076	-2,636,829	94,854	-27.80	1,542,661	948,544
2	8c	MS	Tugrug Nuur Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	517,026	-878,944	31,618	-27.80	514,221	316,182
3	9c	MS	Booroljuutiin Tal Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	517,026	-878,944	31,618	-27.80	514,221	316,182
4	39c	MS	Other Mines NSO	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	10,340,502	-17,578,853	632,363	-27.80	10,284,405	6,323,625
5	1h	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, CFB boilers- Boiler Water Blowdown Reuse	6,626,025	-2,732,091	109,058	-25.05	-2,732,091	304,921
6	1g	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse,	Hybrid (Dry/Wet) Cooling, CFB boilers, Cooling Water Treatment - Cooling Water Blowdown Reuse	6,626,025	-2,732,091	195,863	-13.95	-2,732,091	195,863

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
				Boiler Water Blowdown Reuse							
7	2j	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	18,405,625	-4,292,083	361,866	-11.86	- 4,292,083	1,373,625
8	1j	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Dry/Air Cooled, CFB boilers - Boiler Water Blowdown Reuse	5,439,601	-1,186,424	109,058	-10.88	-3,918,516	713,520
9	2k	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Dry FGD	18,405,625	-4,292,083	664,190	-6.46	- 4,292,083	2,037,814
10	2l	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	18,405,625	-4,292,083	913,850	-4.70	- 4,292,083	2,951,664

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
11	1i	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Dry/Air Cooled - Circulating fluidized bed (CFB) boilers	5,439,601	-1,186,424	299,541	-3.96	-3,918,516	604,462
12	36b1	GW	Borefield in Target I - BT	NA	New groundwater abstraction	3,457,597	3,457,597	4,730,400	0.73	3,457,597	4,730,400
13	35b2	GW	Borefield in Target F - TN	NA	New groundwater abstraction	3,468,614	3,468,614	4,730,400	0.73	3,468,614	4,730,400
14	36b2	GW	Borefield in Target J - BT	NA	New groundwater abstraction	4,485,555	4,485,555	4,730,400	0.95	4,485,555	4,730,400
15	35b1	GW	Borefield in Target E - TN	NA	New groundwater abstraction	3,280,479	3,280,479	3,153,600	1.04	3,280,479	3,153,600
16	34b2	GW	Borefield in Target C - SO	NA	New groundwater abstraction	5,457,580	5,457,580	4,730,400	1.15	5,457,580	4,730,400
17	35b4	GW	Borefield in Target H - TN	NA	New groundwater abstraction	4,197,420	4,197,420	3,153,600	1.33	4,197,420	3,153,600
18	34b1	GW	Borefield in Target B - SO	NA	New groundwater abstraction	4,671,992	4,671,992	3,153,600	1.48	4,671,992	3,153,600
19	35b3	GW	Borefield in Target G - TN	NA	New groundwater abstraction	5,082,160	5,082,160	3,153,600	1.61	5,082,160	3,153,600
20	2p	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	21,612,656	3,207,031	913,850	3.51	-1,085,051	4,307,436

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
21	20	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Dry/Air Cooled, Boiler Water Blowdown Reuse - Dry FGD	21,612,656	3,207,031	664,190	4.83	-1,085,051	3,393,586
22	7b	MS	Shivee Ovoo Mine	Use of water for dust suppression	Use of organic binders for dust suppression	4,187,905	4,179,491	853,690	4.90	4,179,491	853,690
23	8b	MS	Tugrug Nuur Mine	Use of water for dust suppression	Use of organic binders for dust suppression	1,395,970	1,393,165	284,564	4.90	1,393,165	284,564
24	9b	MS	Booroljuutiin Tal Mine	Use of water for dust suppression	Use of organic binders for dust suppression	1,395,970	1,393,165	284,564	4.90	1,393,165	284,564
25	39b	MS	Other Mines NSO	Use of water for dust suppression	Use of organic binders for dust suppression	27,919,355	27,863,258	5,691,263	4.90	27,863,258	5,691,263
26	5h	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD - Cooling Water Treatment	10,391,951	6,247,140	1,179,033	5.30	6,247,140	5,310,769
27	6h	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD - Cooling Water Treatment	4,723,614	2,839,609	530,565	5.35	2,839,609	2,389,846
28	5i	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment - Cooling Water Blowdown Reuse	10,391,951	6,247,140	1,044,256	5.98	6,247,140	6,355,025

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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	6i	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment -Cooling Water Blowdown Reuse	4,723,614	2,839,609	469,915	6.04	2,839,609	2,859,761
30	24h	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD - Cooling Water Treatment	5,668,337	3,407,531	563,287	6.05	3,407,531	2,537,239
31	5p	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse-Circulating fluidized bed boilers	16,453,389	6,061,438	907,912	6.68	12,308,578	9,517,122
32	6p	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	7,478,813	2,755,199	408,561	6.74	5,594,808	4,282,705
33	24i	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment - Cooling Water Blowdown Reuse	5,668,337	3,407,531	498,897	6.83	3,407,531	3,036,136
34	5l	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	10,391,951	6,247,140	880,807	7.09	6,247,140	8,224,788

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
35	6l	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	4,723,614	2,839,609	396,363	7.16	2,839,609	3,701,155
36	24p	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	8,974,576	3,306,239	433,758	7.62	6,713,770	4,546,839
37	24l	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	5,668,337	3,407,531	420,809	8.10	3,407,531	3,929,422
38	2n	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	21,612,656	3,207,031	361,866	8.86	-1,085,051	2,729,396
39	50	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Boiler Water Blowdown Reuse - Dry FGD	16,453,389	6,061,438	659,874	9.19	12,308,578	8,609,209

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
40	60	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Boiler Water Blowdown Reuse - Dry FGD	7,478,813	2,755,199	296,943	9.28	5,594,808	3,874,144
41	5k	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Dry FGD	10,391,951	6,247,140	640,174	9.76	6,247,140	7,343,981
42	6k	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Dry FGD	4,723,614	2,839,609	288,078	9.86	2,839,609	3,304,791
43	240	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Boiler Water Blowdown Reuse - Dry FGD	8,974,576	3,306,239	315,257	10.49	6,713,770	4,113,081
44	24k	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Dry FGD	5,668,337	3,407,531	305,846	11.14	3,407,531	3,508,613
45	5n	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	16,453,389	6,061,438	359,515	16.86	12,308,578	7,949,335

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
46	6n	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	7,478,813	2,755,199	161,782	17.03	5,594,808	3,577,201
47	5j	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	10,391,951	6,247,140	348,781	17.91	6,247,140	6,703,807
48	6j	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	4,723,614	2,839,609	156,952	18.09	2,839,609	3,016,713
49	24n	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	8,974,576	3,306,239	171,759	19.25	6,713,770	3,797,823
50	24j	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	5,668,337	3,407,531	166,632	20.45	3,407,531	3,202,768
				Total				55,639,622			

A.8.2. Tavan Tolgoi – Financial Cost Curve

Table 41 Cost effectiveness of measures to increase water availability in Tavan Tolgoi (financial, against previous alternative)

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
1	19c	MS	Tavan Tolgoi Mine 1	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,874,243	-3,186,212	114,617	-27.80	1,864,075	1,146,173
2	20c	MS	Ukhaa Khudag Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	1,185,022	-2,014,537	72,469	-27.80	1,178,593	724,688
3	30c	MS	Tavan Tolgoi Mine 2	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	530,911	-902,550	32,467	-27.80	528,031	324,673
4	40c	MS	Other Mines TT	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	4,142,551	-7,042,336	253,333	-27.80	4,120,078	2,533,333
5	25b	CW	Coal Washing 2 - ETT (High)	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	3,674,368	-4,034,498	4,541,184	-0.89	-4,034,498	4,541,184
6	32b	CW	Coal Washing 7 - Mongolian Mining Co. (High)	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	1,837,184	-2,017,249	2,270,592	-0.89	-2,017,249	2,270,592
7	33b10	GW	Borefield in Target J1+J2 - TT	NA	New groundwater abstraction	19,382,043	19,382,043	9,460,800	2.05	19,382,043	9,460,800
8	38b	WT	Orhon-Gobi Project	NA	Water transfer to Talvai-Tolgoi mines	46,167,402	46,167,402	17,198,892	2.68	46,167,402	17,198,892
9	33b3	GW	Borefield in Target C - TT	NA	New groundwater abstraction	9,400,765	9,400,765	3,153,600	2.98	9,400,765	3,153,600
10	33b6	GW	Borefield in Target F - TT	NA	New groundwater abstraction	10,041,437	10,041,437	3,153,600	3.18	10,041,437	3,153,600

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
11	33b8	GW	Borefield in Target H - TT	NA	New groundwater abstraction	10,737,194	10,737,194	3,153,600	3.40	10,737,194	3,153,600
12	33b7	GW	Borefield in Target G - TT	NA	New groundwater abstraction	5,925,378	5,925,378	1,576,800	3.76	5,925,378	1,576,800
13	33b4	GW	Borefield in Target D - TT	NA	New groundwater abstraction	6,245,714	6,245,714	1,576,800	3.96	6,245,714	1,576,800
14	19b	MS	Tavan Tolgoi Mine 1	Use of water for dust suppression	Use of organic binders for dust suppression	5,060,455	5,050,287	1,031,556	4.90	5,050,287	1,031,556
15	20b	MS	Ukhaa Khudag Mine	Use of water for dust suppression	Use of organic binders for dust suppression	3,199,558	3,193,130	652,219	4.90	3,193,130	652,219
16	30b	MS	Tavan Tolgoi Mine 2	Use of water for dust suppression	Use of organic binders for dust suppression	1,433,461	1,430,581	292,206	4.90	1,430,581	292,206
17	40b	MS	Other Mines TT	Use of water for dust suppression	Use of organic binders for dust suppression	11,184,887	11,162,414	2,280,000	4.90	11,162,414	2,280,000
18	33b9	GW	Borefield in Target I - TT	NA	New groundwater abstraction	9,209,252	9,209,252	1,576,800	5.84	9,209,252	1,576,800
19	33b2	GW	Borefield in Target B - TT	NA	New groundwater abstraction	9,275,353	9,275,353	1,576,800	5.88	9,275,353	1,576,800
20	33b1	GW	Borefield in Target A - TT	NA	New groundwater abstraction	10,249,076	10,249,076	1,576,800	6.50	10,249,076	1,576,800
21	33b5	GW	Borefield in Target E - TT	NA	New groundwater abstraction	11,475,336	11,475,336	1,576,800	7.28	11,475,336	1,576,800
			Total					57,121,935			

A.8.3. Nyalga Shivee Ovoo – Holistic Cost Curves

Table 42 Cost effectiveness of measures to increase water availability in Nyalga Shivee Ovoo (financial, economic and environmental criteria against previous alternative)

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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	7c	MS	Shivee Ovoo Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	314,089	-529,303	94,854	-5.58	1,551,076	1,542,661	948,544
2	8c	MS	Tugrug Nuur Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	104,697	-176,434	31,618	-5.58	517,026	514,221	316,182
3	9c	MS	Booroljuutiin Tal Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	104,697	-176,434	31,618	-5.58	517,026	514,221	316,182
4	39c	MS	Other Mines NSO	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	2,093,928	-3,528,685	632,363	-5.58	10,340,502	10,284,405	6,323,625
5	1h	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, CFB boiler -Boiler Water Blowdown Reuse	1,336,403	-547,911	109,058	-5.02	6,626,025	-2,732,091	304,921
6	1g	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse,	Hybrid (Dry/Wet) Cooling, Circulating fluidized bed boilers, Cooling Water Treatment -	1,336,403	-547,911	195,863	-2.80	6,626,025	-2,732,091	195,863

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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 Water Blowdown Reuse	Cooling Water Blowdown Reuse							
7	2j	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	3,712,231	-862,564	361,866	-2.38	18,405,625	-4,292,083	1,373,625
8	1j	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Dry/Air Cooled, Circulating fluidized bed boilers - Boiler Water Blowdown Reuse	1,105,837	-230,566	109,058	-2.11	5,439,601	-3,918,516	713,520
9	2k	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Dry FGD	3,712,231	-862,564	664,190	-1.30	18,405,625	-4,292,083	2,037,814
10	2l	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating	3,712,231	-862,564	913,850	-0.94	18,405,625	-4,292,083	2,951,664

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
					fluidized bed boilers							
11	1i	TPP	TPP 1 Shivee Ovoo (270MW)	Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Dry/Air Cooled - Circulating fluidized bed boilers	1,105,837	-230,566	299,541	-0.77	5,439,601	-3,918,516	604,462
12	10b	CTB	CTB Tugrug Nuur	Wet closed circuit cooling	Wet closed circuit cooling, Wet FGD - Cooling Water Treatment	105,178	-705	13,130	-0.05	513,952	-	13,130
13	10c	CTB	CTB Tugrug Nuur	Wet closed circuit cooling	Wet closed circuit cooling, Cooling Water Treatment - Dry FGD	104,973	-204	3,808	-0.05	513,952	-	16,938
14	10d	CTB	CTB Tugrug Nuur	Wet closed circuit cooling	Wet closed circuit cooling, Cooling Water Treatment, Dry FGD -Efficient Sprinklers	104,404	-570	10,611	-0.05	513,952	513,952	27,548
15	5n	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	3,347,683	-9,994	359,515	-0.03	16,453,389	12,308,578	7,949,335
16	5o	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse - Dry FGD	3,329,339	-18,343	659,874	-0.03	16,453,389	12,308,578	8,609,209

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
17	5p	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse -Circulating fluidized bed boilers	3,304,101	-25,238	907,912	-0.03	16,453,389	12,308,578	9,517,122
18	6n	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	1,521,415	-4,497	161,782	-0.03	7,478,813	5,594,808	3,577,201
19	6o	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Boiler Water Blowdown Reuse-Dry FGD	1,513,160	-8,254	296,943	-0.03	7,478,813	5,594,808	3,874,144
20	6p	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	1,501,803	-11,357	408,561	-0.03	7,478,813	5,594,808	4,282,705
21	24n	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	1,822,149	-4,775	171,759	-0.03	8,974,576	6,713,770	3,797,823
22	24o	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Boiler Water Blowdown Reuse - Dry FGD	1,813,386	-8,764	315,257	-0.03	8,974,576	6,713,770	4,113,081
23	24p	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse -Circulating	1,801,328	-12,058	433,758	-0.03	8,974,576	6,713,770	4,546,839

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
					fluidized bed boilers							
24	5h	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD -Cooling Water Treatment	2,137,209	-14,789	1,179,033	-0.01	10,391,951	6,247,140	5,310,769
25	5i	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment - Cooling Water Blowdown Reuse	2,124,110	-13,098	1,044,256	-0.01	10,391,951	6,247,140	6,355,025
26	5j	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	2,119,735	-4,375	348,781	-0.01	10,391,951	6,247,140	6,703,807
27	5k	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Dry FGD	2,111,705	-8,030	640,174	-0.01	10,391,951	6,247,140	7,343,981
28	5l	CTL	CTL Tugrug Nuur	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water	2,100,657	-11,048	880,807	-0.01	10,391,951	6,247,140	8,224,788

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
					Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers							
29	6h	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD - Cooling Water Treatment	971,191	-6,655	530,565	-0.01	4,723,614	2,839,609	2,389,846
30	6i	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment - Cooling Water Blowdown Reuse	965,297	-5,894	469,915	-0.01	4,723,614	2,839,609	2,859,761
31	6j	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	963,328	-1,969	156,952	-0.01	4,723,614	2,839,609	3,016,713
32	6k	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Dry FGD	959,715	-3,613	288,078	-0.01	4,723,614	2,839,609	3,304,791

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
33	6l	CTL	CTL Booroljuutiin Tal	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	954,743	-4,972	396,363	-0.01	4,723,614	2,839,609	3,701,155
34	24h	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD -Cooling Water Treatment,	1,161,768	-7,065	563,287	-0.01	5,668,337	3,407,531	2,537,239
35	24i	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment - Cooling Water Blowdown Reuse	1,155,510	-6,258	498,897	-0.01	5,668,337	3,407,531	3,036,136
36	24j	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse - Boiler Water Blowdown Reuse	1,153,420	-2,090	166,632	-0.01	5,668,337	3,407,531	3,202,768
37	24k	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water	1,149,584	-3,836	305,846	-0.01	5,668,337	3,407,531	3,508,613

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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 - Dry FGD							
38	24l	CTL	CTL Shivee Ovoo	Wet Closed Cycle Recirculating, Wet FGD	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse - Circulating fluidized bed boilers	1,144,306	-5,278	420,809	-0.01	5,668,337	3,407,531	3,929,422
39	36b1	GW	Borefield in Target I - BT	NA	New groundwater abstraction	945,447	945,447	4,730,400	0.20	3,457,597	3,457,597	4,730,400
40	35b2	GW	Borefield in Target F - TN	NA	New groundwater abstraction	947,651	947,651	4,730,400	0.20	3,468,614	3,468,614	4,730,400
41	36b2	GW	Borefield in Target J - BT	NA	New groundwater abstraction	1,151,039	1,151,039	4,730,400	0.24	4,485,555	4,485,555	4,730,400
42	35b1	GW	Borefield in Target E - TN	NA	New groundwater abstraction	825,381	825,381	3,153,600	0.26	3,280,479	3,280,479	3,153,600
43	34b2	GW	Borefield in Target C - SO	NA	New groundwater abstraction	1,345,444	1,345,444	4,730,400	0.28	5,457,580	5,457,580	4,730,400
44	35b4	GW	Borefield in Target H - TN	NA	New groundwater abstraction	1,008,769	1,008,769	3,153,600	0.32	4,197,420	4,197,420	3,153,600
45	34b1	GW	Borefield in Target B - SO	NA	New groundwater abstraction	1,103,684	1,103,684	3,153,600	0.35	4,671,992	4,671,992	3,153,600

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
46	35b3	GW	Borefield in Target G - TN	NA	New groundwater abstraction	1,185,717	1,185,717	3,153,600	0.38	5,082,160	5,082,160	3,153,600
47	2p	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse -Circulating fluidized bed boilers	4,372,301	660,070	913,850	0.72	21,612,656	-1,085,051	4,307,436
48	7b	MS	Shivee Ovoo Mine	Use of water for dust suppression	Use of organic binders for dust suppression	843,392	818,464	853,690	0.96	4,187,905	4,179,491	853,690
49	8b	MS	Tugrug Nuur Mine	Use of water for dust suppression	Use of organic binders for dust suppression	281,131	272,822	284,564	0.96	1,395,970	1,393,165	284,564
50	9b	MS	Booroljuutiin Tal Mine	Use of water for dust suppression	Use of organic binders for dust suppression	281,131	272,822	284,564	0.96	1,395,970	1,393,165	284,564
51	39b	MS	Other Mines NSO	Use of water for dust suppression	Use of organic binders for dust suppression	5,622,613	5,456,426	5,691,263	0.96	27,919,355	27,863,258	5,691,263
52	2o	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse - Dry FGD	4,372,301	660,070	664,190	0.99	21,612,656	-1,085,051	3,393,586
53	2n	TPP	TPP 2 Shivee Ovoo (750MW)	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Dry/Air Cooled, Wet FGD - Boiler Water Blowdown Reuse	4,372,301	660,070	361,866	1.82	21,612,656	-1,085,051	2,729,396

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
				Total				55,667,171				

A.8.4. Tavan Tolgoi – Holistic Cost Curves

Table 43 Cost effectiveness of measures to increase water availability in Tavan Tolgoi (financial, economic and environmental criteria against previous alternative)

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
1	19c	MS	Tavan Tolgoi Mine 1	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	379,530	-639,583	114,617	-5.58	1,874,243	1,864,075	1,146,173
2	20c	MS	Ukhaa Khudag Mine	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	239,964	-404,387	72,469	-5.58	1,185,022	1,178,593	724,688
3	30c	MS	Tavan Tolgoi Mine 2	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	107,508	-181,173	32,467	-5.58	530,911	528,031	324,673
4	40c	MS	Other Mines TT	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	838,857	-1,413,641	253,333	-5.58	4,142,551	4,120,078	2,533,333
5	25b	MS	Coal Washing 2 - ETT (High)	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	734,874	-1,380,028	4,541,184	-0.30	3,674,368	-4,034,498	4,541,184
6	32b	MS	Coal Washing 7 - Mongolian Mining Co. (High)	Coal washing with 60% water reuse	Dry Coal Cleaning Technology	367,437	-690,014	2,270,592	-0.30	1,837,184	-2,017,249	2,270,592

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
7	33b10	MS	Borefield in Target J1+J2 - TT	NA	New groundwater abstraction	4,384,265	4,384,265	9,460,800	0.46	19,382,043	19,382,043	9,460,800
8	33b3	MS	Borefield in Target C - TT	NA	New groundwater abstraction	2,049,438	2,049,438	3,153,600	0.65	9,400,765	9,400,765	3,153,600
9	33b6	MS	Borefield in Target F - TT	NA	New groundwater abstraction	2,177,573	2,177,573	3,153,600	0.69	10,041,437	10,041,437	3,153,600
10	33b8	MS	Borefield in Target H - TT	NA	New groundwater abstraction	2,316,724	2,316,724	3,153,600	0.73	10,737,194	10,737,194	3,153,600
11	38b	MS	Orhon-Gobi Project	NA	Water transfer to Talvai-Tolgoi mines	13,536,614	13,536,614	17,198,892	0.79	46,167,402	46,167,402	17,198,892
12	33b7	MS	Borefield in Target G - TT	NA	New groundwater abstraction	1,269,718	1,269,718	1,576,800	0.81	5,925,378	5,925,378	1,576,800
13	33b4	MS	Borefield in Target D - TT	NA	New groundwater abstraction	1,333,786	1,333,786	1,576,800	0.85	6,245,714	6,245,714	1,576,800
14	19b	MS	Tavan Tolgoi Mine 1	Use of water for dust suppression	Use of organic binders for dust suppression	1,019,113	988,991	1,031,556	0.96	5,060,455	5,050,287	1,031,556
15	20b	MS	Ukhaa Khudag Mine	Use of water for dust suppression	Use of organic binders for dust suppression	644,352	625,306	652,219	0.96	3,199,558	3,193,130	652,219

Rank	ID	Project Type	Project title	Baseline Technology	New measure	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)
16	30b	MS	Tavan Tolgoi Mine 2	Use of water for dust suppression	Use of organic binders for dust suppression	288,681	280,149	292,206	0.96	1,433,461	1,430,581	292,206
17	40b	MS	Other Mines TT	Use of water for dust suppression	Use of organic binders for dust suppression	2,252,498	2,185,921	2,280,000	0.96	11,184,887	11,162,414	2,280,000
18	33b9	MS	Borefield in Target I - TT	NA	New groundwater abstraction	1,926,493	1,926,493	1,576,800	1.22	9,209,252	9,209,252	1,576,800
19	33b2	MS	Borefield in Target B - TT	NA	New groundwater abstraction	1,939,713	1,939,713	1,576,800	1.23	9,275,353	9,275,353	1,576,800
20	33b1	MS	Borefield in Target A - TT	NA	New groundwater abstraction	2,134,458	2,134,458	1,576,800	1.35	10,249,076	10,249,076	1,576,800
21	33b5	MS	Borefield in Target E - TT	NA	New groundwater abstraction	2,379,710	2,379,710	1,576,800	1.51	11,475,336	11,475,336	1,576,800
			Total					57,121,935				

A.7.5. Example of financial and holistic cost-effectiveness ratios calculation

Table 40 Calculation of the financial cost-effectiveness ratio for dust suppression using calcium chloride in Tavan Tolgoi (financial, against previous alternative, i.e. use of organic binders)

ID	Project title	Baseline Technology	New measure	Marginal financial EAC costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	**Financial CE Ratio (USD/ m³)**
19c	Tavan Tolgoi Mine 1	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	- 3,186,212	114,617	**-27.8**

Table 41 Calculation of the holistic cost-effectiveness ratio for dust suppression using calcium chloride in Tavan Tolgoi (financial, economic and environmental criteria against previous alternative, i.e. use of organic binders)

Weights				0.2	0.3	0.5				
ID	Project title	Baseline Technology	New measure	Marginal financial EAC costs, USD (against previous alternative)	Reduced health risk (against previous alternative)	Air quality and climate change impacts (against previous alternative)	Impacts on biodiversity (against previous alternative)	Marginal financial and environmental costs, USD (against previous alternative)	Incremental water availability (m³) (against previous alternative)	**Holistic CE Ratio (USD/ m³)**
19c	Tavan Tolgoi Mine 1	Use of water for dust suppression	Use of Calcium Chloride for dust suppression	- 3,186,212	-3,447	-424	-2,190	- 639,583	114,617	**-5.58**
Adjusted for weights				-637,242	-1,034	-212	-1,095			

Hydro-economic Analysis in Mongolia

Report Supplements 1 & 3 -5

Please note: Report Supplement 2 is available as a separate copy due to the large document size.

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Report Supplement # 1 - Water Demand Estimation & Demand Forecasting

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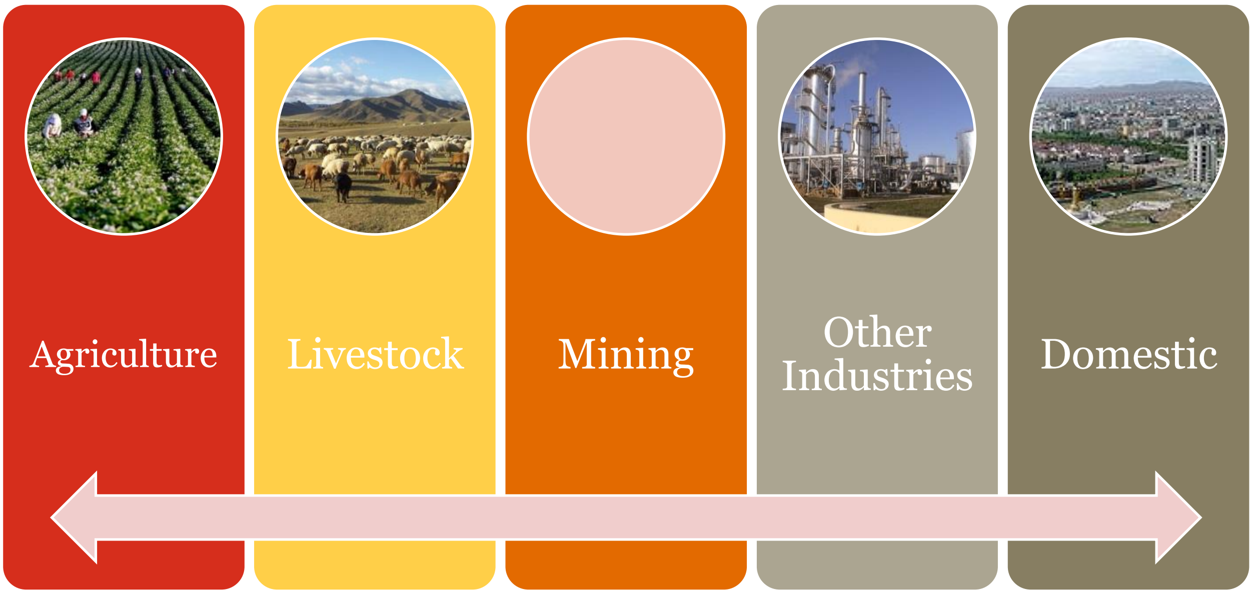
1. Water Demand Estimation & Demand Forecasting

This report covers the demand assessment of water for various sectors in two regions of Mongolia, i.e. Nyalga-Shivee Ovoo and Tavan Tolgoi.

Water demand is calculated for the base line (2015) as well as for the years 2030 and 2040. To allow for a more diversified understanding of future water usage, water demand is estimated for three water demand scenarios: low, medium and high water demand.

Water demand is calculated based on the primary and secondary data collection. In cases in which no direct water usage data was available, water use norms, as outlined in Resolution No A 301, were used. To ensure consistency across various studies on water resource management, water usage scenarios and forecast estimates were applied from the widely accepted Water Demand Handbook (2012) – an outcome of the "Strengthening Integrated Water Resource Management Project"[1] – in cases for which no explicit development plans were available.

The Water demand is forecasted for the following set of sectors:



- Agriculture – including irrigation, horticulture (fruits & vegetables)
- Livestock
- Mining – including mine processing water, dust suppression and drinking water for workers
- Other industries - including manufacturing, construction, energy
- Domestic – including formal and informal water supplies, as well as municipal water usage

The detailed methodology adopted in assessing current and forecasting future water demand is provided in the report. The report is divided into five chapters which cover the methodology adopted in deriving the current demand and future demand in the five sectors mentioned above. The chapters provide the base data, its source and the assumptions considered which form the basis for all forecasting calculations.

For water demand estimation, all suoms within our study area were considered. In case the suom is only partially in the study area, a percentage of the total area was taken while suom centre water demand was only included when located in our study area.

[1]The project was implemented at the Ministry of Environment and Green Development with support from the Government of The Kingdom of the Netherlands. The Water Demand Handbook was prepared by prepared by G. Dolgorsuren, Wim van der Linden and Ch. Puntsagsuren.

2. Agricultural Water Demand

The water demand for agricultural purposes is calculated considering the extent of land being used for cultivating a specific type of crop in each suom/aimag and the normative amount of water required for such category of crop.

$$Agri\ Water\ demand\ \left(^{in\ cubic\ meters}/_{year}\right) = [\ (C1\ X\ W1\ X\ AC1) + (C2\ X\ W2\ X\ AC2) + \cdots\ (C6\ X\ W6\ XAC6)]$$

C1 is the total land under cultivation in hectares for crop 1 in the year 2014 (base year)
W1 is Water usage of Crop 1 as per norm (in cubic meters/hectare)
AC is % of Area Coverage under this study
In this study, we have considered 6 different types of crops which are prominent in the region

Baseline data on agricultural production was either accessed directly from the suom's websites and/ or was verified by contacting the suom officers directly. To estimate the water usage, water norms from Resolution No A 301 were applied. For suoms which are only partially covered in our study area, the percentage of the area coverage is applied to the suom's agricultural water demand. This assumes that the cultivated area is equally distributed across the suom, as more concrete information on the exact location was not available.

The base line data on the extent of land cultivated for various types of crop and % inclusion of rural area under study is below:

(in hectares)

Aimag	Soum	Region	Rapseed	Wheat	Forage	Oats	Potato	Other vegetable	Study Area (%)
Tuv	Arkhust	Central	-	-	-	-	-	-	100%
Tuv	Bayan	Central	-	-	512.00	-	-	-	100%
Tuv	Bayandelger	Central	575.00	640.00	90.00	20.00			25%
Tuv	Bayanjargalan	Central	-	-	-	-	-	-	100%
Tuv	Bayantsagaan	Central	-	-	-	-	-	-	100%
Tuv	Sergelen	Central	-	-	99.00	-	11.00	4.20	66%
Tuv	Erdene	Central	-	-	-	-	-	-	10%
UB city	Bagakhangai	Central	-	-	-	-	2.47	2.16	100%
Govi-sumber	Sumber	Northern	-	-	-	-	2.00	5.00	100%
Govi-sumber	Bayantal	Northern	-	-	-	-	2.00	5.00	100%
Govi-sumber	Shiveegovi	Northern	-	-	-	-	2.00	6.00	100%
Dornogovi	Airag	Northern	-	-	-	-	-	-	50%
Dornogovi	Dalanjargalan	Northern	-	-	-	-	-	-	100%
Dundgovi	Bayanjargalan	Northern	-	-	-	-	-	-	100%
Dundgovi	Govi-Ugtaal	Northern	-	-	-	-	-	-	100%
Dundgovi	Tsagaandelger	Northern	-	-	-	-	-	-	100%
Dundgovi	Ondorshil	Northern	-	-	-	-	-	-	50%
Khentii	Darkhan	Northern	-	-	-	-	8.00	3.00	80%
Umnugovi	Dalanzadgad	Southern	-	-	-	-	-	-	100%
Umnugovi	Khankhongor	Southern	-	-	-	-	-	-	80%
Umnugovi	Bayan-Ovoo	Southern	-	-	-	-		5.00	50%
Umnugovi	Tsogt-Ovoo	Southern	-	-	-	-	-	-	50%
Umnugovi	Tsogttsetsii	Southern	-	-	-	-	-	-	100%

Aimag	Soum	Region	Rapseed	Wheat	Forage	Oats	Potato	Other vegetable	Study Area (%)
Umnugovi	Nomgon	Southern	-	-	-	-	-	-	33%

Considering different types of crops being cultivated, the water required for each type of crop as per the norm is assumed for calculating the demand. The water requirement for crops varies from region to region within Mongolia due to varying climatic conditions. The norm of water consumption[2] for each category of crop for various regions is given below:

(cubic meter/hectare)

Crop Type	Central region	Northern Gobi region	Southern Gobi region
Cereals	2,400	3,000	4,400
Green Fodder	3,300	4,100	4,200
Potatoes	3,000	3,600	4,500
Vegetables	3,200	4,000	4,200
Others	2,900	3,200	3,600

To allow for a more differentiated analysis, agricultural water demand is forecasted in three scenarios. The scenarios are taken from the Water Demand Handbook (MEGDT, 2012). [3] The assumptions for the three scenarios are listed in the table below.

Scenarios →	Low	Low	Medium	Medium	High	High
Time frame →	2010-15	2015-21	2010-15	2015-21	2010-15	2015-21
Growth rates	2.00%	2.00%	7.80%	2.40%	2.8%	2.8%

For the period from 2021-2040, the growth rate of 2015-21 is assumed in the calculations. Based on all the assumptions stated above, the demand for agricultural water is estimated for the following scenarios:

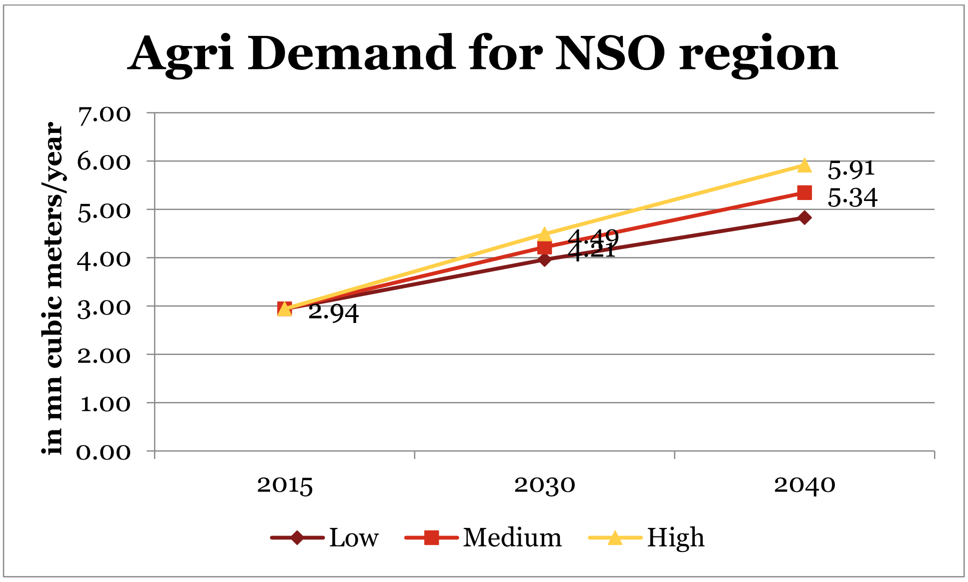
(In million cubic meters/annum)

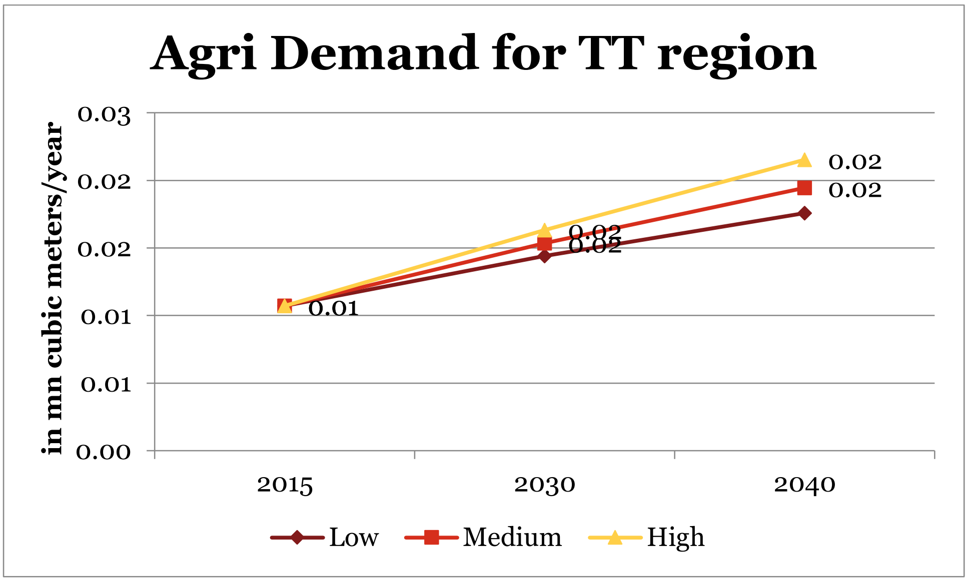
Scenarios →	2015	2030			2040		
Aimag/Suom	Base Case	Low	Medium	High	Low	Medium	High
Dornogovi	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Airag	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dalanjargalan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dundgovi	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Bayanjargalan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Govi-Ugtaal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tsagaandelger	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ondorshil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Govi-sumber	**0.09**	**0.12**	**0.13**	**0.13**	**0.14**	**0.16**	**0.18**
Bayantal	0.03	0.04	0.04	0.04	0.05	0.05	0.06
Shiveegovi	0.03	0.04	0.05	0.05	0.05	0.06	0.06
Sumber	0.03	0.04	0.05	0.05	0.05	0.06	0.06
Khentii	**0.03**	**0.04**	**0.05**	**0.05**	**0.05**	**0.06**	**0.07**

[3] G. Dolgorsuren et al (2012) Water Demand Handbook, page 48

Scenarios →	2015	2030			2040		
Aimag/Suom	Base Case	Low	Medium	High	Low	Medium	High
Darkhan	0.03	0.04	0.05	0.05	0.05	0.06	0.07
Tuv	**2.81**	**3.78**	**4.02**	**4.28**	**4.60**	**5.10**	**5.64**
Bayan	1.72	2.32	2.47	2.63	2.83	3.13	3.46
Bayandelger	0.83	1.12	1.19	1.27	1.36	1.51	1.67
Bayanjargalan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bayantsagaan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Erdene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sergelen	0.25	0.34	0.36	0.38	0.41	0.46	0.50
Arkhust	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UB city	**0.01**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**
Bagakhangai	0.01	0.02	0.02	0.02	0.02	0.03	0.03
Umnugovi	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**
Bayan-Ovoo	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Dalanzadgad	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tsogt-Ovoo	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tsogttsetsii	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Khankhongor	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nomgon	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sub-total NSO	**2.94**	**3.96**	**4.21**	**4.49**	**4.83**	**5.34**	**5.91**
Sub-total TT	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**
Grand Total	**2.95**	**3.97**	**4.23**	**4.51**	**4.85**	**5.36**	**5.93**

The range of water demand in future is depicted in the graph below:




Agri Demand for TT region
in mn cubic meters/year
0.03
0.02
0.02
0.01
0.01
0.00
2015
2030
2040
0.01
0.02
0.02
0.02
0.02
Low
Medium
High

3. Livestock Water Demand

The water demand from livestock in the specific areas within the region is estimated from the base data on the population of livestock under various categories and after considering the norm for water consumption for each category of livestock.

$$Livestock\ demand\ per\ Suom\ \left(\frac{cubic\ meters}{year}\right) = \frac{[\ (L1\ X\ W1) + (L2\ X\ W2) + \cdots \ldots.(L5\ X\ W5)]}{1000} X\ 365\ X\ AC$$

L 1 is population of Livestock 1 in the year 2013 (base year)
W1 is Water consumption of L1 as per norm (in liters/head/day)
AC is % of Area Coverage under this study
In this study we have considered 5 different livestock categories which are prominent in the region

The data on livestock in each suom (headcount) was taken from the National Statistical Office of Mongolia (http://en.nso.mn/). The latest livestock numbers are of the year 2013.

To estimate the livestock water usage, water norms from Resolution No A 301 were applied. For suoms which are only partially covered in our study area, the percentage of the area coverage is applied to the suom's livestock water demand. This assumes that the livestock populations are equally distributed across the suom, as more concrete information on the exact location was not available.

The population of livestock at soum level for the year 2013 is listed below:

(population in no's)

Aimag	Soum	Area Coverage (%)	Horse	Cow	Camel	Sheep	Goat
Tuv	Arkhust	100%	5,264	3,773	2	29,217	21,204
Tuv	Bayan	100%	8,913	4,157	151	44,331	29,067
Tuv	Bayandelger	25%	11,651	8,269	149	76,615	42,512
Tuv	Bayanjargalan	100%	10,698	4,459	369	75,225	44,991
Tuv	Bayantsagaan	100%	10,262	4,584	221	75,679	55,431
Tuv	Sergelen	66%	15,054	5,791	28	50,638	31,577
Tuv	Erdene	10%	11,134	16,008	25	74,928	52,964
UB city	Bagakhangai	100%	2150	1,760	8	8,362	7,923
Govi-sumber	Sumber	100%	8,334	5,595	582	86,607	97,612
Govi-sumber	Bayantal	100%	2,678	1,030	160	19,879	18,419
Govi-sumber	Shiveegovi	100%	1,110	1,072	79	14,467	15,140
Dornogovi	Airag	50%	8,093	3,414	894	52,334	46,497
Dornogovi	Dalanjargalan	100%	6,651	4,457	677	61,479	52,987
Dundgovi	Bayanjargalan	100%	3,225	2,193	144	46,508	39,317
Dundgovi	Govi-Ugtaal	100%	4,242	1,722	310	60,603	59,733
Dundgovi	Tsagaandelger	100%	4,129	1,463	499	34,978	33,256
Dundgovi	Ondorshil	50%	6,918	2,112	1,721	66,854	55,015
Khentii	Darkhan	80%	7,553	6,347	528	78,650	65,064
Umnugovi	Dalanzadgad	100%	1,467	952	1,680	14,633	43,526
Umnugovi	Khankhongor	80%	4,743	865	4,928	34,158	83,272
Umnugovi	Bayan-Ovoo	50%	4,148	688	5,244	23,021	56,476
Umnugovi	Tsogt-Ovoo	50%	2,081	363	7,049	18,480	33,893

Aimag	Soum	Area Coverage (%)	Horse	Cow	Camel	Sheep	Goat
Umnugovi	Tsogttsetsii	100%	4,472	778	2,141	21,401	36,949
Umnugovi	Nomgon	33%	5,589	1,485	6,625	31,385	171,900

To estimate the water demand from livestock, the water norms of water consumption per head of livestock was used from the Water Demand Handbook (2012). While these norms were recently updated as part Resolution No A/ 301, the updated values require additional detail on age of the livestock to estimate water consumption. This detailed information was not available from NSO.

The applied water consumption norms are listed in the table below:

Livestock water consumption norm (l/head/day)			
Livestock water consumption norm (l/head/day)	**2005 - 2010**	**2011 – 2015**	**2016 – 2021**
Sheep and goat	3.5	3.5	3.5
Cattle	23	23	23
Horses	24	24	24
Camels	57	57	57

To allow for a more differentiated analysis, livestock water demand is forecasted in three scenarios. The scenarios are taken from the Water Demand Handbook (MEGDT, 2012). [4] The assumptions for the three scenarios are listed in the table below. For the period from 2021-2040, the growth rate of 2015-21 has been assumed to apply in the calculations.

Growth percentages of water usage of livestock						
	Low	Low	Medium	Medium	High	High
	2010-15	2015-21	2010-15	2015-21	2010-15	2015-21
Sheep	1.50%	-0.40%	2.50%	-0.40%	6.80%	0.40%
Cattle	8.70%	6%	10%	6%	7.40%	6.80%
Horses	4%	2.90%	5.10%	2.90%	6.20%	3.70%
Camels	0.40%	1.70%	1.40%	1.70%	0%	2.50%
Goat	-1.50%	-2.80%	-0.50%	-2.80%	10.50%	-2.00%

The estimated water demand for livestock, based on the above mentioned input data and assumptions, is outlined in the table below.

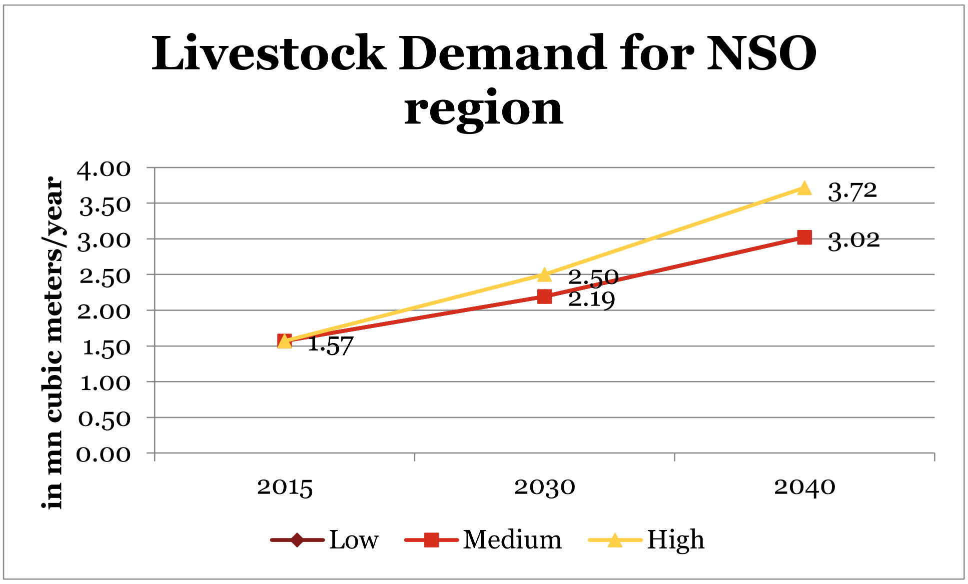
(In million cubic meters)

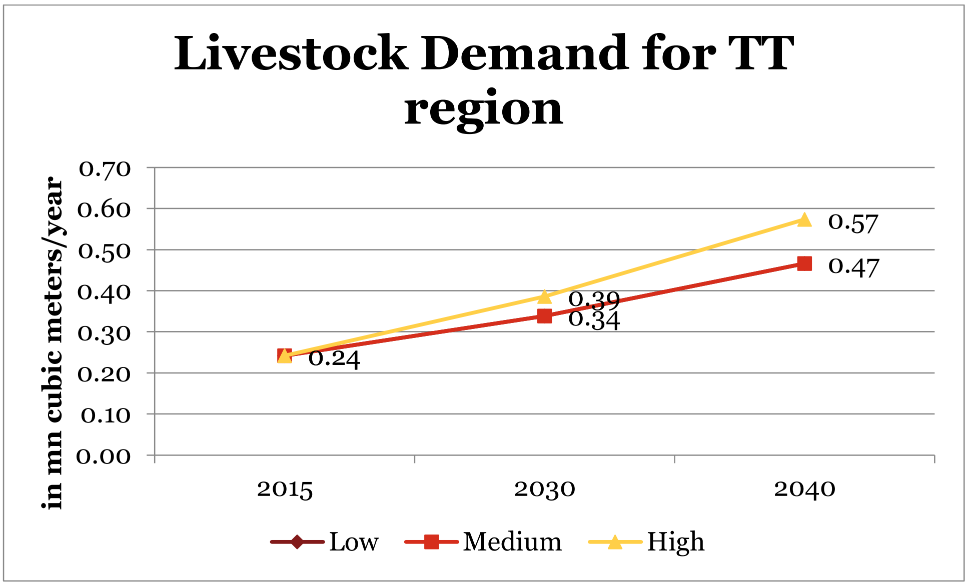
Scenarios →	**2015**	**2030**			**2040**		
Aimag/Soum	**Base case**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Dornogovi	**0.18**	**0.25**	**0.25**	**0.28**	**0.34**	**0.34**	**0.42**
Airag	0.07	0.09	0.09	0.11	0.13	0.13	0.16
Dalanjargalan	0.11	0.15	0.15	0.17	0.21	0.21	0.26
Dundgovi	**0.25**	**0.35**	**0.35**	**0.40**	**0.48**	**0.48**	**0.59**
Bayanjargalan	0.05	0.07	0.07	0.08	0.10	0.10	0.13
Govi-Ugtaal	0.07	0.10	0.10	0.11	0.13	0.13	0.17
Tsagaandelger	0.07	0.10	0.10	0.09	0.13	0.13	0.14
Ondorshil	0.06	0.08	0.08	0.11	0.11	0.11	0.16

[4] G. Dolgorsuren et al (2012) Water Demand Handbook, page 48

Scenarios →	2015	2030			2040		
Aimag/Soum	**Base case**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Govi-sumber	**0.20**	**0.28**	**0.28**	**0.32**	**0.38**	**0.38**	**0.47**
Bayantal	0.04	0.06	0.06	0.07	0.08	0.08	0.10
Shiveegovi	0.02	0.03	0.03	0.03	0.04	0.04	0.04
Sumber	0.14	0.19	0.19	0.22	0.26	0.26	0.33
Khentii	**0.10**	**0.14**	**0.14**	**0.16**	**0.19**	**0.19**	**0.24**
Darkhan	0.10	0.14	0.14	0.16	0.19	0.19	0.24
Tuv	**0.76**	**1.06**	**1.06**	**1.29**	**1.47**	**1.47**	**1.92**
Bayan	0.15	0.21	0.21	0.23	0.28	0.28	0.35
Bayandelger	0.05	0.07	0.07	0.08	0.09	0.09	0.11
Bayanjargalan	0.18	0.25	0.25	0.28	0.34	0.34	0.42
Bayantsagaan	0.17	0.24	0.24	0.27	0.33	0.33	0.40
Erdene	0.02	0.03	0.03	0.03	0.04	0.04	0.04
Sergelen	0.16	0.23	0.23	0.26	0.32	0.32	0.39
Arkhust	0.09	0.12	0.12	0.14	0.17	0.17	0.21
Umnugovi	**0.24**	**0.34**	**0.34**	**0.39**	**0.47**	**0.47**	**0.57**
Bayan-Ovoo	0.03	0.05	0.05	0.05	0.07	0.07	0.08
Dalanzadgad	0.02	0.03	0.03	0.04	0.05	0.05	0.06
Tsogt-Ovoo	0.02	0.02	0.02	0.10	0.03	0.03	0.15
Tsogttsetsii	0.07	0.10	0.10	0.05	0.14	0.14	0.07
Khankhongor	0.06	0.09	0.09	0.03	0.12	0.12	0.04
Nomgon	0.03	0.04	0.04	0.12	0.06	0.06	0.17
UB city	**0.04**	**0.05**	**0.05**	**0.06**	**0.07**	**0.07**	**0.08**
Bagakhangai	0.04	0.05	0.05	0.06	0.07	0.07	0.08
Sub-total (NSO)	**1.43**	**2.19**	**2.19**	**2.50**	**3.02**	**3.02**	**3.72**
Sub-total (TT)	**0.24**	**0.34**	**0.34**	**0.39**	**0.47**	**0.47**	**0.57**
Total	**1.81**	**2.53**	**2.53**	**2.89**	**3.49**	**3.49**	**4.29**

Based on the above demand forecasting, it can be seen that the growth rates for low and medium growth scenarios are same; hence the water demand in both of these scenarios is the same. The objective of having multiple scenarios is to assess a range of water demand (min and max) in the future years and the same is depicted in the chart below:


Livestock Demand for NSO region
in mn cubic meters/year
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2015
2030
2040
1.57
2.50
2.19
3.72
3.02
Low
Medium
High


Livestock Demand for TT region
in mn cubic meters/year
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2015
2030
2040
0.24
0.39
0.34
0.57
0.47
Low
Medium
High

4. Domestic Water Demand

The demand for domestic water usage is arrived separately for urban and rural population as the consumption patterns differ substantially across these categories of users given the varying degrees of access to water supply in urban and rural areas. The extent of water available is also a factor of source of water, i.e. the quantum of water available is different for a centralised piped water supply source and water being transported.

In addition, municipal water demand, i.e. for hospitals, schools, kindergartens, etc., was considered.

Wherever possible, actual data on water usage from the River Basin Administrations (RBA) was used. However, this data is only available for selected suom centres. In the absence of actual water usage data, statistics on suom population were used as basis to derive urban and rural water demand.

Given the population distribution, urban centres are mostly only to be found in suom centres. Thus, in cases in which the suom centre falls outside of the study area, only rural water supply is considered.

The population and soum level for 2014 is taken from the National Statistical Office of Mongolia (http://en.nso.mn/) and is summarised below.

Aimag	Soum	Population 2014	Soum Centre	Study Area (%)
Tuv	Arkhust	1,254	Yes	100%
Tuv	Bayan	2,063	Yes	100%
Tuv	Bayandelger	1,330	No	25%
Tuv	Bayanjargalan	1,571	Yes	100%
Tuv	Bayantsagaan	1,803	Yes	100%
Tuv	Sergelen	1,841	No	66%
Tuv	Erdene	3,862	No	10%
UB city	Bagakhangai	3,903	Yes	100%
Govi-sumber	Sumber	11,609	Yes	100%
Govi-sumber	Bayantal	1,084	Yes	100%
Govi-sumber	Shiveegovi	3,198	Yes	100%
Dornogovi	Airag	3,607	Yes	50%
Dornogovi	Dalanjargalan	2,641	Yes	100%
Dundgovi	Bayanjargalan	1,178	Yes	100%
Dundgovi	Govi-Ugtaal	1,564	Yes	100%
Dundgovi	Tsagaandelger	1,003	Yes	100%
Dundgovi	Ondorshil	1,443	No	50%
Khentii	Darkhan	10,601	Yes	80%
Umnugovi	Dalanzadgad	22,187	Yes	100%
Umnugovi	Khankhongor	2,099	Yes	80%
Umnugovi	Bayan-Ovoo	1,706	yes	50%
Umnugovi	Tsogt-Ovoo	1,677	yes	50%
Umnugovi	Tsogttsetsii	6,574	yes	100%
Umnugovi	Nomgon	2,572	Yes	33%

For estimating the total water demand under the study area, a combination of two methods has been adopted based on the availability of data. In case of soum centres in which actual water usage data was available, Method 1 is used. Method 2 is based on the current population and deriving the water demand is based on the water consumption norms outlined in Resolution No A 301.

Method 1: Demand estimation based on actual water usage

Actual water usage is available for three suom centres from the respective RBAs in the study area. This data is used for actual urban water usage for each respective suom and is as below:

Suom Centres	Actual water usage (in million cubic meters per annum) in 2014
Sumber	1.08
Dalanzadgad	0.30
Tsogttsetsii	1.67

The actual water usage in urban areas of the above three suoms is assumed to increase at a rate equal to the rate of population growth in these suoms. The table below provides the annual growth rate and the projected water usage for these suoms.

Aimag/Suom	Annual population growth rate (%)	Projected water demand in million cubic meters/annum		
		2015	2030	2040
Sumber	1.52%	1.08	1.36	1.58
Dalanzadgad	3.04%	0.30	0.46	0.63
Tsogttsetsii	3.04%	1.67	2.62	3.53

It is to be noted that the actual demand in the soum centres of Dalanzadgad and Tsogttsetsii is higher compared to the water demand estimation based on the norms (which is adopted for other soums). This is owing to the fact that in case of Tsogttsetsii, there are many un-permanent residents when mining activities take place which are not registered as residents and thus do not feature on the population statistics.

Method 2: Demand estimation based on population and water consumption norms

Population projections for the years 2015 and 20121 are in the Water Demand Handbook[5]. For years beyond 2021, the same growth rate as up to 2021 is assumed to prevail. The projected population numbers for the entire suoms are listed below:

(Projected population in nos)

Aimag	Soum	2015	2030	2040
Tuv	Arkhust	1,271	1,519	1,711
Tuv	Bayan	2,090	2,499	2,815
Tuv	Bayandelger	1,330	1,611	1,814
Tuv	Bayanjargalan	1,592	1,903	2,143
Tuv	Bayantsagaan	1,827	2,184	2,460
Tuv	Sergelen	1,865	2,230	2,512
Tuv	Erdene	3,913	4,678	5,269
UB city	Bagakhangai	3,955	4,727	5,325
Govi-sumber	Sumber	11,762	14,061	15,838
Govi-sumber	Bayantal	1,098	1,313	1,479
Govi-sumber	Shiveegovi	3,240	3,873	4,363
Dornogovi	Airag	3,655	4,369	4,921
Dornogovi	Dalanjargalan	2,676	3,199	3,603
Dundgovi	Bayanjargalan	1,194	1,427	1,607
Dundgovi	Govi-Ugtaal	1,585	1,894	2,134

[5] Table 24, Annexure 1 – Population projections

Aimag	Soum	2015	2030	2040
Dundgovi	Tsagaandelger	1,016	1,215	1,368
Dundgovi	Ondorshil	1,462	1,748	1,969
Khentii	Darkhan	10,741	12,840	14,463
Umnugovi	Dalanzadgad	22,480	26,873	30,269
Umnugovi	Khankhongor	2,127	2,542	2,864
Umnugovi	Bayan-Ovoo	1,729	2,066	2,327
Umnugovi	Tsogt-Ovoo	1,699	2,031	2,288
Umnugovi	Tsogttsetsii	6,661	7,963	8,969
Umnugovi	Nomgon	2,606	3,115	3,509

There is a wide difference between water usage in urban and rural areas. Thus, estimating rural and urban water demand separately is very important. For two of the suoms, the data on urban and rural population was available, i.e. for suom – Sumber and Dalanzadgad. In case of Sumber, the urban population constituted 84% of the population and in Dalanzadgad it was 100% in the base year 2014. For other suoms, the breakup of urban and rural population is based on the assumptions in the Water Demand Handbook. The projected population of urban and rural for the years 2015 and 2021 is considered on aimag level[6]. This is further used to extrapolate the urbanisation at the same rate up to 2040. The table below provides the growth in urban population from year 2015-21.

	2015		2021	
AIMAG	Rural Population (%)	Urban Population (%)	Rural Population (%)	Urban Population (%)
TUV	80%	20%	77%	23%
Govi-sumber	33%	67%	32%	68%
Dornogovi	62%	38%	59%	41%
Umnugovi	64%	36%	61%	39%
Dundgovi	76%	24%	74%	26%
Khentii	75%	25%	74%	26%

Based on the above change in urban and rural population, a projection was made at the same rate to assess the urban/rural population for 2030, 2040 and 2050 and is as below:

AIMAG	Rural Population in 2015 (%)	Rural Population in 2030 (%)	Rural Population in 2040 (%)
TUV	80%	72%	67%
Govi-sumber	32%	31%	29%
Dornogovi	62%	55%	50%
Umnugovi	64%	56%	51%
Dundgovi	75%	71%	67%
Khentii	75%	72%	69%

Considering the population projection and the percentage of rural population in the future, the total urban and rural population at Aimag/Soum level is derived and is as below:

(Projected population in nos)

[6] Annexure 2, Page 31, Water Demand Handbook

Aimag	Soum	2015		2030		2040	
		Rural	Urban	Rural	Urban	Rural	Urban
Tuv	Arkhust	1,011	260	1,098	421	1,154	557
Tuv	Bayan	1,663	427	1,806	693	1,898	917
Tuv	Bayandelger	270	0	322	0	363	0
Tuv	Bayanjargalan	1,266	325	1,375	527	1,445	698
Tuv	Bayantsagaan	1,453	373	1,578	605	1,659	801
Tuv	Sergelen	979	0	1,064	0	1,118	0
Tuv	Erdene	311	0	338	0	355	0
UB city	Bagakhangai	0	3,955	0	4,727	0	5,325
Govi-sumber	Sumber	1,878	9,702	2,275	11,786	2,562	13,276
Govi-sumber	Bayantal	356	743	401	912	433	1,046
Govi-sumber	Shiveegovi	1,050	2,191	1,182	2,692	1,277	3,086
Dornogovi	Airag	1,126	2,528	1,193	3,176	1,228	3,692
Dornogovi	Dalanjargalan	1,650	1,026	1,747	1,452	1,799	1,804
Dundgovi	Bayanjargalan (Dundgovi)	900	293	1,008	419	1,084	523
Dundgovi	Govi-Ugtaal	1,196	389	1,338	556	1,439	695
Dundgovi	Tsagaandelger	767	250	858	357	923	446
Dundgovi	Ondorshil	552	0	617	0	664	0
Khentii	Darkhan	6,467	4,274	7,361	5,479	8,014	6,449
Umnugovi	Dalanzadgad	0	22,187	0	26.873	0	30,269
Umnugovi	Khankhongor	1,083	1,043	1,134	1,408	1,157	1,707
Umnugovi	Bayan-Ovoo	550	1,178	576	1,490	588	1,740
Umnugovi	Tsogt-Ovoo	541	1,158	566	1,465	578	1,710
Umnugovi	Tsogttsetsii	4,242	2,419	4,441	3,522	4,529	4,439
Umnugovi	Nomgon	548	2,058	573	2,542	585	2,924

Further, it is important to look at the different sources of water and the expected change in the sources over a period of time. The Water Demand Handbook has provided assumptions related to the quantum of water consumed (as norm) for various sources of water supply for the year 2015 and 2021[7]. Here, it is assumed that going forward, there will be a slight reduction of per capita water usage in piped sources.

Sources of Water	Water supplied in litres/head/day	
	2015	2021
Central Water System – other Aimags/Suoms	170	160
CWS – kiosks	25	30
Water transportation - kiosks/vendors	25	30
Protected wells, rivers etc.	15	15
Unprotected wells	15	15
Other sources*	15	15

[7] Table 9, Drinking water consumption norms, page 12, Water Demand Handbook

* It is assumed to be 15 litres/head/day (minimum water required/person)

Further, the breakup of population having access to different types of sources is based on assumptions provided in the Water Demand Handbook[8].

To allow for a differentiated analysis, three water usage scenarios are estimated. It is assumed that the "Low growth" scenario is 5% less than that of base case/"Medium growth" scenario and "High growth" scenario is 10% more that of "Medium growth" scenario[9]. For the time period from 2021-40, same rate of growth of Central Water System is assumed for each of the growth scenarios.

Scenarios	2015			2021		
Type of water supply system	Low	Medium	High	Low	Medium	High
Central Water System - Apartments connected to water supply & Sanitation	24.80%	29.80%	39.80%	28.30%	33.30%	43.30%
Central Water System - Ger districts supplied from kiosks	17.10%	17.10%	17.10%	18.60%	18.60%	18.60%
Water Transportation - from kiosks/water vendors	17.30%	17.30%	17.30%	18.20%	18.20%	18.20%
Protected sources	14.20%	14.20%	14.20%	15.70%	15.70%	15.70%
Unprotected sources	15.70%	15.70%	10.70%	11.50%	11.50%	4.50%
Other sources	10.90%	5.90%	0.90%	7.70%	2.60%	0.00%

Urban domestic water demand is arrived at as depicted below. Urban water demand is only considered if the suom centre lies within the study area.

$$Urban\ Domestic\ Water\ demand \left(in\ cubic\ meters/_{year}\right) = \frac{[\ (UP\ X\ S1\ X\ W1) + (UP\ X\ S2\ X\ W2) + \cdots\ (UP\ X\ S6\ X\ W6)]}{1000}\ X\ 365$$

UP is the urban population
S1 is % of population access to Source 1
W1 is quantum of water supplied through Source 1 (in litres/head/day)
In this study, 6 different sources of water are considered

Based on the above assumptions, the demand forecast for urban water usage is as below:

(In million cubic metres)

Scenarios →	**High**	**2030**			**2040**		
Aimag/Suoms	**Base case**	**Low**	**Medium**		**Low**	**Medium**	**High**
Dornogovi	**0.08**	**0.12**	**0.13**	**0.15**	**0.16**	**0.17**	**0.20**
Airag	0.06	0.08	0.09	0.10	0.10	0.11	0.13
Dalanjargalan	0.02	0.04	0.04	0.05	0.05	0.06	0.06
Dundgovi	**0.02**	**0.03**	**0.04**	**0.04**	**0.05**	**0.05**	**0.06**
Bayanjargalan	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Govi-Ugtaal	0.01	0.01	0.02	0.02	0.02	0.02	0.02

[8] Table 7, Access to water in Mongolia by percentage of population, page 8, Water Demand Handbook
[9] Section 7.1, Scenarios – Drinking water, page 16, Water Demand Handbook

Scenarios →	High	2030			2040		
Aimag/Suoms	**Base case**	**Low**	**Medium**		**Low**	**Medium**	**High**
Ondorshil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tsagaandelger	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Govi-sumber	**1.15**	**1.45**	**1.46**	**1.48**	**1.70**	**1.71**	**1.73**
Bayantal	0.02	0.02	0.03	0.03	0.03	0.03	0.04
Shiveegovi	0.05	0.07	0.07	0.09	0.09	0.10	0.11
Sumber	1.08	1.36	1.36	1.36	1.58	1.58	1.58
Khentii	**0.10**	**0.14**	**0.15**	**0.18**	**0.19**	**0.20**	**0.24**
Darkhan	0.10	0.14	0.15	0.18	0.19	0.20	0.24
Tuv	**0.03**	**0.06**	**0.06**	**0.07**	**0.08**	**0.09**	**0.11**
Arkhust	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Bayan	0.01	0.02	0.02	0.02	0.03	0.03	0.03
Bayanjargalan	0.01	0.01	0.01	0.02	0.02	0.02	0.03
Bayantsagaan	0.01	0.01	0.02	0.02	0.02	0.02	0.03
Erdene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sergelen	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UB city	**0.09**	**0.12**	**0.13**	**0.16**	**0.15**	**0.17**	**0.20**
Bagakhangai	0.09	0.12	0.13	0.16	0.15	0.17	0.19
Umnugovi	**2.09**	**3.26**	**3.28**	**3.32**	**4.39**	**4.41**	**4.45**
Bayan-Ovoo	0.03	0.04	0.04	0.05	0.05	0.05	0.06
Dalanzadgad	0.30	0.46	0.46	0.46	0.63	0.63	0.63
Khankhongor	0.02	0.04	0.04	0.05	0.05	0.05	0.06
Nomgon	0.05	0.06	0.07	0.08	0.08	0.09	0.11
Tsogt-Ovoo	0.03	0.04	0.04	0.05	0.05	0.05	0.06
Tsogttsetsii	1.67	2.62	2.62	2.62	3.53	3.53	3.53
Sub-total (NSO)*	**1.59**	**2.08**	**2.14**	**2.26**	**2.54**	**2.61**	**2.75**
Sub-total (TT)*	**2.13**	**3.31**	**3.33**	**3.37**	**4.46**	**4.48**	**4.53**
Grand Total	**3.58**	**5.18**	**5.26**	**5.41**	**6.72**	**6.81**	**6.99**

* Regional sub-totals are inclusive of additional municipal water demand as provided below:

Additional municipal water demand:

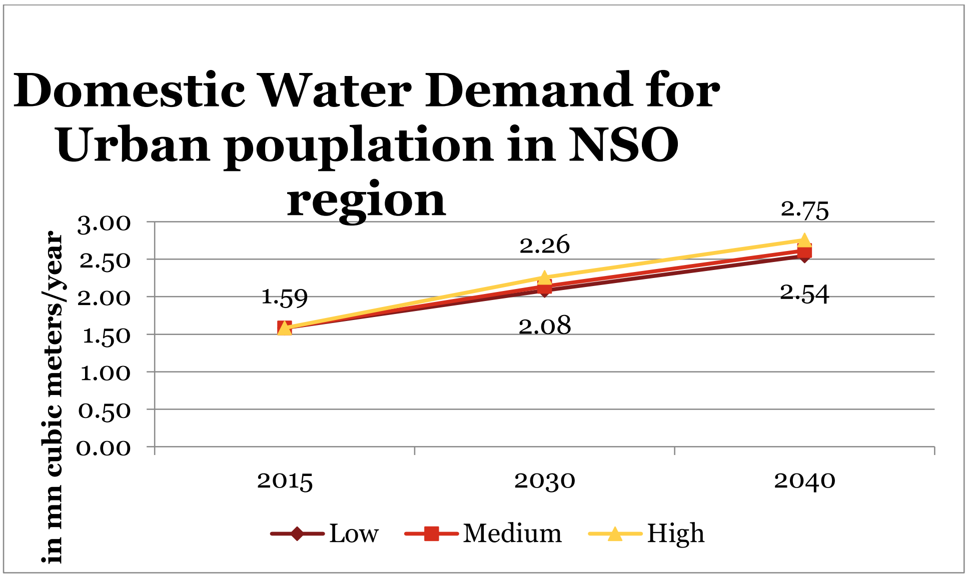
Additional domestic demand in the study area is collected from various institutions such as kindergartens, hospitals, resorts, schools, apartments, etc. in the respective suoms. The cumulative data on the water usage at region level is as below:

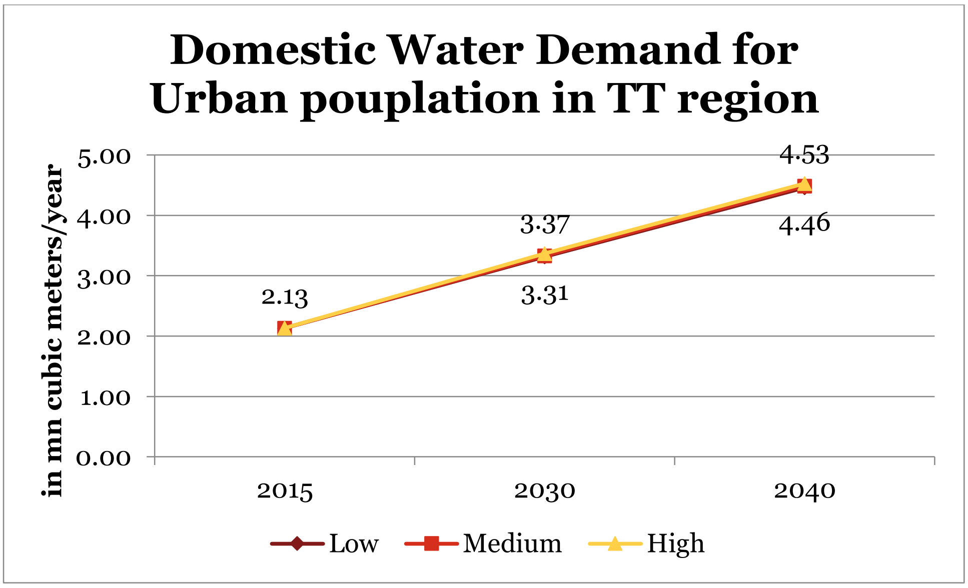
Region under study	Water usage in million cubic meters/year
NSO	0.103
TT	0.035
Total	0.138

Considering that these institutions are primarily present in the soum centres (urban areas), the above additional demand is added to the urban water demand and is increased at the same rate of growth as that of the urban water demand in the region without this.

Municipal water usage is included as additional domestic demand to arrive at the cumulative urban water demand in the region.

Based on the calculations, the water demand range in urban areas is as shown in the chart below:





Rural domestic water demand is arrived at as depicted below:

$$Rural\ Domestic\ Water\ demand\ \left(in\ cubic\ meters/_{year}\right) = \frac{[\,(RP\ X\ S1\ X\ W1) + (RP\ X\ S2\ X\ W2) + \cdots\ (RP\ X\ S6\ X\ W6)]}{1000}\ X\ 365$$

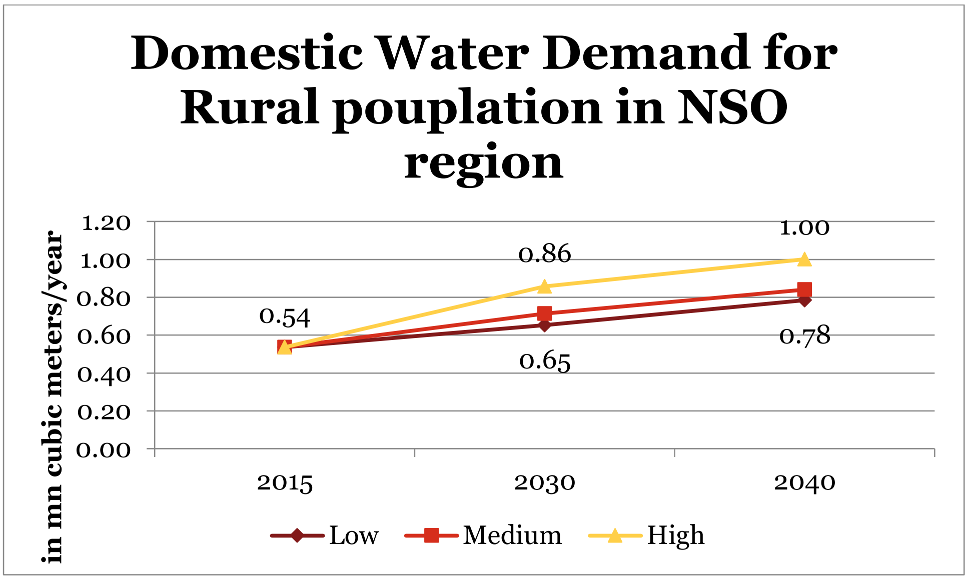
RP is the rural population under study area – derived based on the % of the area considered for study under each soum
S1 is % of population access to Source 1
W1 is quantum of water supplied through Source 1 (in litres/head/day)
In this study, 6 different sources of water are considered

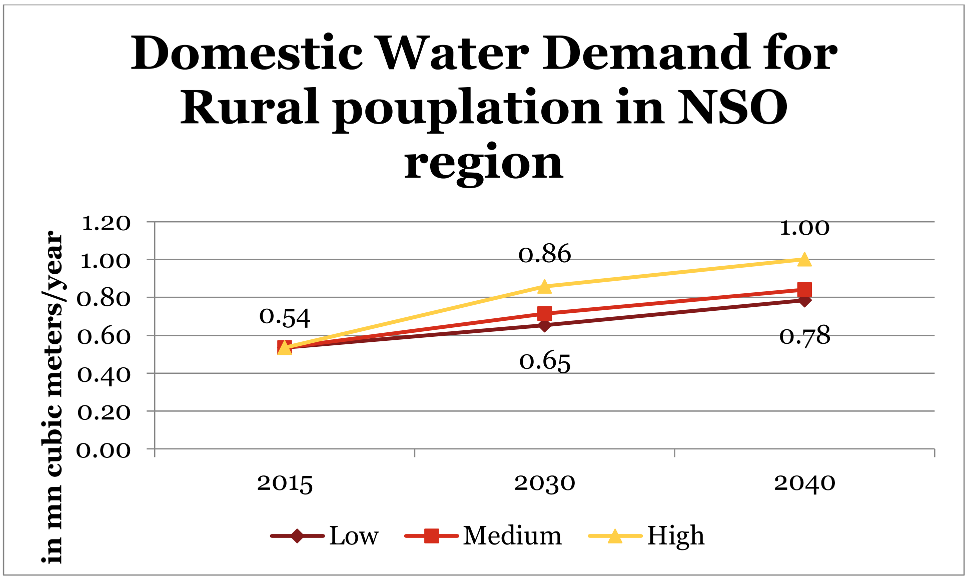
Based on the above mentioned assumptions, the demand forecast for rural areas is as below:

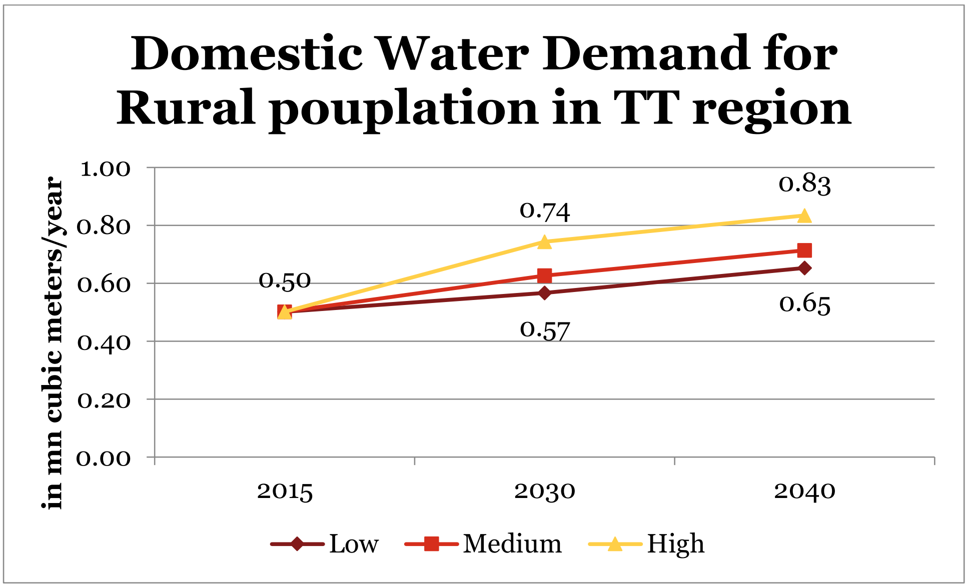
(In million cubic metres)

	2015	2030			2040		
	Base case	Low	Medium	High	Low	Medium	High
Dornogovi	**0.07**	**0.07**	**0.08**	**0.10**	**0.09**	**0.10**	**0.11**
Airag	0.03	0.03	0.03	0.04	0.04	0.04	0.05
Dalanjargalan	0.04	0.04	0.05	0.06	0.05	0.06	0.07
Dundgovi	**0.08**	**0.10**	**0.11**	**0.13**	**0.12**	**0.13**	**0.15**
Bayanjargalan (Dundgovi)	0.02	0.03	0.03	0.03	0.03	0.03	0.04
Govi-Ugtaal	0.03	0.03	0.04	0.04	0.04	0.05	0.05
Ondorshil	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Tsagaandelger	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Govi-sumber	**0.07**	**0.10**	**0.10**	**0.13**	**0.12**	**0.11**	**0.15**
Bayantal	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Shiveegovi	0.02	0.03	0.03	0.04	0.04	0.04	0.05
Sumber	0.04	0.06	0.06	0.08	0.07	0.06	0.09
Khentii	**0.15**	**0.19**	**0.21**	**0.25**	**0.23**	**0.25**	**0.29**
Darkhan	0.15	0.19	0.21	0.25	0.23	0.25	0.29
Tuv	**0.16**	**0.19**	**0.21**	**0.25**	**0.23**	**0.25**	**0.29**
Arkhust	0.02	0.03	0.03	0.04	0.03	0.04	0.04
Bayan	0.04	0.05	0.05	0.06	0.05	0.06	0.07
Bayandelger	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bayanjargalan (Tuv)	0.03	0.03	0.04	0.05	0.04	0.05	0.05
Bayantsagaan	0.03	0.04	0.04	0.05	0.05	0.05	0.06
Erdene	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sergelen	0.02	0.03	0.03	0.04	0.03	0.04	0.04
UB city	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Bagakhangai	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Umnugovi	**0.50**	**0.57**	**0.63**	**0.74**	**0.65**	**0.71**	**0.83**
Bayan-Ovoo	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Dalanzadgad	0.34	0.38	0.42	0.50	0.44	0.48	0.56
Khankhongor	0.03	0.03	0.03	0.04	0.03	0.04	0.04
Nomgon	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Tsogt-Ovoo	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Tsogttsetsii	0.10	0.11	0.12	0.15	0.13	0.14	0.17
Sub-total (NSO)	**0.54**	**0.65**	**0.71**	**0.86**	**0.78**	**0.84**	**1.00**
Sub-total (TT)	**0.50**	**0.57**	**0.63**	**0.74**	**0.65**	**0.71**	**0.83**
Grand Total	**1.04**	**1.22**	**1.34**	**1.60**	**1.43**	**1.55**	**1.83**

The water demand for domestic usage will be in the range as shown below:


Domestic Water Demand for Rural pouplation in NSO region
in mn cubic meters/year
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.54
0.86
1.00
0.65
0.78
2015
2030
2040
Low
Medium
High


Domestic Water Demand for Rural pouplation in NSO region
in mn cubic meters/year
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.54
0.86
1.00
0.65
0.78
2015
2030
2040
Low
Medium
High


Domestic Water Demand for Rural pouplation in TT region
in mn cubic meters/year
1.00
0.80
0.60
0.40
0.20
0.00
0.50
0.74
0.83
0.57
0.65
2015
2030
2040
Low
Medium
High

5. Mine Water Demand

Mine water demand is derived following two approaches:

1. For all key mines analysed in our study area, primary data collection on water usage, as well as future development plans and scenarios, took place.
2. For all additional mines in the study area, the water usage was estimated based on mining licenses, annual production and water usage per unit of production

Key components of mine water demand include water for dust suppression and drinking water for workers/ offices. The amount of water used for dust suppression is a function of area of the mine, road length and production volumes. The below table shows derived estimates of dust suppression according to international standards, following expert opinions.

Table 1 Mine Water Demand – International Best Practice for Southern Gobi mines

Size	Key mines	Coal Production	Dust Suppression	Other	Total
		Approx. Mt/pa	L/s	L/s	L/s
very small	Other mines	<5	8	2	10
small	UHG, TT JSC, Other mines	5	17.5	5	22.5
medium	UHG, ETT	10	35	5	40
medium	UHG, ETT	15	40	5	45
large	ETT	30	52.5	5	57.5

While primary/ actual data is available on dust suppression for key mines, these values prove to be very low, as compared to international standards. To ensure sufficient water is allocated to the practice of environmentally sustainable mining, the actual dust suppression is recorded as baseline value, while future scenarios adopt water requirements to meet international standards.

If values for drinking water for workers in camps exist, (e.g. for Energy Resources) these values are adopted. If no values are provided, or only values for drinking water during working hours, the value for "other" is included to ensure that the impact of a higher workforce is reflected in the data.

Water requirements for planned investments (power plants, coal washing, CTL CTB) are reflected in a separate section. For the baseline, it is assumed that mining production continues at the planned rate (or current rate) as if investments would not occur ("business as usual").

Water usage provided by mines to suom centres (e.g. Energy Resources) is accounted for domestic demand.

Mine water demand of key mines

We consider key mines as those being active within the core of our study area in each region, i.e. ETT, ER and TT JSC in the Tavan Tolgoi region and Shivee Ovoo in the Nyalgo Shivee Ovoo region.

For these mines, primary data was collected via stakeholder interviews. Data collected includes information on current and future production (low, medium, high estimates), current and estimated water usage, future plans on adding value activities to coal production. Primary data collection on current water usage was verified with water abstraction values from respective River Basin Administrations.

An overview of the information provided is illustrated in the tables below.

Energy Resources	Production (ROM)	Dust suppression	Other mine demand	Total
	mn tonnes/ year	l/sec	l/sec	l/sec
Baseline (2015)	5.00	7.13	5.36	12.49
Low Scenario	5.00	17.5	5.36	22.86
Medium Scenario	5.00	17.5	5.36	22.86
High Scenario	5.00	17.5	5.36	22.86

ETT	Production	Dust suppression	Other mine demand	Total
	mn tonnes/ year	l/sec	l/sec	l/sec
Baseline (2015)	5	8		**8**
Low Scenario	5	35	5.36	**40.36**
Medium Scenario	5	35	5.36	**40.36**
High Scenario	5	35	5.36	**40.36**

TT JSC	Production	Dust suppression	Other mine demand	Total
	ROM mn tonnes/ year	l/sec	l/sec	l/sec
Baseline (2015)	0.8	1.30		1.30
Low Scenario	0.6	17.50	5	22.5
Medium Scenario	0.8	17.50	5	22.5
High Scenario	2	17.50	5	22.5

Shivee Ovoo	Production	Dust suppression	Other mine demand	Total
	mn tonnes/ year	l/sec	l/sec	l/sec

Baseline (2015)	1.96	12.73	0.05	12.78
Low Scenario	0.98	17.5	5	22.5
Medium Scenario	1.96	17.5	5	22.5
High Scenario	3.00	17.5	5	22.5

Mine water demand of additional mines

In addition to the key mines, as listed above, there are multiple valid mining licenses in the study areas. Two additional mining areas are included in the NSO study region – namely Tugrug Nuur and Buuruljuutyn Tal mines. However, these are currently not operational. Coal production and related water requirements are linked to planned investment programmes as thus considered in that part of the analysis.

In some cases, mining activities have taken place in the past, in others, mining operations are yet to start. Thus, no actual water usage data, neither are available, nor are estimated on annual production volumes. A list of valid mining licenses considered in our analysis can be found in Table 2.

Table 2 List of valid mining licenses in study areas (source: MRAM)

Area name	Soum	Licence Number	Area (km2)	Type	Status	Holder/ Applicant	Product	Radius Distance
Gashuun ovoo	Tsogttsetsii soum	14840	374	Mining License	Valid	Aurum-Aurug	Coal	<50
Caidam-1	Bayan	17536	75	Mining License	Valid	Booroljuutiin tal	Coal	<50
To'grog	Bayanjargalan (Tuv)	17516	236	Mining License	Valid	Commonmax	Coal	<50
Xo'moolt-1	Bayanjargalan (Tuv)	17515	91	Mining License	Valid	Commonmax	Coal	<50
Xo'moolt-2	Bayanjargalan (Tuv)	17575	61	Mining License	Valid	Commonmax	Coal	<50
Uxaa xudag	Tsogttsetsii soum	11952	30	Mining License	Valid	Energy resource	Coal	<50
Tsagaan tolgoi	Nomgon	15041	105	Mining License	Valid	Goldland	Coal	50 to 100
Baruun naran	Khankhongor	14493	45	Mining License	Valid	Khangad Exploration LLC	Coal	<50
Caixar xudag	Khankhongor	17336	83	Mining License	Valid	Khangad Exploration LLC	Coal	<50
Xotgor	Tsogt-ovoo	15631	20	Mining License	Valid	Khotgor minerals	Rare Earth Minerals	50 to 100
Cagaan-O'ndor	Ondorshil	17384	21	Mining License	Valid	MDFI	Flourite	50 to 100
Nu'urst	Bayanjargalan (Tuv)	17349	25	Mining License	Valid	Modunresoures	Coal	<50
Cant uul	Bayan-ovoo	16872	692	Mining License	Valid	Mo'nxnoyon suvarga	Coal	50 to 100
Eedemt-2	Bayanjargalan (Dundgovi)	17185	54	Mining License	Valid	Narantuul trade	Coal	50 to 100
Eedemt-3	Bayanjargalan (Dundgovi)	17234	47	Mining License	Valid	Narantuul trade	Coal	50 to 100
Xarmagtai	Tsogttsetsii soum	17387	66	Mining License	Valid	Oyut-Ulaan	Copper	50 to 100
Choir	Bayanjargalan (Dundgovi)	17013	341	Mining License	Valid	Talyn shigtgee	Coal	50 to 100
Caidam-1	Bayan	17187	23	Mining License	Valid	Tsetsens mining and energi	Coal	<50
Bayanjargalan raion	Bayanjargalan (Tuv)	16871	84	Mining License	Valid	Zanaducoal mongolia	Coal	<50

Other coal mining water demand

To allow for a more differentiated analysis, three water demand scenarios are estimated: low, medium and high. When compared to ETT and Energy Resources, the other mines are assumed to be smaller and estimated to produce coal volumes similar to TT JSC. Dust suppression values are taken from international best practice benchmarks (see Table 1). Other mines are assumed to be categorised as “very small (< 5 Mtpa)” in low and medium scenarios and as “small (5 Mtpa)” in the high scenario.

Given the momentarily high uncertainty of the coal market in Mongolia, it is uncertain how many of the mines will start production until 2040. To account for this, the share of license holders who might start production is included in the scenario analysis. Average water demand per tonne of coal production is taken as the average value of those provided by active mines (see section above) in each region. Mine water usage for coal production (excluding potential coal enrichment activities) includes water for dust suppression, drinking water for offices and workers, in addition to water for cleaning, etc. Table 3 summarises the assumptions made for estimating other mine water usage.

Table 3 Assumptions for scenario development of other coal mining

Input values	Low	Medium	High
Annual Coal Production (million tonnes/yr)	0.50	1.00	2.00
Dust suppression water requirement (l/sec)	8	8	17.5
Other mine water requirement (l/sec)	2	2	5
Share of license holders who might start production	50%	80%	100%

While a number of exploration licenses are valid in our study area, the high uncertainty of when and how many of these licenses will eventually turn into mining licenses and start production is quite uncertain and thus not further considered in the mine water demand estimation. Mine water demand for mining licenses for fluorite and rare earth materials (marked in red in Table 2) was not estimated due to lack of further information.

An overview of total water demand and coal production in each study region is summarised in the table below.

Output values	Low	Medium	High	Scenario
No. of other mines in TT (4)				
Annual coal production in TT	1.00	3.20	8	million tonnes/yr
Annual Water demand in TT	0.32	1.01	5.68	million m3/yr
No. of other mines in NSO (10)				
Annual coal production in NSO	2.5	8	20	million tonnes/yr
Annual Water demand in NSO	0.79	2.52	14.19	million m3/yr
Total coal production	**3.50**	**11.20**	**28.00**	million tonnes/yr
Total water demand	**1.10**	**3.53**	**19.87**	million m3/yr

(Other) copper mining water demand

Within the Tavan Tolgoi study region, Xanadu Mine has a mining license for copper. If ore is processed to copper at the mining site, this results in considerably higher water requirements than for coal mining and thus was estimated separately.

Building on company data reflecting planned operation and production targets[10] and using Mongolia's key copper mine Oyu Tolgoi as a benchmark, the following estimation was done:

[10] Source: Mining Associates (2015) Independent Technical Report Kharmagtai Copper Gold Project Mongolia. Prepared for Xanadu Mines Ltd.

Xanadu Mine			
Estimated annual production[11]	10		mn tonnes/ year
Estimated daily production		0.03	mn tonnes/ day
Estimated total water usage		180.79	l/sec
Estimated total water usage		5.70	mn m3/year
Estimated processing water (ore to copper)		4.44	mn m3/year
Estimated processing water (ore to copper)		140.79	l/sec
Dust suppression	35		l/sec
Workers	5		l/sec

Oyu Tolgoi - Benchmark			
Current production	0.1		mn tonnes/ day
Water usage (total)		575.89	l/sec
Processing water (ore to copper)	444		l/ ton
Processing water (ore to copper)		513.89	l/sec
Dust suppression	57		l/sec
Workers	5		l/sec

Xanadu mine is estimated to start as a "small" mine, with a potential to increase production to a "medium" mine with respect to dust suppression water requirement. The above results in the following estimates for Xanadu coal mine water requirements:

Xanadu	Production	Processing Water	Dust suppression	Water supply - workers	Total water demand (l/sec)
Low	no production				0
Medium	5	70.40	17.5	5	92.90
High	10	140.79	35	5	180.79

6. Other Industrial Water Demand

The data on the industrial water usage was collected from each responsible River Basin Administration (RBA) and the Ministry of Environment, Green Development and Tourism (MEGDT) and corresponds to the year 2014. The following sub-categories are covered within the RBA data:

- Manufacturing & Services– includes enrichment factories such as CTL/ CTB, beverage making, cement plants, food production and bakeries, grocery stores and car washing, etc.
- Energy – includes power plants, power network, etc.
- Construction – includes civil engineering, airports, construction activities, construction material related, etc.

The base year water requirement across industries as collected from RBA Data source is as below:

Aimag	Suom	Company Name	Total Water Usage (m3/year)
Umnugovi	Dalanzadgad	Saikhany Uvur LLC	12,959.04
Umnugovi	Dalanzadgad	Goviin Gurvan Uul LLC	10,101.38
Umnugovi	Dalanzadgad	Goviin Gurvan Uul LLC	18,213.50
Umnugovi	Dalanzadgad	New Phormoso LLC	18,096.24
Umnugovi	Dalanzadgad	Galtuud LLC	14,600.00
Umnugovi	Dalanzadgad	Tuvshin Shankhat LLC	823.23
Umnugovi	Dalanzadgad	Morit Khuleg LLC	3,373.36
Umnugovi	Dalanzadgad	Thermal Power Plant	91,275.00
Umnugovi	Dalanzadgad	Makh zakh	63.00
Umnugovi	Dalanzadgad	Tansag bakery	81.00
Umnugovi	Dalanzadgad	Saruul-Od bakery	60.00
Umnugovi	Dalanzadgad	Bayan khuudas bakery	67.00
Umnogovi	Dalanzadgad	Unud Uvlukh Urlakhiu Beverage	848.00
Umnogovi	Dalanzadgad	Gurvan Mankh Beverage	1,265.00
Umnogovi	Dalanzadgad	Mungun Khuus car wash	640.00
Umnogovi	Dalanzadgad	Khuch service car wash	2,670.00
Umnogovi	Dalanzadgad	Argalant Batbuyan car wash	278.00
Umnogovi	Dalanzadgad	Nandin bakery	15.00
Umnogovi	Dalanzadgad	Chamin bakery	56.00
Umnogovi	Dalanzadgad	Bumbuulei bakery	25.00
Umnogovi	Dalanzadgad	Amtlag bakery	84.00
Umnogovi	Dalanzadgad	Tansag bakery	15.00
Umnogovi	Dalanzadgad	Jargalant bakery	3.00
Umnogovi	Dalanzadgad	Oyut car wash	45.00
Umnugovi	Other Suoms Galba Uush	United Power LLC	35,946.25
Umnugovi	Other Suoms Galba Uush	United Power LLC Power Network	233.00
Umnugovi	Other Suoms Galba Uush	Transgobi LLC	12,505.00
Umnugovi	Other Suoms Galba Uush	Goviin Zam LLC	781.00
Umnugovi	Other Suoms Galba Uush	Tavan Tolgoi airport	492.00
Umnugovi	Other Suoms Galba Uush	MCS Property LLC	1,233.33
Umnugovi	Other Suoms Galba Uush	MCS Property LLC	1,845.00

Umnugovi	Other Suoms Galba Uush	Golomt bank	276.00
Umnugovi	Other Suoms Galba Uush	State bank	552.00
Umnugovi	Other Suoms Galba Uush	Khas Bank	139.00
Umnugovi	Other Suoms Galba Uush	Anandiin Zam LLC	0.98
Umnugovi	Other Suoms Galba Uush	Goviin Torkh LLC	2,004.00
Umnugovi	Other Suoms Galba Uush	Khet Motors LLC	4.00
Umnugovi	Other Suoms Galba Uush	Mon Odon LLC	12.00
Umnugovi	Other Suoms Galba Uush	Ogosts LLC	65.00
Umnugovi	Other Suoms Galba Uush	Petrovis	18.00
Umnugovi	Other Suoms Galba Uush	Sun food shop	18.00
Umnugovi	Other Suoms Galba Uush	Suuri LLC	1,971.00
Umnugovi	Other Suoms Galba Uush	Tedment LLC	55.00
Umnugovi	Other Suoms Galba Uush	Umnudiin Nuudel LLC	3,807.00
Khentii	Tseeliin Bulag 45 km north of Darkhan soum and Bayan-Undur sum	Bor-Undur enrichment factory	1,613,758.00
Tuv	Bayandavaa in Erdene soum	New Sheiling International LLC	3,130.00
Dornogovi	Dalanjargalan	MAK Cement plant	17,692.80
Govi-sumber	Bayantal	Choir Khairkhan LLC	14,829.00
Total Water requirement			**1,887,024.10**

To summarise, the demand for industrial water usage for the two study regions of Tavan Tolgoi (TT) and Nyalga Shivee Ovoo (NSO) is given below:

Industrial demand	
Regions	Water demand in million m3/year
NSO	1.65
TT	0.24
Total	**1.89**

The forecasting of the industrial water demand is done considering the potential of industrial growth as per the assumptions on the growth rates provided in Water Demand Handbook (2012). The table below provides growth rates for three different scenarios for multiple sub-categories under the industries:

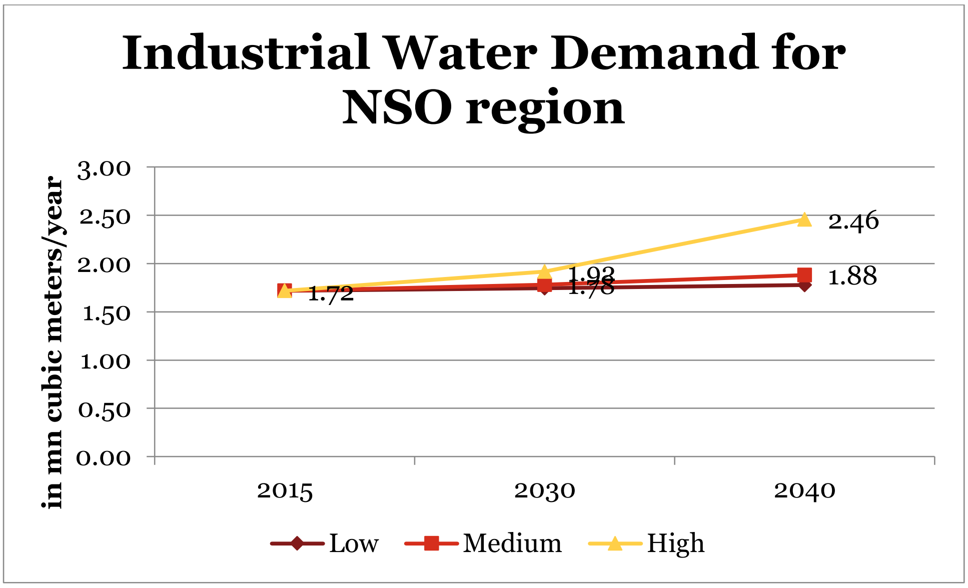
Sub-categories	Low	Medium	High
Manufacturing	4.0%	6.9%	12.6%
Construction	4.0%	6.9%	10.0%
Energy	2.5%	6.0%	10.2%

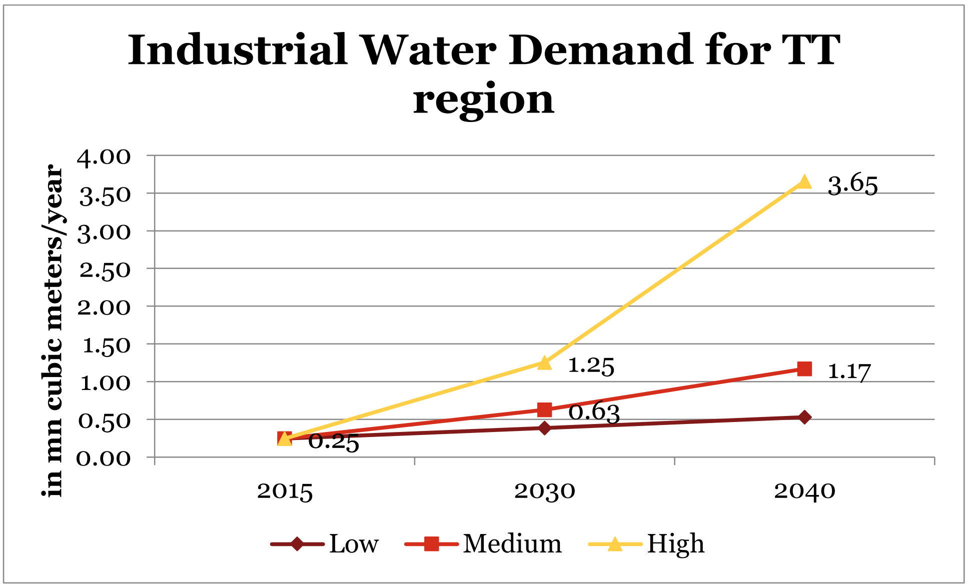
Based on the categorisation of the industries as mentioned above, different growth rates were considered and the water demand is projected for 2030 and 2040. The water demand across suoms is as below:

	2015	**2030**			**2040**		
Regions	**Base Case**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Dornogovi	**0.02**	**0.03**	**0.05**	**0.12**	**0.05**	**0.10**	**0.39**

Dalanjargalan	0.02	0.03	0.05	0.12	0.05	0.10	0.39
Govi-sumber	**0.02**	**0.03**	**0.04**	**0.10**	**0.04**	**0.08**	**0.32**
Bayantal	0.02	0.03	0.04	0.10	0.04	0.08	0.32
Khentii	**1.68**	**1.68**	**1.68**	**1.68**	**1.68**	**1.68**	**1.68**
Khentii	**1.68**	**1.68**	**1.68**	**1.68**	**1.68**	**1.68**	**1.68**
Tuv	**0.00**	**0.01**	**0.01**	**0.02**	**0.01**	**0.02**	**0.07**
Erdene	0.00	0.01	0.01	0.02	0.01	0.02	0.07
Umnugovi	**0.25**	**0.38**	**0.63**	**1.25**	**0.53**	**1.17**	**3.65**
Dalanzadgad	0.18	0.28	0.46	0.93	0.39	0.86	2.71
Other Suoms Galba Uush	0.07	0.10	0.17	0.33	0.14	0.31	0.94
Sub-total (NSO)	1.76	3.09	4.80	11.01	4.57	9.35	36.09
Sub-total (TT)	0.25	0.38	0.63	1.25	0.53	1.17	3.65
Grand Total	**1.96**	**2.13**	**2.41**	**3.17**	**2.31**	**3.05**	**6.11**

The range of industrial water demand in the two study regions is depicted in the graphs below:




Industrial Water Demand for TT region
in mn cubic meters/year
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2015
2030
2040
3.65
1.25
1.17
0.63
0.25
Low
Medium
High

7. Planned investments/ projects water demand

Information on planned investments and projects has been received from responsible ministries (Ministry of Energy, Ministry of Mining, Ministry of Environment, Green Development and Tourism) , from River Basin Administrations and the (state) companies planning these projects.

Water demand and the respective technologies have been verified with international benchmarks and have been cross checked against multiple sources, if available, to ensure accuracy. However, in some cases, data was insufficient to complete the required information. In these cases, international benchmarks were adjusted to the local context.

7.1. Planned projects in Nyalga Shivee Ovoo

Thermal Power Plants

MW	Operator	Mine Location	Baseline Water demand (m3 water withdrawals/ yr)
270	One Power Global Limited	Shivee Ovoo	860,000
750	IM Power Plc	Shivee Ovoo	380,000
5280	IM Power Plc	Shivee Ovoo	15,700,000
600	Tsetsens Minging and Energy LLC	Buuruljuutyn Tal	2,000,000

Coal-to-Liquid Plants

Production Volume	Operator	Mine Location	Baseline Water demand (m3 water withdrawals/ yr)
880,000 tons of diesel/gasoline and 84,000 tons LPG, 50,000 tons of other products	CTL Mongolia LLC	Tugrug Nuur	10,000,000
500,000 tons of diesel/gasoline	Tsetsens Mining and Energy	Buuruljuutyn Tal	4,500,000
600,000 tons of diesel/ gasoline	Germon Gas LLC	Shivee Ovoo	4,777,536

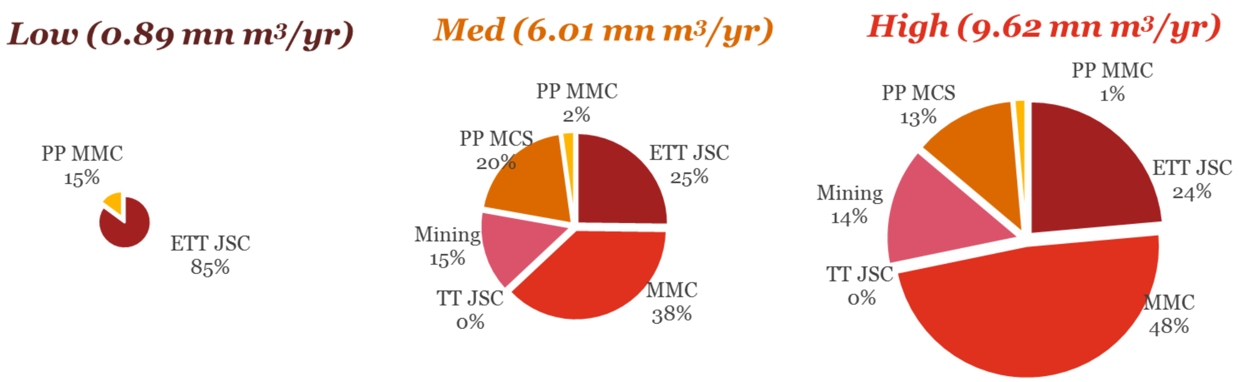
Coal to Briquette Plant

Production Volume	Operator	Mine Location	Baseline Water demand (m3 water withdrawals/ yr)
57,600 tons of coking coal	CAMEX LLC	Tugrug Nuur	57,600

7.2. Existing and planned projects in Tavan Tolgoi

In Tavan Tolgoi, some projects already exist and while scaling up, production may be planned. Other projects are currently planned. Some projects are mutually exclusive. Thus three scenarios on potential investments (expansion and new ones) were developed through stakeholder interaction.

The scenarios are listed below.



Coal washing options:

- *ETT JSC sand washing plant with 5 mn ROM/ yr cap*
- *MMC existing plant operating at 5 mn/ yr ROM*
- *TT JSC no operations*

Power plant option

- *MMC Power Plant 18 MW*

Coal washing options

- *ETT JSC wet washing plant with 15 mn ROM/ yr cap*
- *MMC existing plant operating at 10 mn ROM/ yr*
- *TT JSC existing dry enrichment plant operating*

Power plant option

- *MMC Power Plant 18 MW*
- *MCS Consortium Power Plant 450 MW*

Coal washing options

- *ETT JSC wet washing plant with 30 mn ROM/ yr cap.*
- *MMC existing plant operating at full capacity (15 mn ROM/ yr)*
- *TT JSC existing and planned dry enrichment plants operating*

Power plant option

- *MMC Power Plant 18 MW*
- *MCS Consortium Power Plant 450 MW*

7.3. Additional coal mining water requirements

To implement the above mentioned projects, additional coal will be required. To fully understand the impact of the additional coal mining on water requirements, this is separately assessed for each mining region. The estimates for Tavan Tolgoi region include the increase of production of the existing coal washing plant.

Nyalga Shivee Ovoo Region

L/ sec		Current Coal Production (mn tonnes)	Coal required for projects	Additional coal required	Current dust suppression	Current other water usage required	Total dust suppression required	Total other water usage required	Total additional water required
Shivee Ovoo Mine	Shivee Ovoo JSC	**1.96**	**29.24**	**27.28**	**17.50**	**5.00**	**52.5**	**5**	**29.24**
Tugrug Nuur Mine	Camex Tugrug Nuuryn Energy	**0**	**4.144**	**4.14**	**-**	**-**	**17.50**	**5.00**	**22.50**
Buuruljuuty n Tal Mine	Tsetsens Mining & Energy	**0**	**4.24**	**4.24**	**-**	**-**	**17.50**	**5.00**	**22.50**

Tavan Tolgoi region

l/ sec	**Coal requirement (mn tonnes/ year)**			**Dust suppression + Other water usage**	**Total Mine Water Demand required**			**Additional Mine Water Demand required**		
From Mine	**Low**	**Medium**	**High**	**No projects - international standard dust suppression**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
ETT	5	17	32	35.00	40.36	50.72	68.58	-	15.72	33.58
ER / UK	5.1	10.1	30.1	22.86	22.86	45.72	56.08	-	22.86	33.22
TT JSC	0.6	0.8	2	22.50	22.50	22.50	22.50	-	-	-
Total (l/sec)	10.7	27.9	64.10	80.36	85.72	118.94	147.15	-	38.58	66.79

Report Supplement # 3 – Water Demand Reduction Solutions

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1. Water Demand Reduction Solutions

This appendix identifies potential technological alternatives that could be implemented to reduce water withdrawal demand at existing projects and planned investments in the Nyalga-Shivee Ovoo and Tavan Tolgoi regions of Mongolia. Information on planned investments and projects in these regions has been received from responsible Ministries (Ministry of Energy, Ministry of Mining, Ministry of Environment, Green Development and Tourism), from River Basin Administrations and the (state) companies planning these projects.

For the purpose of this report, existing projects and planned investments can be summarised into the following categories:

- Thermal Power Plants;
- Coal-to-Liquid Plants;
- Coal to Briquette Plants;
- Coal Mining; and
- Coal Washing.

As highlighted in Chapter 4 and Appendix A2, baseline water withdrawal demand figures were identified for the different projects and investments. However, only minimal information could be obtained about the existing design/configuration of most of the existing projects and also those of the planned investments. This, therefore, presented a challenge in ensuring the application of appropriate technological alternatives and making required assumptions.

The following sections provide a brief summary of the different water withdrawal demands at each of project categories, details of the different technological options, and the assumptions that were used to calculate the revised demands at each of the projects with the application of these technological alternatives. The applicability of technological alternatives and the associated factors for water withdrawal reduction were discussed with stakeholders for verification.

2. Thermal Power Plants

2.1. Key water demands from thermal power plants

Thermal power generation requires a reliable access to large volumes of water. Traditionally, the largest single demand for water is associated with the cooling water system for the steam turbine condenser. Water is used to cool and condense the steam from the turbine. The second largest user of water is typically for the make-up water treatment plant that supplies the boilers for steam generation. The make-up water for fossil fuel boilers needs to be high purity deionised water with virtually complete removal of impurities. Other minor components of water use include: flue gas desulphurisation (FGD) for the removal of SO2 from gas flues at coal power stations; backwashing for boilers and other plant components; ash handling and dust suppression; domestic-type water use; and for cleaning and maintenance.

2.2. Cooling water systems

Power stations use different technologies for cooling. The preferred hierarchy of cooling technologies to achieve best thermal efficiency, subject to water resource availability and environmental impacts, is once through wet tower cooling, to air cooling (EC, 2001).

The main types of cooling technology can be summarised as:

Power stations use different technologies for cooling. The preferred hierarchy of cooling technologies to achieve best thermal efficiency, subject to water resource availability and environmental impacts, is once through wet tower cooling, to air cooling (EC, 2001).

The main types of cooling technology can be summarised as:

- **Once through cooling**: Characterised by very high abstraction volumes, the abstracted water is pumped to a cooling water circuit where it cools the turbine water, and is subsequently returned back to the environment at a higher temperature. This is the least complex, most thermally efficient, often cheapest option but not suitable in environments with low water availability.
- **Open wet recirculating systems**: Water from the condenser is sprayed into a cooling tower where it is cooled through a combination of evaporation and mixing with cool air as it moves up the tower through natural convection. This method has abstraction rates of about 1% of the rates required for the once through cooling method. Overall consumption rates can be up to 50% higher than for once through cooling.
- **Closed cycle recirculating systems**: The water from the condenser circulates within an internal circuit tube coil. A second external circuit, in which spray water circulated over the coil and mixes with the outside air. Heat is transferred from the warm fluid in the coil to the spray water and then into the atmosphere. This system has the advantage that the cooling water in the internal circuit remains clean and contaminant free in a closed loop.
- **Hybrid wet/dry cooling system**: A cooling system that uses both dry and wet cooling systems. These can be used individually or together. Wet cooling performance is better on the hottest days and dry cooling during the remainder of the year. Hybrid systems typically use 50% less water than wet systems.
- **Dry/air cooling**: The exhaust steam from the turbine condenser is air-cooled (e.g. a series of fans is used), utilising convective heat transfer. This avoids the need for cooling water and is suitable for sites where water availability is severely constrained.

2.2.1. Boiler make-up

Water is lost from the boilers through steam leaks and through water that is intentionally removed as boiler blowdown to remove impurities that accumulate. Replacement water is required to continue the production of steam. Make-up water is initially treated to remove floating and suspended materials and modern high-pressure boilers will require high quality demineralised water.

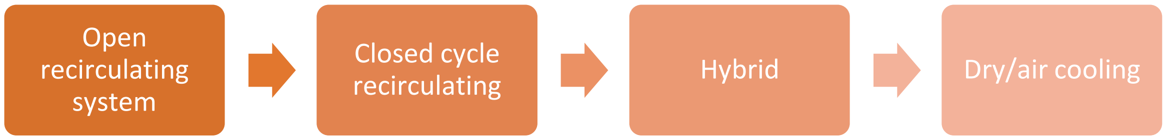
2.2.2. Flue gas desulphurisation

Flue-gas desulphurisation (FGD) is a set of processes to remove sulphur dioxide (SO_2) from exhaust flue gases of fossil-fuel power plants. Typical FGD systems in operation are wet systems whereby an aqueous slurry of the alkaline reagent is injected into the flue gas as it is passed through the scrubber. Wet systems have the highest removal efficiencies.

2.3. Technological alternatives

2.3.1. Cooling water system

The most significant requirement for water at coal power stations is for cooling purposes. Therefore, the main method to reduce water use is to select the most water efficient cooling system for new power stations and to consider the option to upgrade the cooling systems of the existing power station in the Tavan Tolgoi region. Disregarding once through systems, the hierarchy to reduce water use is shown in the Figure below. There are a wide variety of estimates of water withdrawals for different cooling systems and those used for this assessment are summarised in Table 14



2.3.2. Cooling water treatment

The concentration of harmful mineral solids in cooling water increases over time as water is evaporated. If left undiluted, these minerals can cause scaling of equipment and possibly damage the system. Treatment of this water to extend the time it can be used within the cooling system will save on the need for additional makeup and reduce the potentially harmful effects of blow-down water in receiving water bodies. McKinsey (2030 WRG, 2009) estimated that a 33% reduction in consumption could be achieved through water treatment. Operating expenditure was estimated to be $0.2-0.8/m3 with capital expenditure estimated at a quarter of this.

2.3.3. Boiler/cooling blowdown reuse

Blow down water, the water that is drained from cooling systems and boilers, could be reused following appropriate treatment, rather than discarded, for use elsewhere in the power station (e.g. makeup water, domestic water, irrigation) operation or for external purpose.

2.3.4. Semi-dry flue gas desulphurisation

Semi-dry FGD processes consume around 60% less water than wet scrubbers used in conventional wet FGD processes. The semi dry systems typically utilise a calcium based reagent which is introduced as a slurry or a dry power.

2.3.5. Use circulating fluidised bed boiler rather than a pulverised coal boiler

The combustion technology used to burn the coal in the power station can be changed to reduce the use of water. The use of a circulating fluidised bed (CFB) boiler rather than a pulverised coal boiler would reduce the consumption of water as:

- It requires less demineralised water to produce the same amount of steam (it is more effective and there is less losses) compared to a standard coal oven boiler

- A wet flue gas treatment is not required, as the exhaust has less SOx and NOx, compared to a standard pulverised coal oven.

McKinsey (2030 WRG, 2009) estimated that the installation of CFB boilers could typically reduce water withdrawals by 0.1m3/MWh.

2.4. Water withdrawal calculations

Estimates were obtained from the literature on the per unit water use at thermal power plants associated with above processes and technological alternatives and these were used as benchmarks for this study and are summarised in Table 2.1.

Table 4 Benchmark water withdrawal estimates obtained from the literature

Classification	Process	Baaseline			Water withdrawals (m3/MWh) following application of Technical Options when applied to Baseline							
		Water withdrawals (m3/MWh)	Cooling water treatment	% Reduction	Boiler blowdown reuse	% Reduction	Cooling water blowdown reuse	% Reduction	Semi-Dry FGD	% Reduction	CFB boilers	% Reduction
Cooling system	Open wet recirculating systems	2.010[1]	1.340[5]	33%								
	Closed cycle recirculating	1.100[2]	0.733[5]	33%								
	Hybrid wet/dry	0.777[1]	0.518[5]	33%								
	Dry/air cooled	0.000[3]										
Other	Boiler makeup	0.230[4]			0.153[7]	33%	0.000[6]	100%			0.130[5]	43%
	Wet FGD	0.235[4]							0.094[4]	60%		
	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);

ADB (2014) provides estimates of water withdrawals and consumption for thermal power plants in Mongolia. The data shows that withdrawals and consumption are typically much higher than those figures reported above and in Macknick et. al. (2012) with only two power plants having withdrawal rates in line with the ranges for recirculating systems.

Very limited information was available describing the existing or planned design of the thermal power plants in the Nyalga-Shivee Ovoo and Tavan Tolgoi region and extended to the broad class of cooling system (e.g. wet or dry/air cooled), generation capacity, boiler type and an annual estimate of water use. As such, we did not have an exact specification to use as the baseline design/configuration for each thermal power plant (e.g. which technological alternatives may already be implemented or exist in the plan) that additional technological alternatives could then be applied, and hence estimate the water demand reduction that could be achieved.

Our approach to overcome this was to use the benchmark per unit water use estimates from Table 2.1 to derive a theoretical benchmark water demand for a range of different design configurations (including the implementation of the different technological alternatives) and then find the closest match based on the annual water demand data and design information that had been provided. We assumed a capacity factor of 70% within the calculations. For example, if we knew the power plant was dry/air cooled with a CFB boiler we would choose the design configuration that had a calculated water demand that matched the closest to the provided annual water use figure. The baseline water withdrawal that we used in the analysis for each of the thermal plants was always the data that had been provided and the demand reduction was calculated for each technological alternative based on the proportional variation from the theoretical values.

Table 15 below summarises, for each thermal power plant, the demand reduction achieved by application of technological alternatives.

Table 5 Calculated water withdrawals with the application of technological alternatives for thermal power plants in Nyalga-Shivee Ovoo and Tavan Tolgoi

ID	Thermal Power Plant	Operator	Process Configuration	Added Technological Alternative	Annual generation capacity (MWh)	Water withdrawals (m^3/MWh)	Derived water withdrawals (m^3/yr)	Estimate Water withdrawals (m^3/yr)
Nyalga Shivee Ovoo								
1a	270 MW	One Power Global Limited	Wet Closed Cycle Recirculating, Circulating fluidised bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Baseline	1,655,640	0.606	1,002,954	860,000
1g	270 MW	One Power Global Limited	Hybrid (Dry/Wet) Cooling, Circulating fluidised bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	1,655,640	0.468	774,533	664,137
1h	270 MW	One Power Global Limited	Hybrid (Dry/Wet) Cooling, Circulating fluidised bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,655,640	0.391	647,347	555,079
1i	270 MW	One Power Global Limited	Dry/Air Cooled, Circulating fluidised bed boilers,	Dry/Air Cooled	1,655,640	0.180	298,015	255,538
1j	270 MW	One Power Global Limited	Dry/Air Cooled, Circulating fluidised bed boilers, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,655,640	0.103	170,829	146,480
2q	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Baseline	4,599,000	1.018	4,679,942	4,793,472
2r	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	4,599,000	0.941	4,326,647	4,431,606
2a	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	4,599,000	0.800	3,678,188	3,767,417
2b	750 MW	IM Power Plc	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	4,599,000	0.606	2,785,982	2,853,567
2k	750 MW	IM Power Plc	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	4,599,000	0.585	2,690,392	2,755,658
2l	750 MW	IM Power Plc	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	4,599,000	0.391	1,798,186	1,841,808
2m	750 MW	IM Power Plc	Dry/Air Cooled, Wet FGD	Dry/Air Cooled	4,599,000	0.515	2,368,485	2,425,942
2n	750 MW	IM Power Plc	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	4,599,000	0.438	2,015,190	2,064,076

2o	750 MW	IM Power Plc	Dry/Air Cooled, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	4,599,000	0.297	1,366,731	1,399,886
2p	750 MW	IM Power Plc	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	4,599,000	0.103	474,525	486,036
3a	5280 MW	IM Power Plc	Dry/Air Cooled, Wet FGD	Baseline	32,376,960	0.515	16,674,134	15,700,000
3b	5280 MW	IM Power Plc	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	32,376,960	0.438	14,186,936	13,358,109
3c	5280 MW	IM Power Plc	Dry/Air Cooled, Boiler Water Blowdown Reuse, Semi-Dry FGD	Semi-Dry FGD	32,376,960	0.297	9,621,785	9,059,662
3d	5280 MW	IM Power Plc	Dry/Air Cooled, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	32,376,960	0.103	3,340,655	3,145,487
4a	600 MW	Tsetsens Minging and Energy LLC	Dry/Air Cooled, Circulating fluidised bed boilers	Baseline	3,679,200	0.180	662,256	2,000,000
4b	600 MW	Tsetsens Minging and Energy LLC	Dry/Air Cooled, Circulating fluidised bed boilers, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	3,679,200	0.103	379,620	1,146,444
Tavan Tolgoi								
17a	18 MW	MMC	Dry/Air Cooled, Circulating fluidised bed boilers, Boiler Water Blowdown Reuse	Baseline	110,376	0.180	19,868	132,000
18a	450 MW	MCS	Dry/Air Cooled, Circulating fluidised bed boilers, Boiler Water Blowdown Reuse	Baseline	2,759,400	0.274	756,076	1,200,000

3. Coal to Liquid Plants

3.1. Key water demands from Coal to Liquid Plants

Converting coal to a liquid fuel (CTL), a process referred to as coal liquefaction, allows coal to be utilised as an alternative to oil. There are two different methods for converting coal to liquid fuels:

- Direct liquefaction works by dissolving the coal in a solvent at high temperature and pressure. This process is highly efficient, but the liquid products require further refining to achieve high grade fuel characteristics.
- Indirect liquefaction gasifies the coal to form a 'syngas' (a mixture of hydrogen and carbon monoxide). The syngas is then condensed over a catalyst – the 'Fischer-Tropsch' process – to produce high quality, ultra-clean products.

A range of products can be made via these processes – ultra-clean petroleum and diesel, as well as synthetic waxes, lubricants, chemical feedstocks and alternative liquid fuels such as methanol and dimethyl ether.

CTL facilities require substantial amounts of water (Nowakowski, 2008) and the three main processes where water is required for cooling, process water and boiler feed water. As for coal power plants in Section 2 above, cooling water is the largest water requirement. Process water is used in the liquefaction process and often plays a part in chemical reactions. Boiler feed water is used to produce steam. The volume of water required to operate a coal liquefaction plant is impacted by many variables, including the design of the liquefaction unit, the type of gasifier used to provide the syngas or hydrogen, the coal properties, and the average ambient temperature and humidity (Nowakowski,2008).

Nowakowski (2008) reports that in the 1990s, Bechtel analysed various coal indirect liquefaction schemes for the DOE, finding that eastern coal used about 7.3 gallons of water/gallon Fischer Tropsch liquid and western coal used about 5.0 gallons of water/gallon of Fischer Tropsch liquid.

NETL (2013) report water requirements for two different configurations of CTL plant using three different cooling technologies and are shown in Table 16

Table 6 Water requirements for CTL production.

	Recycle Fischer Tropsch			Once Through Fischer Tropsch		
Cooling	Wet Recirculating	Dry/Air Cooled	Hybrid	Wet Recirculating	Dry/Air Cooled	Hybrid
bbl water/bbl FFT product	6.68	1.61	3.92	7.91	1.85	4.66

Source: NETL (2013)

3.2. Technological alternatives

The water requirements for CTL plants are similar to that of thermal power plants. As such, the technological alternatives as described in A3.2 apply.

3.3. Water withdrawal calculations

Very limited information was available describing the planned design of the CTL plants in the Nyalga-Shivee Ovoo region. The information available differed between the different projects but included the installed capacity, coal requirement, and total annual water requirement. As with the thermal power plants, we did not have a specification to use as the baseline design/configuration for each CTL plant (e.g. which technological alternatives may already exist in the plan) that additional technological alternatives could then be applied, and hence estimate the water demand reduction that could be achieved.

To overcome this, we used the benchmark recycle Fischer Tropsch per unit water withdrawal estimates from Table 3.1 and the known installed capacity figures to derive theoretical benchmark water withdrawals for plants that use wet, hybrid and dry/air cooling systems. These figures were then compared to the data on water withdrawals that were provided. For the two plants that data was available, there was a close match to the water withdrawals calculated for wet cooling systems so this process was assumed to be the baseline.

The available water withdrawal data for these two plants was used as the baseline and the demand reduction was calculated for each technological alternative based on the proportional variation from the derived values as calculated for the thermal power plants.

Table 17 below summarises, for each CTL plant, the water withdrawal demand reduction achieved by application of technological alternatives.

Table 7 Calculated water withdrawals with the application of technological alternatives for planned CTL plants in Nyalga-Shivee Ovoo.

ID	Location	Operator	Process Configuration	Added Technological Alternative	Fuel Production Volume (m^3/year)	Water to fuel ratio	Derived water withdrawals (m^3/yr)	Estimate Water withdrawals (m^3/yr)
5a	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD	Baseline: Wet Closed Cycle Recirculating, Wet FGD	1,311,200	6.680	8,758,816	10,000,000
5b	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment,	Cooling Water Treatment	1,311,200	5.160	6,766,253	7,725,077
5c	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	1,311,200	4.209	5,518,868	6,300,929
5d	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,311,200	3.891	5,102,241	5,825,263
5e	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	1,311,200	3.308	4,337,539	4,952,198
5f	Tugrug Nuur	CTL Mongolia LLC	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse,Circulating fluidised bed boilers	Circulating fluidised bed boilers	1,311,200	2.506	3,285,397	3,750,960
5i	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	1,311,200	2.435	3,192,566	3,644,975
5j	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,311,200	2.202	2,887,075	3,296,193
5k	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	1,311,200	1.774	2,326,358	2,656,019
5l	Tugrug Nuur	CTL Mongolia LLC	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	1,311,200	1.186	1,554,876	1,775,212
5m	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD	Dry/Air Cooled, Wet FGD	1,311,200	1.610	2,111,032	2,410,180
5n	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	1,311,200	1.370	1,796,140	2,050,665
5o	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	1,311,200	0.929	1,218,168	1,390,791

5p	Tugrug Nuur	CTL Mongolia LLC	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	1,311,200	0.323	422,944	482,878
6a	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD	Baseline: Wet Closed Cycle Recirculating, Wet FGD	596,000	6.680	3,981,280	4,500,000
6b	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment,	Cooling Water Treatment	596,000	5.160	3,075,570	3,476,285
6c	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	596,000	4.209	2,508,576	2,835,418
6d	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	596,000	3.891	2,319,200	2,621,368
6e	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	596,000	3.308	1,971,609	2,228,489
6f	Buuruljuutyn Tal	Tsetsens Mining and Energy	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse,Circulating fluidised bed boilers	Circulating fluidised bed boilers	596,000	2.506	1,493,362	1,687,932
6i	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	596,000	2.435	1,451,167	1,640,239
6j	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	596,000	2.202	1,312,307	1,483,287
6k	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	596,000	1.774	1,057,436	1,195,209
6l	Buuruljuutyn Tal	Tsetsens Mining and Energy	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	596,000	1.186	706,762	798,845
6m	Buuruljuutyn Tal	Tsetsens Mining and Energy	Dry/Air Cooled, Wet FGD	Dry/Air Cooled, Wet FGD	596,000	1.610	959,560	1,084,581
6n	Buuruljuutyn Tal	Tsetsens Mining and Energy	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	596,000	1.370	816,427	922,799
6o	Buuruljuutyn Tal	Tsetsens Mining and Energy	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	596,000	0.929	553,713	625,856
6p	Buuruljuutyn Tal	Tsetsens Mining and Energy	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	596,000	0.323	192,247	217,295
24a	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Wet FGD	Baseline: Wet Closed Cycle Recirculating, Wet FGD	715,200	6.680	4,777,536	4,777,536
24b	Shivee Ovoo	Germon Gas LLC	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment,	Cooling Water Treatment	715,200	5.160	3,690,684	3,690,684

24c	Shivee Ovoo	Germon LLC	Gas	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	715,200	4.209	3,010,291	3,010,291
24d	Shivee Ovoo	Germon LLC	Gas	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	715,200	3.891	2,783,040	2,783,040
24e	Shivee Ovoo	Germon LLC	Gas	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	715,200	3.308	2,365,930	2,365,930
24f	Shivee Ovoo	Germon LLC	Gas	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	715,200	2.506	1,792,035	1,792,035
24i	Shivee Ovoo	Germon LLC	Gas	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Cooling Water Blowdown Reuse	715,200	2.435	1,741,400	1,741,400
24j	Shivee Ovoo	Germon LLC	Gas	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	715,200	2.202	1,574,768	1,574,768
24k	Shivee Ovoo	Germon LLC	Gas	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	715,200	1.774	1,268,923	1,268,923
24l	Shivee Ovoo	Germon LLC	Gas	Hybrid (Dry/Wet) Cooling, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	715,200	1.186	848,114	848,114
24m	Shivee Ovoo	Germon LLC	Gas	Dry/Air Cooled, Wet FGD	Dry/Air Cooled, Wet FGD	715,200	1.610	1,151,472	1,151,472
24n	Shivee Ovoo	Germon LLC	Gas	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse	Boiler Water Blowdown Reuse	715,200	1.370	979,713	979,713
24o	Shivee Ovoo	Germon LLC	Gas	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Dry FGD	Dry FGD	715,200	0.929	664,455	664,455
24p	Shivee Ovoo	Germon LLC	Gas	Dry/Air Cooled, Wet FGD, Boiler Water Blowdown Reuse, Circulating fluidised bed boilers	Circulating fluidised bed boilers	715,200	0.323	230,697	230,697

4. Coal to Briquette

4.1. Water use for Coal to Briquette Plants

Coal briquetting is a process by which low grade coal is converted into a higher grade, uniform, hard and impact resistance agglomeration with increased calorific value, that can be used for domestic and industrial purposes. The coal briquetting process consists of crushing and screening it, mixing the dry coal with a binder, briquetting this mixture in roll type briquette machine and finally cooling the briquettes before distribution. Water is used for cooling purposes and can form part of the binder which is applied to the pulverised coal by spray nozzles.

4.1.1. Technological alternatives

The following options were considered for use at the coal to briquette plant:

4.1.2. Water efficient sprinklers

Improved efficiency of the application of the binders could be achieved through the use of more efficient spray nozzles to reduce wastage through over application. With the right choice of nozzles, efficiency can be increased by up to 50% (WRAP, 2005, 2007).

4.1.3. Cooling water treatment

Cooling water treatment could be implemented to extend the time it can be used within the cooling system will save on the need for additional makeup and reduce the potentially harmful effects of blow-down water in receiving water bodies.

4.1.4. Semi-dry flue gas desulphurisation

Semi-dry FGD processes consume around 60% less water than wet scrubbers used in conventional wet FGD processes (Carpenter, 2012). The semi dry systems typically utilise a calcium based reagent which is introduced as a slurry or a dry power.

4.2. Water withdrawal calculations

No design information was available describing the planned configuration for the coal to briquette plant. The information available included the anticipated input coal (20 tonnes/cycle), output of coke (8 tonnes/cycle), total annual coal requirement (144,000 tonnes/year), and water requirement (8m^3/ cycle). From this data, the annual water requirement was calculated as 57,600m^3/year and 0.4m3/tonne of coke.

For the process of this assessment, it has been assumed that the cooling system in operation is wet closed loop and that water will be used as for binding. Information obtained from stakeholder interviews highlighted a water use rate of 0.07l/kg of coal for binding and 3m3/day for cooling water makeup per 10 tonnes of coke (Tseveen, 2015). It was also assumed that wet FGD would be in operation.

The water withdrawal data for the plant was used as the baseline and the demand reduction was calculated for each technological alternative based on the proportional variation from the derived values.

Table 18 below summarises the water withdrawal reduction achieved by application of technological alternatives. The derived baseline annual water withdrawal calculated using the per unit water demand for binding, cooling and wet FGD gave a total of 27,360m^3/year which is just under half the figure provided (57,700m^3/year).

Table 8 Calculated water withdrawals with the application of technological alternatives for planned coal to briquette plant.

ID	Process Configuration	Added Technological Alternative	Derived water withdrawals (m^3/yr)	Estimated water withdrawals (m^3/yr)
10a	Wet closed circuit cooling, binding, wet FGD	Baseline	27,360	57,600
10b	Wet closed circuit cooling, binding, wet FGD, cooling water treatment	Cooling water treatment	21,123	44,470
10c	Wet closed circuit cooling, binding, semi-dry FGD, cooling water treatment,	Semi-dry FGD	19,314	40,662
10d	Wet closed circuit cooling, semi-dry FGD, cooling water treatment, efficient sprinklers	Efficient sprinklers	14,274	30,052

5. Coal mining

5.1. Water use for the mining of coal

The quantity of water used to mine coal is dependent on whether it is a surface mine or is underground and the related processes and transportation that are used. There are a range of estimates of water use reported in the literature and Meilke et al. (2010) provide estimates from the US that covers water use for mining, washing and for transport via slurry.

Appendix A1 sets out information on water use at the existing and planned mines in the in the Nyalga Shivee Ovoo and Tavan Tolgoi regions respectively. The main water use at the mines is for suppressing dust associated with haul roads and stock piles. Water for domestic uses for workers (on and off-site) provides a small demand in comparison within Shivee Ovoo JSC

Excessive dust generation from unpaved mine haul roads is a common problem at most surface mine operations. Typically, mining operations require a significant focus on handling dust, both on mine roads and in the plant. Mines generally have a number of water trucks which spray the haul roads and other transportation routes to minimise dust generation. The exact volume of water required for water-spray based dust suppression varies depending upon the climatic conditions, area of coal stockpile and the area of active roads. The rate of watering volume can be derived by calculating the effective evaporation at the mine site multiplied by the surface area that requires watering increased by a factor of 1.4 on roads where vehicles increase the rate of evaporation. Increased rates of spraying for dust suppression will be required in the summer when maximum evaporation rates are recorded decreasing by a factor of 0.75 in the winter.

5.2. Technological alternatives

5.2.1. Dust suppressants

In addition to regular watering, a range of suppression or palliative treatment practices to reduce dust emissions from unsealed or unpaved mine haul roads are available to modify the erodability or erosivity of the road-truck surface interactions which include (Thompson and Visser, 2007):

- Chemical dust palliatives
- Armouring of the surface
- Application of a seal to the road
- The use of a tightly bound, high strength wearing course material

Thompson and Visser (2007) report that in addition to regular watering, the optimal selection of wearing course materials and chemical dust suppressants are the only viable alternatives that can be used. Jones (1996) and ARRB (1996) characterise the broad class of chemical products as hygroscopic salts, lignosulphonates (organic binders), petroleum resins, polymer emulsions and tar and bitumen-emulsion products. For the purpose of this study we have considered the following suppression treatments:

5.2.1.1. Organic binders

Organic binders (e.g. lignosulphonate and vegetable oils) act to adhere particles together directly and hence reduces dust generation. These require less water in preparation and in the application of the binders – than just using water on its own.

General Electric have reported reductions in water use associated with dust suppression by between 67-90% by using organic binders to harden road surfaces. In Newmont Mining Corporation's eastern operations in the state of Nevada, western United States, high dust levels were a concern. Water use for dust suppression on 7 miles of haul roads was reduced by 90% or 110 million gallons of water over a 7 month period saving $378,000 annually (GE, 2006). In a gold mine in Chile, nearly 12 million gallons of water (nearly two thirds) was saved annually, reducing operating expenses by $54,000 annually (GE, 2010).

Based on the outputs of these two studies, an average reduction in water use of 75% will be used.

5.2.1.2. Calcium Chloride

Hygroscopic salts (chlorides) attract moisture from the surrounding air, keeping the road surface moist which holds the particles together and hence act to reduce dust generation. Typically applied in solution to the road, the overall water requirement is lower than water on its own and with the use of organic binders. Amponsah-Dacosta (1997) investigated the effectiveness of different dust suppressant techniques including the use of calcium chloride and reported that an 83% reduction in water use could be achieved through the use of this treatment.

5.3. Water withdrawal calculations

Primary/actual data is available on dust suppression for key mines, however, these values are low, as compared to international benchmarks. To ensure sufficient water is allocated to the practice of environmentally sustainable mining, the actual dust suppression is recorded as baseline value, while future scenarios adopt water requirements to meet international benchmarks. Estimates of water withdrawals for each of the different mines is provided in Tables 19-24 below given different growth scenarios as highlighted in Appendix A2.

Table 9 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining - Shivee Ovoo JSC

ID	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m^3/yr)
	Baseline		12.73	275,999
	Baseline	Organic Binders	3.18	69,000
	Baseline	Calcium Chloride	2.12	46,000
	Low		52.50	1,138,253
	Low	Organic Binders	13.13	284,563
	Low	Calcium Chloride	8.75	189,709
	Medium		52.50	1,138,253
	Medium	Organic Binders	13.13	284,563
	Medium	Calcium Chloride	8.75	189,709
7a	High		52.50	1,138,253
7b	High	Organic Binders	13.13	284,563
7c	High	Calcium Chloride	8.75	189,709

Table 10 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining - Tugrug Nuur

ID	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m^3/yr)
	Low		17.50	379,418
	Low	Organic Binders	4.38	94,854
	Low	Calcium Chloride	2.92	63,236
	Medium		17.50	379,418

	Medium	Organic Binders	4.38	94,854
	Medium	Calcium Chloride	2.92	63,236
8a	High		17.50	379,418
8b	High	Organic Binders	4.38	94,854
8c	High	Calcium Chloride	2.92	63,236

Table 11 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining - Buuruljuutyn Tal

ID	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m3/yr)
	Low		17.50	379,418
	Low	Organic Binders	4.38	94,854
	Low	Calcium Chloride	2.92	63,236
	Medium		17.50	379,418
	Medium	Organic Binders	4.38	94,854
	Medium	Calcium Chloride	2.92	63,236
9a	High		17.50	379,418
9b	High	Organic Binders	4.38	94,854
9c	High	Calcium Chloride	2.92	63,236

Table 12 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining – Other mines

ID	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m3/yr)
	Low		8.00	433,620
	Low	Organic Binders	2.00	108,405
	Low	Calcium Chloride	1.33	72,270
	Medium		8.00	1,387,584
	Medium	Organic Binders	2.00	346,896
	Medium	Calcium Chloride	1.33	231,264
39a	High		17.50	7,588,350
39b	High	Organic Binders	4.38	1,897,088
39c	High	Calcium Chloride	2.92	1,264,725

Table 13 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining - Erdenes TT

ID	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m^3/yr)
	Baseline		8.00	173,448
	Baseline	Organic Binders	2.00	43,362
	Baseline	Calcium Chloride	1.33	28,908
	Low		35.00	758,800
	Low	Organic Binders	8.75	189,700
	Low	Calcium Chloride	5.83	126,467
	Medium		50.94	1,104,395
	Medium	Organic Binders	12.74	276,099
	Medium	Calcium Chloride	8.49	184,066
19a	High		63.44	1,375,408
19b	High	Organic Binders	15.86	343,852
19c	High	Calcium Chloride	10.57	229,235

Table 14 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining - Energy Resources

	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m^3/yr)
	Baseline		7.13	139,409
	Baseline	Organic Binders	1.78	34,852
	Baseline	Calcium Chloride	1.19	23,235
	Low		17.50	379,418
	Low	Organic Binders	4.38	94,854
	Low	Calcium Chloride	2.92	63,236
	Medium		35.11	761,220
	Medium	Organic Binders	8.78	190,305
	Medium	Calcium Chloride	5.85	126,870
20a	High		40.11	869,625
20b	High	Organic Binders	10.03	217,406
20c	High	Calcium Chloride	6.69	144,937

Table 15 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining - TT JSC

ID	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m3/yr)
	Baseline		1.30	28,185
	Baseline	Organic Binders	0.98	7,046
	Baseline	Calcium Chloride	0.22	4,698
	Low		17.50	379,418
	Low	Organic Binders	4.38	94,854
	Low	Calcium Chloride	2.92	63,236
	Medium		17.97	389,608
	Medium	Organic Binders	4.49	97,402
	Medium	Calcium Chloride	3.00	64,935
30a	High		17.97	389,608
30b	High	Organic Binders	4.49	97,402
30c	High	Calcium Chloride	3.00	64,935

Table 16 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining – Other mines

ID	Scenario	Added Technological Alternative	Dust Suppression (l/sec)	Estimated water withdrawals (m3/yr)
	Baseline		0	0
	Baseline	Organic Binders	0	0
	Baseline	Calcium Chloride	0	0
	Low		8.00	173,400
	Low	Organic Binders	2.00	43,350
	Low	Calcium Chloride	1.33	28,900
	Medium		17.50	555,030
	Medium	Organic Binders	4.38	138,758
	Medium	Calcium Chloride	2.92	92,505
40a	High		17.50	3,040,000
40b	High	Organic Binders	4.38	760,000
40c	High	Calcium Chloride	2.92	506,667

6. Coal washing plants

Coal washing is a process whereby impurities (e.g. ash, rock and sulphur) are removed from the coal, improving its combustion efficiency and therefore increasing its value. Physical cleaning processes are most commonly used, which involves the mechanical separation of the contaminants from the coal using gravity separation processes.

6.1. Water use in coal wash plants

The exact physical processes used in coal wash facilities vary between plants but generally involve four phases of preparation, fine coal processing, coarse coal processing and lastly final preparation. The fine and coarse coal processing will typically use the same approach whereby a bed of crushed coal and impurities are fluidised (usually by water) causing the heavier impurities to sink to the bottom and can be removed and the lighter coal particles will rise to the top. The wet clean coal must then go through a process to be dried.

6.2. Technological alternatives

The following technological alternatives have been identified:

6.2.1. Belt presses

Dewatering of the wet clean coal by belt presses is currently being used in the existing coal wash facility in Tavan Tolgoi. Water is recycled through 'squeezing' out the tailings through these highly efficient belt presses which are estimated to have a 60% recovery rate (MMC, 2015). Total water requirements for coal washing are estimated to be 60l/s for 5Mt/year production and with this, 60% recovery in place equates to 24l/s makeup from other supplies (MMC, 2015).

6.2.2. Dry Coal Cleaning technology

Coal washing can be achieved without the use of water using dry cleaning technologies. Houwelingen and de Jong, (2004) investigated the improvements of dry fluidised bed separation technologies for coal separation and summarise the different dry separating processes (cleaners) which can be used, based on gravity force in combination with the density, friction, and resiliency of the materials. Sand washing is one such separation technique which uses dry fluidised sand beds. For the purpose of this assessment, we assumed zero water demand when using dry coal cleaning technologies.

6.3. Water withdrawal calculations

Based on the existing/planned production rates and water requirements for the different technological alternatives, water withdrawals estimates for coal plants are provided in Table 25 below given different growth scenarios.

Table 17 Calculated water withdrawals for dust suppression with the application of technological alternatives for coal mining - Booroljuutiin Tal

ID	Coal Wash Plant	Scenario	Production (Mt/year)	Added Technological Alternative	Water Requirement (l/sec)	Estimated water withdrawals (m^3/yr)
28a	Energy Resources	Baseline/Low	5	Belt Presses	24	756,864
28b	Energy Resources	Baseline/Low	5	Dry Cleaning	0	0
31a	Energy Resources	Medium	10	Belt Presses	48	1,513,728
31b	Energy Resources	Medium	10	Dry Cleaning	0	0
32a	Energy Resources	High	15	Belt Presses	72	2,270,592

32b	Energy Resources	High	15	Dry Cleaning	0	0
27a	ETT	Low	5	Dry Cleaning	0	0
15a	ETT	Medium	15	Belt Presses	72	2,270,592
15b	ETT	Medium	15	Dry Cleaning	0	0
25a	ETT	High	30	Belt Presses	144	4,54,184
25b	ETT	High	30	Dry Cleaning	0	0

7. References

2030 WRG (2009) Charting Our Water Futures: Economic frameworks to inform decision-making.

ADB (2014). Demand in the dessert. Mongolia's water-energy-mining nexus.

Amec Foster Wheeler (2015), Pers. Comm. Elena Gil-Aunon.

Amponsah-Dacosta, F (1997). Cost-effective strategies for dust control in an opencast coal mine. Master of Science Dissertation. Faculty of Engineering, University of Witwatersand, Jonnesburg.

Australian Roads Research Board, (1996). Evaluation of chemical dust suppressants performance. Road dust control techniques. Australian Roads Research Board Special Report 54, Victoria, Australia.

Bushart, S. (2014) Advanced Cooling Technologies for Water Savings at Coal-Fired Power Plants. Electric Power Research Institute. Accessed 09/10/2015 http://cornerstonemag.net/advanced-cooling-technologies-for-water-savings-at-coal-fired-power-plants.

Carpenter, A.M. (2012). Low water FGD technologies. IEA Clean Coal Centre

Department of Energy (2010). Cooling water issues and opportunities at US Nuclear Power Plants. A Report to the U.S. Department of Energy Office of Nuclear Energy.

European Commission (2001). IPPC Reference Document on the application of Best Available Techniques to Industrial Cooling Systems.

General Electric (2006). Dust suppression strategy saves gold mine 378,000 annually. Retrieved 09/07/2015. http://www.ge.com/in/sites/www.ge.com.in/files/GE-Newmont-save-Dustreat.pdf

General Electric (2010). GE Dust Control Solution Helps La Coipa Gold Mine In Chile's High Desert Save Nearly 12 Million Gallons Of Water Annually. Retrieved 09/07/2015. http://www.wateronline.com/doc/ge-dust-control-solution-helps-la-coipa-gold-0001

GWMS (2015a) Working Paper 3 – Groundwater availability and development potential: Shivee Ovoo.

GWMS (2015b) Working Paper 4 – Groundwater availability and development potential: Tavan Tolgoi

Houwelingen, J.A & Tako P.R. de Jong (2004). Dry cleaning of coal: review, fundamentals and opportunities. Geologica Belgica, 7/3-4: 335-343.

Jones, D. (1996). The impacts and control of dust on mine haul roads. Proceedings of the South African Institute of Mining and Metallury Conference on Surface Mining. Glen H.W. (ed.), Sandton, South Africa.

Koch Membrane, (2010) Boiler feed water: Purifying cooling tower water reduces costs. In Filtration + Separation March/April 2010. Retrieved 17/09/2015. http://csmres.co.uk/cs.public.upd/article-downloads/Purifying%20cooling%20tower%20water%20reduces%20costs_a8535.pdf.

MMC, (2015). Pers. Comm. Baasandorj Tsogoo 7th October 2015

Thompson, R.J and A. T. Visser (2007). Selection, performance and economic evaluation of dust palliatives on surface mine haul roads. Journal of the Southern Africa Institute of Mining and Metallurgy. Vol. 107.

Macknick, J., Newark, R., Heath, G. and Hallet, K.C (2012). Operational water consumption and withdrawal factors for electricity generating technologies: a review of existing literature. Environ. Rs. Lett.

Mielke, E., Diaz Anadon, L., and Narayanamurti, V. (2010). Water Consumption of Energy Resource Extraction, Processing, and Conversion, A review of the literature for estimates of water intensity of energy-resource extraction, processing to fuels, and conversion to electricity. Energy Technology Innovation Policy Discussion Paper No. 2010-15, Belfer Center for Science and International Affairs, Harvard Kennedy School, Harvard University.

NETL (2013). Coal to liquids and water use. [Online] Available from: http://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/ctl-water-use. [Accessed 24th April 2015].

Nowakowski, S, (2008) Coal to Liquids Water Usage. Available from: http://leg.mt.gov/content/committees/interim/2007_2008/energy_telecom/assigned_studies/coal2liquidpage/Coal2liquidone.pdf [Accessed 24th April 2015].

Sahut Conreur (2006). Coal briquetting technology. Retrieved 16/09/2015. http://almoit.com/allegati/applicazioni_particolari/15/COAL%20BRIQUETTING%20TECHNOLOGY.pdf

Tsveen (2015). Pers. Comm.

WRAP (2005). The Rippleffect: water efficiency for business. Cost-effective water saving devices and practices - for industrial sites.

WRAP (2007). Reducing water use in washrooms: taps

Report Supplement # 4 – Assessment Framework

1. Assessment Framework

A.1. Methodology on Assessment Framework

A.1.1. Review of criteria

A.1.1.1. Financial criteria

A.1.1.1.1. 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 (mining activities, TPPs, CTLs and CTB as well as new groundwater borehole development), 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 include12 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 criteria 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. For the comparative analysis of different alternatives.
3. As a critical element for the estimation of a cost-effectiveness ratio (see below).

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 TPP of the share of total investment that corresponds to that of the cooling system. In other cases, installed capacity of the project (MW for TPP, m^3 for CTL, tonnes for mining, etc.) 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 or per tonne of mining output were used.

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 mining and energy projects. They would be more relevant if appraising these projects themselves, which is not the case.

A.1.1.1.2. Technical effectiveness

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

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 and groundwater abstraction issues in the regions 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 total water demand per alternative (e.g. TPP, CTL, CTB plants or mining sites). It is expressed in m^3 of water per year per project alternative. The impact of water supply measures, most notably, development of new groundwater abstraction boreholes is expressed in m^3 of water supplied per year per borehole field.

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.1.1.1.3. 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 at mining sites, TPPs, CTLs and CTB plants).

This ratio also allows prioritizing different project alternatives considered in NSO and TT regions 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. new groundwater boreholes).

A.1.1.1.4. Potential impact of an increase in the Water Abstraction Fee

This criterion aims at reflecting anticipated impact of the increase in the Mongolian water resources use fee on the project alternatives considered.

Increase in the Mongolian water resources use fee would directly contribute to the increase in opex. However, such increase may instigate consideration of water efficient technologies and installation of water reuse and recycling systems.

This criterion is not used in the prioritization of project alternatives. The assessment is qualitative, focused on presenting available evidence on the impacts of the increase in the water abstraction fee on the planned investments using the outcomes of consultation activities.

A.1.1.2. Economic criteria

A.1.1.2.1. Impacts on recreation and (eco-) tourism

This criterion aims to reflect economic impacts on (eco-) tourism and recreation stemming from the implementation of the project alternatives considered.

The considered types of projects (mining, TPPs, CTLs and CTBs) have a potential to cause adverse impact on tourism and recreation in the regions. However, the impacts associated with the project alternatives considered would be project and site specific and may vary with distance and for every other project.

This criterion is not used in the prioritization of project alternatives. Quantitative information is not available at a project level so the assessment is qualitative focusing on presenting diverging and limited evidence on the impacts on eco-tourism and recreation.

A.1.1.2.2. 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 for mining 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 (i.e. through dust suppression in mining activities).

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 or mining output. This information on emissions does not reflect actual emissions from these plants or mining sites since such information has not been disclosed but rather data from life-cycle analyses (LCA) of lignite-fueled power plants, CTLs, CTBs and coalmines 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.1.1.5. on assumptions for more detailed information on coefficients and unit damage values)

A.1.1.2.3. Employment

This criterion is aimed to reflect anticipated impacts of the project alternatives considered on direct (at the project level), indirect (e.g. in sectors supplying goods and services to the mining and power generation sectors) and induced (in other sectors of economy) employment. Any investment projects (including investments in water management projects) have the potential to generate and induce new employment benefiting the welfare of the soum, the aimag and Mongolia as a whole.

This is part of the so-called multiplier effect of these investments and represents a wider macroeconomic impact.

This criterion is used in the prioritization of different project alternatives at a semi-qualitative level. Generation of employment as a result of implementation of the planned projects is expressed in terms of the estimated number of full time jobs generated. Generation of employment as a result of implementation of different project alternatives considered is also expressed in terms of the FTEs (full time equivalent, i.e. number of jobs), which in the absence of data can be calculated with employment multipliers based on the project investment.

Generation of indirect and induced employment is also calculated using multipliers available for the Mongolian economy or similar projects in the country.

A.1.1.2.4. Induced investment and growth

This criterion is aimed to reflect anticipated impacts of the investments associated with implementation of different project alternatives on induced investments and growth.

Any investment projects (including investments in water management projects) have the potential to generate and induce new investments and economic growth; thus, increasing the welfare of the soum, the aimag and Mongolia as a whole.

This criterion is not used in the prioritization of different project alternatives.

Impact of investments associated with different project alternatives on investment and growth has been expressed in monetary terms, i.e. USD per project. Induced impacts on investment and growth associated with some of the project alternatives are calculated using the so-called multipliers available for Mongolia including, for example, the GDP and tax multiplier.

A.1.1.3. Environmental criteria

A.1.1.3.1. Impact on available water quantity

This criterion aims to reflect on availability of water for environmental needs (in addition to meeting domestic, industrial (including mining and power 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 is used in the prioritization of project alternatives at a semi-qualitative level. The assessment is semi-qualitative (using a scale) focused on presenting available evidence on the impacts of different project alternatives on water availability for environmental needs.

A.1.1.3.2. 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 mines, TPPs, CTLs and CTB, substantial chemical pollution of land and water .

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

A.1.1.3.3. 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 TPPs and CTLs, can result in substantial adverse impacts to the land ecosystem, as these change oxygen levels in the surrounding environment.

This criterion is used in the prioritization of different project alternatives at a semi-qualitative level. The assessment is semi-qualitative (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.1.1.3.4. 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 the mining and power production sector as well as development of new groundwater abstraction boreholes 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, installed capacity, or mining output.

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.1.1.5 on assumptions for more detailed information on coefficients and unit damage values).

A.1.1.3.5. 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 mining and power production 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 mining and energy projects, as well as new groundwater abstraction 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, installed capacity, or mining output. 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.1.1.5 on assumptions for more detailed information on coefficients and unit damage values).

A.1.1.4. Social criteria

A.1.1.4.1. Access to and affordability of water services

This criterion is aimed at reflecting anticipated impacts of different project alternatives considered on provision and affordability of water services. Impacts of the implementation of different project alternatives in the regions could be complex in relation to water services provision and access to these.

On one hand, intention to provide water to local communities is included in the planned projects. On the other, increased use of water resources for planned energy projects could result in a reduced access by local communities. However, implementation of such investments for mining and energy purposes as well as for water transfers may entail an increase in water prices as a means to recover (if partially) the costs affecting users' affordability.

This criterion is not used in the prioritization of project alternatives. The assessment is qualitative, focusing on presenting available evidence regarding potential contribution of different project alternatives to an improved water access and resulting in a positive impact on affordability of these services. Available examples of investors' plans to provide water services to local communities are presented as practical illustrations.

A.1.1.4.2. Access to and affordability of energy services

This criterion is aimed at reflecting anticipated impacts of different project alternatives considered on grounds of provision, reliability, and affordability of energy services. Implementation of different project alternatives in power production sector could, potentially, result in expanded provision of domestic supply and consumption of energy. In other words, construction of the TPPs aimed at providing energy to meet demand in Mongolia would contribute to improved energy security to all citizens. However, implementation of such investments within energy plants will have an impact on energy prices.

This criterion is not used in the prioritization of project alternatives. The assessment is qualitative, focusing on presenting available evidence regarding potential contribution of different project alternatives to an improved domestic energy supply and resulting in a positive impact on the affordability of these services due to implementation of water related investments at TPPs and other sites.

A.1.1.4.3. Impacts on human health from improved access to water and electricity

This criterion aimed at reflecting anticipated impacts of different project alternatives considered on improved levels of human health and comfort due to improved access to water and energy services. Implementation of different project alternatives could, potentially, result in an indirect benefit of an improved access to water (because of less demand in mining & energy activities) and energy (as a result of improved supply of energy services) contributing to improved human health and general comfort levels of local population.

This criterion is not used in the prioritization of project alternatives. The assessment is qualitative, focusing on presenting available evidence regarding potential contribution of improved water and energy services provision on human health and improved comfort. Some ratios are available at a country (not project) level.

A.1.1.5. Summary of applied criteria

The following table presents a summative description of the applied criteria and the way these have been assessed:

- Quantitative criteria: Criteria for which there is actual quantitative information or for which it is possible to arrive at an estimated value. These criteria have, then, been converted into semi-qualitative values to be used in the ranking of technological alternatives.
- Semi-qualitative criteria: Criteria for which there is no quantitative information available or for which estimations cannot be arrived at based on literature review, but values are assigned focusing on presenting available evidence on the impacts and using the outcomes of consultation activities.
- Qualitative assessment: there is neither quantitative information nor enough detailed information to assign semi-qualitative values. The assessment is focused on presenting diverging and limited evidence on the impacts of the criteria on water users and other recipients.

Criteria	QT	Semi-QL	QL	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 lifespans · The CE ratio is then converted into semi-qualitative values to be used in the ranking of technological alternatives. Values have been established from 1 to 4; 1 being the most cost effective option and 4 the least cost effective one. Values: <-14:1; -14-0:2; 0-10:3; >10:4 (if water savings are negative, 4 is assumed for comparison)
Potential impact of an increase in the Water Abstraction Fee			★	· It focuses on presenting available evidence in the report on the basis of the impacts of the increase in the water abstraction fee on the planned investments using the outcomes of consultation activities. It is a qualitative assessment not included for quantitative assessment purposes.
Impacts on recreation and (eco-) tourism			★	· It focuses on presenting diverging and limited evidence on the impacts on eco-tourism and recreation. Quantitative information is not available at a project level, thus it is a qualitative assessment not included for for quantitative assessment purposes

Criteria	QT	Semi-QL	QL	Description
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, emission of air pollutants from combustion, lost productivity from mercury emissions, excess mental retardation cases from mercury emissions, and excess cardiovascular disease from mercury. · These damage costs were converted into semi-qualitative values, which were assigned to the reduced health impact of the different technological alternatives. Values have been established from 1 to 4; 1 being the biggest reduction in health impacts and 4 the smallest impact reduction: <-18,500:1; -18,500-0:2; 0-500,000:3; >500,000:4.
Employment		★		· Employment values are either obtained from project specific information or are estimated based on the installed capacity or the investment and employment multipliers for the Mongolian economy. · Values ranging from 1 to 4 are then assigned, being 1 the projects, which are more employment intensive and 4 projects less employment intensive. Values: >3000:1; 3000-500:2; 500-400:3; <400:4
Induced investment and growth			★	· Impact of investments associated with different project alternatives on investment and growth should be expressed in monetary terms, per project. However multipliers for most technologies are not available.
Impact on available water quantity		★		· It focuses on presenting available evidence on the impacts of different project alternatives on water availability for environmental needs. · Values are assigned as follows: not relevant, no impact: 1; low relevance; low impact: 2; relevant, medium impact: 3; high relevance, high impact: 4
Chemical pollution of water and land		★		· It focuses on presenting available evidence on the impacts of different project alternatives on water quality for environmental needs. It includes chemical and wastes affecting water quality. · Values are assigned as follows: not relevant, no impact: 1; low relevance; low impact: 2; relevant, medium impact: 3; high relevance, high impact: 4
Thermal pollution of water and land		★		· Discharge of cooling water associated with alternative projects are expressed in m^3 of wastewater per year per project alternative. · Values are assigned as follows: not relevant, no impact: 1; low relevance; low impact: 2; relevant, medium impact: 3; high relevance, high impact: 4

Criteria	QT	Semi-QL	QL	Description
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). · These damage costs were converted into semi-qualitative values, which were assigned to the reduced damages of the different technological alternatives. Values have been established from 1 to 4; 1 being the biggest reduction in damages and 4 the smallest: <-2,250: 1; -2,205-0: 2; 0-69,000: 3; >69,000: 4
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): NH3 (0.0988 g/t), Non-methane Hydrocarbons, including VOCs (0.21 g/t), NOX (3.35 g/t) and SO2 (6.7 g/t). Coefficients of unit-monetized damages on biodiversity (vegetation, fauna) were used for NH_3, Non-methane Hydrocarbons, including VOCs, NO_X and SO_2. · These damage costs were converted into semi-qualitative values, which were assigned to the reduced damages of the different technological alternatives. Values have been established from 1 to 4; 1 being the biggest reduction in damages and 4 the smallest: <-11,800: 1; -11,800-0: 2; 0-356,000: 3; >356,000: 4
Access to and affordability of water services			★	· The assessment focuses on presenting available evidence regarding potential contribution of different project alternatives to an improved water access and resulting impact on affordability of these services. It is a qualitative assessment not included for assessment purposes.
Access to and affordability of energy services			★	· The assessment focuses on presenting available evidence regarding potential contribution of different project alternatives to an improved domestic energy supply and resulting impact on affordability of these services due implementation of water related investments. It is a qualitative assessment not included for assessment purposes.
Impacts on human health from improved access to water and electricity			★	· The assessment focuses on presenting available evidence regarding potential contribution of improved water and energy services provision on human health and improved comfort. It is a qualitative assessment not included for assessment purposes.

A.1.2. 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 the NSO and TT regions. 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

Social criteria have not been used in the prioritization as it has been explained above.

A.1.3. 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.1.3.1. Financial criteria

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

A.1.3.1.1. Thermal 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 leveled 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.1.3.1.2. Coal to liquid plants

Summary (sub-bituminous)	Recycle FT reactor			Once-through FT reactor		
Cooling type	Wet	Dry	Hybrid	Wet	Dry	Hybrid
Coal feed (TPD)	28,985	29,923	29,413	32,469	32,452	32,452
Diesel (BPD)	34,302	34,302	34,302	34,302	34,302	34,302
Naphtha (BPD)	15,698	15,698	15,698	15,698	15,698	15,698
Total (BPD)	50,000	50,000	50,000	50,000	50,000	50,000
Efficiency, HHV (%)	53	51.3	52.2	50.6	50.1	50.5
Export Power (MW)	0	0	0	227.2	190.9	213.9
Parasitic Power (MW)	504.5	539	524.6	568.4	588	581.9
Water (gpm)	9,741	2,348	5,715	11,540	2,693	6,798
Water (bbl water/bbl FT product)	6.68	1.61	3.92	7.91	1.85	4.66
Cooling water system cost (USDMM)	50	0	31	57	0	35
Air cooling system cost (USDMM)	0	200	122	0	215	130
Bare Erected Cost	4,238	4,473	4,384	4,735	4,848	4,822
Coal (USDMM/yr)	116	120	118	130	130	130
O&M (USD MM/yr)	411	424	418	454	455	455
Total plant costs (USD MM)	5,618	5,929	5,812	6,276	6,426	6,392

Total Overnight Cost (USD MM)	7,020	7,400	7,255	7,836	8,015	7,975
Total Overnight Cost (USD/DB)	140,380	148,020	145,100	156,720	160,300	159,480
Required Selling Price (USD/bbl FT diesel)	112.7	118.1	115.9	117.3	120.7	119.4
Crude Oil Equivalent (USD/bbl petroleum)	93.9	98.4	96.6	97.8	100.6	99.5

Lifetime	Years	Source
Coal to liquid plants	30	NETL, 2011

A.1.3.1.3. Coal to Briquette

Source: England, 2000. Based on a 25 tph plant (in Rand)					
Cost of agglomeration	Briquetting (Koppern)	Briquetting (Sahut Conreur)	Binderless Briquetting	Palletising	Extrusion
Capital cost					
Filtration	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
Thermal Drying	9,500,000	9,500,000	9,500,000		
Binder add/control	1,100,000	1,345,528	0		
Agglom. Equipment	3,500,000	2,022,400	3,500,000	12,500,000	12,500,000
Curing/Post treatment	500,000	195,920	0	12,500,000	12,500,000
Electrical	900,000	628,914	617,647		
Civils & stuctures	1,700,000	1,187,949	1,166,667		
Erection & installation	2,200,000	1,537,346	1,509,804		
Total	29,400,000	26,418,057	23,000,000	35,000,000	35,000,000
Cost R/ton/hour	1,176,000	1,056,722	920,000	1,400,000	1,400,000
Operating cost/month					
Labour	57,600	57,600	57,600	57,600	57,600
Maintenance	212,500	197,440	196,814	291,667	291,667
Binder	531,250	531,250	0	286,875	286,875
Energy					
TOTAL	801,350	786,290	254,414	636,142	636,142

Installed 25 tons/hour plant [Source: Mangena and Korte, 2005]		
	(R/ton) opex	R capex
Capital cost		41,000,000
Operating cost:	53	
> Filtration	10	
> Thermal drying	15	
> Binder less briquetting	18	
> Devolatilisation	10	

Lifetime	Years
Coal to Briquette	20

A.1.3.1.4. Mining

Coal washing

Honaker, 2007	Dry	Wet
Capital cost (USD/tph)	6,200	13,000
Operating cost (USD/tph)	0.5	1.95

Working hours assumed for a Coal Washing Plant (based on project 15)	
350	Day/year
6,000	Hour/year
17	Hour/day

	Coal wash cost	Source
USD/ tonne	5	IEA, 2014

For example, raw coal of 4,000 kilocalories per kilogram (kcal/kg) and 38% ash can produce two fractions: fourth-fifths of the raw coal that now has 4,500 kcal/kg and 30% ash, and the remaining one-fifth with 2,000 kcal/kg and 70% ash. If the poorer fraction is not burned, 10% of the raw coal's energy is lost. Assuming USD 50 per tonne as variable mining costs and USD 5 per tonne as washing costs, the cost of washed coal is 37% higher on a tonnage basis and 22% higher on an energy basis.

	USD/ tph	Source
Eastern Plant Capital Costs "Black Box"	10,000 – 12,000	Economics of a preparation plant (Arch Coal, Inc, 2006)
Associated Materials Handling (Feed, Refuse, Clean Coal Loadout)	10,000 – 15,000	Economics of a preparation plant (Arch Coal, Inc, 2006)
Operating cost – cash cost	1,5 – 2,5 USD/raw ton	Economics of a preparation plant (Arch Coal, Inc, 2006)

Shivee Ovoo mine project (that produces 6Mtpa, and will be increased to 15Mtpa), foresees a Coal Handling Preparation Plant with the following costs (Aspire, 2012).

(Aspire, 2012)	Projected plant of 15Mtpa	Stage 1	Stage 2	Total
CHPP	USD m	187.4	198	385.4

Dust Suppression

Information on the relevant unit costs includes:

	Cost	Units	Source

KWh	0.07	USD/kWh	GWMS WP#3	
Groundwater	2000	MNT/ton water		

Cost of dust suppressants	Calcium chloride	Ligno sulphonate	Polymerised bitumen	Source
Cost of product [R/l]	1	1.8	2	Amponsah-Dacosta, 1997
Cost of product [USD/m³]	72	129.6	144	Amponsah-Dacosta, 1997
Note: cost includes actual chemical cost, transport to the mine and storage				

Cost-effectiveness comparison to achieve 70% control efficiency:

	Annual costs (10^3 R/yr/km)	Cost savings (10^3 R/yr/km)	Total cost savings (10^3 R/yr)*	Percentage saving (%)
Water	483	-	-	-
Calcium chloride	270	213	1,704	44
Ligno-sulphonate	406	77	616	16
Polymerised bitumen	569	-86	-688	-18
*Based on haul road length of 8 km ** Source: Amponsha-Dacosta, 1997				

	Cost	Unit
Calcium Chloride	1550	SEK/tonne
Concentration in solution	450	Kg in 0.8 m³
Amount in 1m³	562.5	Kg
Cost per m³	871.875	SEK/m³
Cost per m³	105.7	USD/m³
Source: Edvardsson, 2010 Note: this information has been used to contrast Amponsha-Dacosta, 1997		

	Unit cost* (USD/L)	Application rate (L/m²)	Cost per km per application** (1986USD)
Asphalt emulsion	0.26	1.8	11,700
Calcium chloride	0.11	2.2	6,000
Calcium lignosulfonate	0.3	1.5	11,300
Surfactant	2.95	0.009	650
Water	-----	-----	35
Source: Tannant & Regensburg, 2001 * Supplied and applied ** For 25m wide road surface [Groundwater solutions working paper 3, assumes a road width of 20 m and an application of 1.75L/s/ha in summer months]			

Lifetime	Years	Source
Mining	34	(Shafiee et al, 2009) [Average lifetime of 20 mines in Australia]
Tavan Tolgoi coal mine (6009 Mt)	35	Economic Modernization in Mongolia: The Impact of Tax and Regulatory Policies on the Mining Sector (January 2009)
Average for mining projects in Mongolia	22.3	

A.1.3.2. Energy use and energy for water

A.1.3.2.1. Energy consumption by Thermal Power Plants

The choice of the cooling system at a thermal power plant affects both water demand and energy demand.

According to the Industrial Cooling Systems BREF document (EC, 2001) energy requirements of cooling systems include direct and indirect means of energy consumption.

Direct consumption is associated with the use of energy to operate the cooling system itself and generally involves the use of pumps and fans. Energy consumption can vary substantially depending on the configuration of the cooling system, its operation pattern (all year around or seasonal), as well as the local circumstances (e.g. temperature).

Indirect energy consumption refers to the consumption of energy during the production process with inefficient cooling, resulting in higher energy consumption.

Industrial Cooling Systems BREF document (2001) presents an example of the comparative energy use associated with different cooling systems.

	Direct energy consumption (kWe/MWth) (pumps and fans)	Indirect energy consumption (kWe/MWth)	Total energy consumption (kWe/MWth)
Closed circuit cooling tower	>23	11	>34
Hybrid cooling	23	7	30
Dry air cooling	20	28	48

Source: ICS Bref (2001).

The energy demand is presented as specific energy consumption as kWe per MWth dissipated heat and needs to be converted for the use in the assessment. In particular, for the TPPs information available includes the installed capacity (MWe), annual calculated electricity generation, cooling technology and water demand for different project alternatives.

In order to use the information from the BREF document, energy consumption per dissipated heat needs to be linked to the installed capacity or energy output.

Thermic regime of steam turbines (assumed type for all TPPs) in terms of kW dissipated per kWh generated is 0.004, allowing to calculate energy consumed by different cooling systems at different TPPs with regard to the annual electricity production. Electricity consumption by TPP and technology is calculated based on the **Error! Reference source not found.**unit data and electricity generation information by TPP.

Direct and indirect energy demand of different cooling systems at TPPs									
Project title (amended)	Technology option applied	Complete Technology Description	Water demand - m3 water withdrawals/ yr	Electricity generation, MWh	MWh dissipated per year	Kwe/MWth dissipated	MWh consumed per year (for cooling annual)	MWh consumed for cooling as a share of the total production	MWh consumed for cooling per m3 used
TPP 1 Shivee Ovoo (270 MW)	Baseline: Wet Closed Cycle Recirculating, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse	Wet Closed Cycle Recirculating, Cooling Water Treatment, Cooling Water Blowdown Reuse, Boiler Water Blowdown Reuse, Circulating fluidized bed boilers	860,000	1,655,640	6,623	34	225	0.01	0.00026
TPP 1 Shivee Ovoo (270 MW)	Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Circulating fluidized bed boilers, Cooling Water Treatment, Cooling Water Blowdown Reuse	664,137	1,655,640	6,623	30	199	0.01	0.00030
TPP 1 Shivee Ovoo (270 MW)	Dry/Air Cooled	Dry/Air Cooled, Circulating fluidized bed boilers	255,538	1,655,640	6,623	48	318	0.02	0.00124
TPP 2 Shivee Ovoo (750 MW)	Baseline: Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	Wet Closed Cycle Recirculating, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	4,793,472	4,599,000	18,396	34	625	0.01	0.00013
TPP 2 Shivee Ovoo (750 MW)	Cooling Water Blowdown Reuse	Hybrid (Dry/Wet) Cooling, Wet FGD, Cooling Water Treatment, Cooling Water Blowdown Reuse	3,781,713	4,599,000	18,396	30	552	0.01	0.00015
TPP 2 Shivee Ovoo (750 MW)	Dry/Air Cooled	Dry/Air Cooled, Wet FGD	2,425,942	4,599,000	18,396	48	883	0.02	0.00036
TPP 3 Shivee Ovoo (5280 MW)	Baseline: Dry/Air Cooled, Wet FGD	Dry/Air Cooled, Wet FGD	15,700,000	32,376,960	129,508	48	6,216	0.02	0.00040
TPP 4 Shivee Ovoo (600 MW)	Baseline: Dry/Air Cooled, Circulating fluidized bed boilers	Dry/Air Cooled, Circulating fluidized bed boilers	2,000,000	3,679,200	14,717	48	706	0.02	0.00035
TPP 1 Tavan Tolgoi (18MW)	Baseline: Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	132,000	110,376	442	48	21	0.02	0.00016
TPP 2 Tavan Tolgoi (450 MW)	Baseline: Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	Dry/Air Cooled, Circulating fluidized bed boilers, Boiler Water Blowdown Reuse	1,200,000	2,759,400	11,038	48	530	0.02	0.00044

A.1.3.2.2. Energy consumption by CTL Plants

The calculation of the energy consumption of CTL plants is based on the same parameters as that of the thermal power plants. The assumptions used are:

	Average MWh consumed for cooling per m^3 used (only first alternative) TPP calculation #1
Closed circuit cooling tower	0.0002
Hybrid cooling	0.0002
Dry air cooling	0.0005

A.1.3.2.3. Energy consumption on groundwater use / abstraction

For CTB plant and mining related activities, the assumptions to obtain the energy consumption related to the water use are the following:

Average GW abstraction	0.601	kWh/m^3
Average GW transfer	0.351	kWh/m^3
Average GW transfer (0-141 km)	0.329	kWh/m^3
Average GW transfer per km distance	0.006	kWh/m^3/ km

Energy for water (source: Water UK (2011))		
Water supply	340	kg CO_2/Ml
	0.544	kgCO_2/kWh
	0.34	kg CO_2/m^3
Energy consumption per m3 of water	0.625	kWh/m^3 (this is for water delivered on the mains, so presumably includes both abstraction and distribution)
Wastewater treatment	700	kg CO_2/Ml
	0.544	kgCO_2/kWh
	0.7	kg CO_2/m^3
Energy consumption for water treatment	1.29	kWh/m^3

For CTB plant, the assumption is that all water used is from groundwater, so the values to calculate related energy consumption are average energy consumption in groundwater abstraction and transfer.

Regarding dust suppression in mining activities, 20% of water supplied is freshwater and 80% comes from water treatment plants (dewatering water) and wastewater plants, as stated during the consultation with stakeholders. Assuming that no water treatment is being carried out for dust suppression, the average energy consumptions for groundwater abstraction and transfer (0,601 kWh/m^3 and 0,351 kWh/m^3, respectively), and the water demand associated to the each dust suppresion project, the following calculations were carried out for each dust suppression project:

Electricity (kWh) = [water demand (m^3/yr) * 0.8 (dewatering water) * energy consumed in dewatering (0.21 kWh/m^3)] + [water demand (m^3/yr) * 0.2 (groundwater) * average energy consumed per m^3 GW abstracted and transferred (i.e. 0.601+0.351 kWh/m^3, respectively)].

For coal washing using water, the electricity consumption is calculated by multiplying the water demand (m^3/yr) by energy consumed per m3 of GW abstracted, treated and conveyed. Energy consumption for dry coal washing is estimated by multiplying coal mining output in tonnes with kWh per tonne of coal (assuming tubular drying technology) (Source: SUPER-HEATED STEAM DRYING: A CLEAN COAL TECHNOLOGY FOR LIGNITE[12])

A.1.3.3. Economic criteria

A.1.3.3.1. Reduced human health risks

This information has been used for all type of projects

Total costs of coal normalized to kWh of electricity produced (Appalachia region, US) [Full life cycle of coal (Epstein et al, 2011)]					
	Monetized estimates from literature in ¢/kWh of electricity (2008 USD)			Monetized life cycle assessment results of in ¢/kWh of electricity (2008 USD)	
	Low	Best	High	IPPC 2007, US Hard coal	US Hard coal eco indicator
Carcinogens (mostly to water from waste)					0.6
Public health burden of mining communities in Appalachia	4.36	4.36	4.36		
Fatalities in the public due to coal transport	0.09	0.09	0.09		
Emissions of air pollutants from combustion	3.23	9.31	9.31		3.59
Lost productivity from mercury emissions	0.01	0.1	0.48		
Excess mental retardation cases from mercury emissions	0.00	0.02	0.19		
Excess cardiovascular disease from mercury	0.01	0.21	1.05		

Values refer to the Appalachia region, in the US, and values are presented in USD 2008. The study refers to the costs of coal normalized to kWh of electricity produced (USD/kWh). It applies Life Cycle Analysis approach for underground mining and surface mining.

The public health impacts due to mortality were valued using the value of statistical life (VSL).

Due to some uncertainty in the monetization of the damages, the study includes three estimates: low, best, and high ("low" and "high" values can indicate both uncertainty in parameters and different assumptions about the parameters that others used to calculate their estimates; "best" are not weighted averages). For Mongolia, low estimate values were chosen for the following variables:

- Damage due to carcinogens associated with coal mining and combustion. It was estimated on the basis of an eco-invent database, which uses an eco-indicator impact assessment method to estimate health damages in disability-adjusted life years due to these emissions and valued using the VSL (value of statistical life)-year.
- Public health burden of mining communities comprises injuries and disabilities, chronic illnesses, and mortality in miners. Estimated excess mortality found in coal mining area was translated into monetary costs using the VSL approach, adjusted by mortality rate (example of calculation: for the period 1997–2005, excess age-adjusted mortality rates in coal mining areas of Appalachia compared to national rates outside Appalachia amounted to 10,923 excess deaths every year, with 2,347 excess deaths every year after adjusting for other socioeconomic factors statistically significantly worse in coal-mining areas -smoking rates, obesity, poverty, and access to health care-. By using this rate, a VSL of USD7.5 million and 91% of coal used for electricity generation a total cost of USD74.6 billion or 4,36 ¢/kWh) is generated.
- Fatalities due to coal transportation are calculated by multiplying the proportion of revenue-ton miles (the movement of one ton of revenue-generating commodity over one mile) of commercial freight activity on domestic railroads accounted for by coal, by the number of public fatalities on freight railroads, then

[12] https://orbi.ulg.ac.be/bitstream/2268/146188/1/SUPER-HEATED%20STEAM%20DRYING%20AN%20INNOVATION%20OF%20CLEAN%20COAL%20TECHNOLOGY%20FOR%20LIGNITE.pdf

multiplied by the proportion of transported coal used for electricity generation. Then the number of coal-related fatalities is multiplied by the VSL in order to estimate the total costs of fatal accidents in coal transportation.

- Emissions of air pollutants from combustion: low estimate based on NRC (2009) risk assessment with aggregate damage of USD65 billion on public health damages (mortality cases, bronchitis cases, asthma cases, hospital admissions related to respiratory, cardiac, asthma, coronary obstructive pulmonary disease, and ischemic heart disease problems, and emergency room visits related to asthma) due to emissions (PM2.5, PM10, SO2, NOx, volatile organic compounds, and ozone) from coal-fired power plants. An average value of 3.2 ¢/kWh was obtained (on a plant-by-plant basis after being normalized to electricity produced by each plant). Plant-to-plant variation (from 1.9 ¢/kWh to 12 ¢/kWh) was due to coal features, controls on the plant, and the population downwind of the plant. 90% of the damages due to air quality were from PM2.5-related mortality, which implies that these damages included, approximately, an excess of 8,158 mortality cases.
- Damages caused by mercury emissions: 1) mental retardation and lost productivity in the form of IQ detriments) were estimated by Trasande et al. (2005; 2006): USD361.2 million and USD1.625 billion, respectively, or 0.02¢/kWh and 0.1¢/kWh, respectively. 2) Association between methylmercury exposure and cardiovascular disease (epidemiological studies): Rice et al. (IPCC, 2007) monetized the benefits of a 10% reduction in mercury emissions for both neurological development and cardiovascular health, accounting for uncertainty that the relationship between cardiovascular disease and methylmercury exposure is indeed causal. Applying these results for the cardiovascular benefits of a reduction in methylmercury to the 41% of total U.S. mercury emissions from coal indicates costs of USD3.5 billion, with low and high estimates of USD0.2 billion and USD17.9 billion, or 0.2 ¢/kWh, with low and high estimates of 0.014 ¢/kWh and 1.05 ¢/kWh.

A.1.3.3.2. Employment

Direct employment in TPP	0.603	Employment/MW	(IUE, CASS, 2010)

Employment in CTL			
150000	Jobs per	1000000	bpd
150000	Jobs per	52079076	m³/year
0.002880235	Jobs/m³year		
Source: NETL, 2006			

Estimations from available information on employment in CTL plants in Mongolia						
800	Employment	1,311,200	m³/year	Unit employment per production	0.00061	Job/m³year
400	Employment	596,000	m³/year	Unit employment per production	0.00067	Job/m³year
458	Employment	715,200	m³/year	Unit employment per production	0.00064	Job/m³year

A.1.3.3.3. Other information on economic criteria

Thermal power plants

Employment	
Data	Source
0.603 employees/MW (China)	(IUE, CASS, 2010)
Thermal power equipment manufacturing: direct employment effect coefficient for the industry is 0.0142 (China)	
Thermal power equipment manufacturing in China: every 1MW of newly added capacity of large power generation units, around 4.5 direct and 11.4 indirect jobs will be created in related industries within the industry chain.	

Employment	
Data	Source
Jobs-years per Gigawatt hour (GWh): 0.11	
Construction of the 12MW power plant will require an estimated 200 workers (Ukhaa Khudag)	ERM (2010)
GDP	
Data	Source
The impact on GDP of the construction of a TPP in UB (450MW) is less than 1% despite investment worth USD1.4 billion	ERI, 2014
China: Coal consumption per unit GDP production in Inner Mongolia and Shanxi are 30,000 tons and 24,000 tons, respectively.	Greenpeace, 2013

Mining

Employment	
Data	Source
USD101,000 towards new mining investment should produce one new mining job for a foreign or local worker, and USD125,500 towards new mining investment should create one new job for a local worker [this data is for a copper and gold mine]	Shapiro, 2009
In the US: The jobs multiplier is 1.8, meaning that for every direct job created in the mining industry another 1.8 jobs are created elsewhere in the economy	IFC, WB
In Australia and New Zeeland: jobs multiplier is 3	IFC, WB
(Ukhaa Khudag Mine): For the purposes of this assessment, it is assumed that the economic multiplier for wages paid to temporary workers is 1.5, while the economic multiplier for wages paid to permanent workers, as well as indirect impacts of the Project's other expenditures is 1.8. That is, each dollar paid to a temporary worker will generate USD1.50 in the Mongolian economy. Similarly, each dollar paid to permanent workers or spent on royalties, taxes, or other payments will generate USD1.80 in the Mongolian economy. Included in these multipliers is the assumption that temporary workers will spend less money locally than permanent workers.	ERM (2010)
(Ukhaa Khudag Mine): However, a conservative multiplier of 1 mine job to 0.8 indirect jobs suggests that over 1,000 jobs will be created to serve the long term needs of the Project and its employees will reside near the mine and railway operations	ERM (2010)
GDP	
Data	Source
Mongolia: 5.9 [The GDP multiplier for the mining sector is 3.93 (each USD in mining investment increases mining output by USD3.93) and for the rest of sectors 1.97 (each USD in mining investment increases output by non-mining sectors by USD1.97)]	Shapiro, 2009
In the US: the mining output multiplier is 1.6, (every dollar of mining output creates an additional USD1.60 in output in other areas)	IFC, WB
Income	
Data	Source
Mongolia revenue multiplier: 1.73 (Every USD1 in mining investment would produce USD1.73 in government revenues from the activities stimulated by the investments)	Shapiro, 2009
In the US: the earnings multiplier is 1.7 (every dollar earned by employees in the mining sector a further USD1.7 is earned elsewhere in the economy)	IFC, WB
In Australia and New Zeeland: income multiplier of 2.0	IFC, WB
Investment	
Data	Source
Multiplier of 6 for copper and gold mine in Mongolia	Stokes, 2005

A.1.3.4. Environmental criteria

A.1.3.4.1. Air quality and climate change

This information has been used for all types of projects

Total costs of coal normalized to kWh of electricity produced (Appalachia region, US) [Full life cycle of coal (Epstein et al, 2011)]					
	Monetized estimates from literature in ¢/kWh of electricity (2008 USD)			Monetized life cycle assessment results of in ¢/kWh of electricity (2008 USD)	
	Low	Best	High	IPPC 2007, US Hard coal	US Hard coal eco indicator
Land disturbance (surface mining)	0	0.01	0.17		
Methane emissions from mines	0.03	0.08	0.34	0.11	
Climate damages from combustion emissions of CO_2 and N_2O	1.02	3.06	10.2	3.56	
Climate damages from combustion emissions of black carbon	0	0	0.01	0.19	
Climate damage (EIA 2007, estimate)	0.16	0.16			
AMLs (Abandoned mine lands)	0.44	0.44	0.44		
Climate total	1.06	3.15	10.7	3.75	1.54

Values are referred to the Appalachia region, in the US, and values are presented in USD 2008. The study refers to the cost of coal normalized to kWh of electricity produced (USD/kWh). It applies Life Cycle Analysis approach for underground mining and surface mining.

The public health impacts caused by mortality were valued using the value of statistical life (VSL).

Due to some uncertainty in the monetization of the damages, the study includes three estimates: low, best, and high ("low" and "high" values can indicate both uncertainty in parameters and different assumptions about the parameters that others used to calculate their estimates; "best" are not weighted averages). For Mongolia, low estimate values were chosen for:

- Climate change impacts were monetized on the basis of the social cost of carbon—the valuation of the damages due to emissions of one metric ton of carbon, of USD30/ton of CO2equivalent (CO_{2e}) (low estimate: USD10/ton; high estimate: USD100/ton).

A.1.3.4.2. Impacts on habitats and biodiversity

This information has been used for all type of projects.

a. Average air emissions:

Average air emissions (a) per kWh of net electricity produced. Average system (surface mining and average user by river) (Spath et al, 1999)	
Pollutant (emission to air)	Total average air emission (g/kWh)
Ammonia (NH_3)	0.0988
Non-methane Hydrocarbons (including VOCs)	0.210
Nitrogen Oxides (NOx as NO_2)	3.350
Sulfur Oxides (SOx as SO_2)	6.700

In the assessment, the information used is from the "average coal plant" presented on Spath et al., 1999. The study calculates the emissions (water, air) per kWh of Net Electricity Produced by an "average coal plant" of 360 MW using Illinois No. 6 coal, excavated from a mine located in central Illinois. The coal is transported via rail, truck, or a combination of rail and barge by one of four cases tested (average user by land). Other materials such as chemicals and wastes are transported via truck and rail.

The average coal power plant consists of the following main equipment/processes: pulverized coal boiler, bag house filter, conventional limestone flue gas clean-up (FGC) system, heat recovery steam generator, and steam turbine. The emission from this system represent the average emission from all U.S. coal-fired power plants in 1995. These were calculated by dividing the total coal generated U.S. emissions of a particular pollutant on a weight basis (kg) by the total electricity generated (kWh) from coal in the U.S. (Utility Data Institute, 1996). To maintain a mass balance around the power plant, a specific plant with emissions similar to the calculated averages and feeding the designated type of coal for this LCA was identified from the database. The actual resource requirements, final emissions, and energy consumption from this identified plant were used to represent the Average power plant in the study. The efficiency is typical of an average base-load plant operating in the U.S. in 1995. The following table contains the key power plant parameters for this system."

Plant information for average system:

Design parameter	Data
Plant capacity	360MW (net, 10% capacity)
Operating capacity factor – base case	60%
Coal feed rate @ 100% operating capacity	3,872,198 kg/day (as-received)
Power plant efficiency	32%

b. Damage cost on biodiversity:

Unit damage costs on biodiversity for air pollutants (electricity generation technologies) in €2000 per elementary flow (source: NEEDS Research Stream 1b) (NEEDS, deliverable 6.1)	
Pollutant (emission to air)	Unit damage cost on biodiversity (€/ton)
NH_3	3409
NMVOC	-70
NO_x	942
SO_2	184

The **unit damage cost** (referred to year 2010) has been used to measure the impact in terms of loss of biodiversity due to air emissions of the following pollutants shown in the above table.

The methodology used by NEEDS is based on dispersion and fate modelling of pollutants in the environment, to improve exposure-response relationships that are used to describe the response of receptors to an increased level of exposure, and to improve monetary valuation.

The impacts of the emission of a pollutant partly depend on the location of the emission source, the release height, and the concentration of other pollutants in the environment. Taking these different parameters into account, based on detailed a model RS1b/RS3a, a set of unit damage costs (damage costs per tonne of pollutant emitted) were arrived at, which differ by the emission source country (all European countries, EU27 average), by release height (average release height, low release height, high release height), and by the year of the background emissions (2010 and 2020).

A.1.3.4.3. Other information on environmental criteria

Reference	Applicable to	Useful data from the reference
NEEDS, deliverable 6.1	Lignite powered plants	We can obtain monetized estimates on: **Environmental damage** due to electricity generation from lignite combustion (expressed in €2000) from greenhouse gas emissions to air by using the following coefficients (unit damage costs for air pollutants in €2000 per elementary flow): • CO_2: 86 €/t (with equity weighting)

Reference	Applicable to	Useful data from the reference
		• CH_4: 2648 €/t (with equity weighting) • N_2O: 102955 €/t ((with equity weighting)
NEEDS, deliverable 6.1	Lignite powered plants	We can obtain: Monetized estimates on **biodiversity damage due to land use change** derived from the implementation of electricity generation plants (expressed in €2000): • Transformation, from arable, unspecified: 0,17€/m2 • Transformation, from forest, unspecified: 2,66 €/m2 • Transformation, from pasture and meadow, unspecified: 0,55 €/m2 • Transformation, from pasture and meadow, extensive: 0,76 €/m2 • Transformation, from pasture and meadow, intensive: 0,34€/m2 • Transformation, from unknown: 1,52 €/m2
Epstein et al., 2011	Coal mining	- We can obtain monetized estimates on certain impacts on the environment derived from coal mining expressed in ¢/kWh of electricity (2008 USD) by using the following coefficients: • **Land disturbance** (surface mining): due to deforestation and landscape changes. Impacts on carbon storage and water cycles [due to mining]**:** BEST: 0.01 ¢/kWh; (HIGH: 0.17 ¢/kWh). • **Methane emissions from mines [due to mining operations**]: BEST: 0.08 ¢/kWh (LOW: 0.03 ¢/kWh; HIGH: 0.34 ¢/kWh). • **AMLs (Abandoned mine lands**: “those lands and waters negatively impacted by surface coal mining and left inadequately reclaimed or abandoned -US, prior to August 3, 1977-”) [due to mining]: 0.44**: ¢/kWh.**

Prioritized solutions to close the water gap

Hydro-economic analysis on the coal mining regions in Mongolia's Gobi desert

Report Supplement #5 – Orkhon-Gobi Water Transfer Scheme

14 March 2016

Final Draft

PricewaterhouseCoopers in Cooperation with Amec Foster Wheeler & Groundwater Management Solutions

Report Supplement #5 – Orkhon-Gobi Water Transfer Scheme

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1. Orkhon-Gobi Water Transfer Scheme

The Orkhon-Gobi Water Transfer Scheme has been identified as a potential project that could provide significant additional water supply to the Tavan Tolgoi region in the Southern Gobi. This new water transfer scheme has received varying responses from different stakeholder groups within Mongolia in terms of its overall cost effectiveness. Due to concerns over the uncertainty of data relating to the scheme, a high level review of information was undertaken with the objective to provide, if possible, outputs that would enable that the scheme be included within the prioritization framework. This report supplement provides further detail of the evaluation undertakenwater for the availability evaluation, cost evaluation and review of financial, economic, environmental and social impacts that have been discussed in Section 4.2.2 of the main body of the report.

2. Water Availability Evaluation

2.1. Introduction

The preferred Alternative C, an integrated supply scheme, has a surface water flow of 216,000m³/d, or about 2.5m³/s. The proposed Orkhon–Gobi pipeline will convey this flow from a dam in the middle reach of the Orkhon River through a 740km long pipeline to Tavan Tolgoi and Oyo Tolgoi, with side branches to Mandalgobi and Dalanzadgad.

A high-level review has been undertaken with respect to water availability associated with Alternative C. The surface water assessment has been based entirely on publicly available documents and information.

In addition, monthly data was obtained for historical flows measured at the Orkhon gauging station and used as a check on public information of river flows, and to derive an estimate of potential diversion dam sizes on the Orkhon River.

The groundwater availability assessment is largely based on works already completed by 2030 WRG in the Tavan Tolgoi area.

2.2. Surface water evaluation

2.2.1. Orkhon River

The Orkhon River is a major surface water resource in Central Mongolia and the most affected river basin in terms of human influences such as agriculture, mining, forestry and urbanization. The river rises in the Khangai Mountain Range and flows north-east to join the Selenge River near the northern Mongolian-Russian border. The main tributaries of the Orkhon River are the Tamir, Tuul, Kharaa and Eroo Rivers. The river meanders in its floodplain and consequently has a long length of ~1100km. The Orkhon River basin is mostly forest-steppe.

The potential diversion dam site is about 250km northwest of Ulaan Bataar and just downstream from the village of Orkhon and the Orkhon gauging station (the so-called Orkhon – Orkhon gauge). The dam site is about 600km north of Tavan Tolgoi in the South Gobi.

2.2.1.1. Climate

The Orkhon river basin has a relativity humid climate compared to other regions of the country. The total average annual precipitation (long term) at Orkhon is about 312 mm pa (Khishigsuren et al, 2012) as shown in Table 1.

Table 18 Average rainfall on the Orkhon River Basin

Month	Average precipitation (mm)
January	3.4
February	1.9
March	3.2
April	6.1
May	19.2
June	69
July	77.2
August	72.0
September	41.8
October	8.3
November	5.8
December	4.5

Total	312.4

In the high mountain areas, the precipitation exceeds 350 mm. Most of the precipitation happens in the summer period. It has been suggested (Davaa et al, 2012) that the Orkhon flows consist of approximately 25% groundwater, 15% spring snow melt and 60% rainfall sources.

2.2.1.2. Flow in the Orkhon River

The catchment area at the Orkhon gauging station is about 37,177km². The long-term mean runoff (1945-2008, i.e. 64 years) is 41.5m³/s (Khishigsuren et al, 2012), which is equivalent to 1.12L/s per km² (the specific run-off of the river per unit area, which also increases with increase of basin elevation).

In the period between 1982 and 2012, the mean run-off reduced to 36.9m³/s largely due to a dramatic fall off in flow from 1996 onwards. The mean was 55m³/s from 1982 to 1996, dropping to 20m³/s in the period 1996 to 2012, based on available monthly data. Mean run-off in the 10 year period from 2000-2009 was less at 13.4m³/s (refer Table 2).

The Orkhon River demonstrates both spring snow melting floods, and rainfall floods. Winter precipitation (snow from October to April) plays a key role in the formation of spring floods. Rainfall summer flood peaks are observed 2-4 times during the summer season.

The maximum discharge of the rainfall floods exceeds the maximum of the spring floods. Based on long term flow series, the 100 year average recurrence interval (ARI) for spring floods (i.e. snow melt floods) have previously been estimated as about 625m³/s; and the 100 year ARI rainfall / summer floods has been estimated to be about 1,200m³/s. The 1000 year floods are estimated as 755m³/s and 2,215m³/s, respectively.

There has been a decreasing trend in the maximum discharge value owing to floods in the Orkhon river basin, mainly, due to the occurrence of the low flow years in the last 20 years. The average flow in July - August - September during the 10 year period from 2000-2009 was 26m³/s (compared with the longer term average of about 100m³/s). Generally, the trend has been that of higher flow in spring (snowmelt), and less rainfall flooding in August.

Table 19 Average monthly flows in the Orkhon River (2000-2009)

Month	Average monthly flows (m³/s)
January	0.8
February	0.6
March	2.7
April	19.1
May	14.8
June	14.3
July	30.7
August	25.7
September	23.4
October	17.6
November	9.4
December	3.3
Total	13.4

2.2.1.3. Water Quality

The ICDD research study paper (Withanachchi et al, 2014) was conducted in collaboration with the multi-disciplinary research “Environmental Flow Assessment in Orkhon River – Mongolia” (2012–2014), which concluded that the river flow is highly vulnerable to extreme climate changes and weather patterns which impact the sustenance of the environmental flow of the river. The ICCD noted "considerable reduction of river flow could be observed at the Orkhon-Orkhon water monitoring site of the Orkhon River from 1978 to 2008…… This highlights the current vulnerability of the water quality and the limited dilution capacity of the river….. if the environmental flows of (the) Orkhon River are not preserved, there might be serious ecological repercussions in the downstream areas" (ICDD, 2014).

Water quality of the Orkhon River changes along the length depending on the water quality of the tributaries that flow into the river. Water quality at Orkhon itself showed a TDS (Total Dissolved Solids) of 200-250mg/L (average measurement from 2005-2010). Water sampling and measurements on nutrient concentrations were performed in September 2012 for the "Environmental Flow Assessment of the Orkhon River" project and categorised according to the Mongolian National Standards for Surface Water. At Orkhon, and nearby areas, Phosphate was measured at 0.08-0.14mg/L (classified as less polluted - polluted), Nitrate up to 10 mg/L (polluted), Nitrite at 0.05 mg/L (more polluted), Ammonium at 0.06mg/L (clean).

2.2.1.4. Environmental Flow

Environmental flows are not the same as 'natural' flows or just the amount of water that flows through a river system, and do not necessarily require restoration of the natural, pristine flow patterns that would occur in the absence of human development, use, and diversion.

Environmental flows rather describe the quantity, timing, and quality of water flows intended to produce a broader set of values and benefits from rivers than from management that is strictlyfocused on water supply, energy, recreation, or flood control required – a balance between benefiting ecology and humans.

It is possible to describe flow regime in terms of five environmental flow components (extreme low flows, low flows, high flow pulses, small floods, and large floods) relating to water quality, sediment deposition, life-cycle needs of fish and wildlife, and river-based communities. Each of these flow components, or events, may be quantified in terms of their volumetric flow rate, the time of year during which a flow event occurs, how long an event lasts, how often the event occurs, and the rate at which flows or levels increase or decrease in magnitude over time.

Initial focus on environmental flow concepts was appertained to minimum necessary flows; while more recently, restoring and maintaining more comprehensive environmental flows has gained increasing support, to maintain the full spectrum of riverine species, processes, and services. Thus, environmental flow stipulation can be complex.

There are various approaches that can be taken, from full expert ecological consideration which can consider minimum flows, minimum flow based on a percentage of seasonal flows or daily flows, mimicking the magnitude frequency and duration of flood flows to provide for river flushing and riparian enrichment, etc. A presumptive standard for environmental flow protection suggests that a high level of ecological protection would be provided when daily flow alterations are no greater than 10%. A more moderate level of protection would be provided with 11‐20% flow alterations, while flow alterations >20% are considered likely to result in moderate to major changes in natural structure and ecosystem functions (Richter et al, 2009).

2.2.1.5. Impact on the Diversion Dam

A simple simulation was carried out ignoring evaporation, seepage, climate change / flow decreases, but using the historical monthly flow series at the Orkhon gauging station, a notional diversion dam, and Gobi demand of 2.5m^3/s. These simulations indicated that with no environmental flow rate provided, such a dam would require a minimum storage capacity of 17GL, but would refill every summer. With an environmental flow up to about 70% of the mean monthly flow, the dam would require a minimum of 25GL storage, and still refill to full volume every summer.

For an environmental flow equal to 88% of the mean monthly flow (proposed by Davaa & Myagmarjav), the required storage volume exceeded 300GL (and did not refill from Year 2000 onwards). A more reasonable environmental flow of 80% required a minimum 50GL storage, and refilled most years (with a 3 year gap 2004-2006 when it remained only partially full).

Ultimately, environmental flows are determined and stipulated by the regulator. Any flow regulation will also need to take into account the fact that the Orkhon-Selenge River is a trans-boundary river, and a key water source to the Baikal Lake, the world's largest fresh water lake.

2.2.1.6. Surface water flows actually reaching the Southern-Gobi

It is noted that whilst a total supply from the Orkhon River is estimated at 216,000 m^3/d, this does not all reach the Southern Gobi. Prestige (2014) highlight that off-takes will be provided along the pipeline route, every 10km, for the purpose of meeting agricultural demand and also supply to urban areas will be provided. With regard to agricultural water use, it is not clear as to how the planned growth in irrigation (water demand for which is assumed to increase to 100,000 m^3/d – almost 50% of the transfer rate) will actually take place. If this is the case, and urban demands of townships along the pipeline route are also serviced, the actual volume of water delivered to the Gobi region will only be in the order of 100,000m^3/d."

2.2.2. Groundwater evaluation

The preferred scheme (Alternative C) assumes that supplementary local groundwater resources will be available to meet the projected total 2030 water demand of 386,800 m^3/d. With an assumed 212,740 m^3/d available from Orkhon for surface water transfer (rounded up to 2.5m^3/s or 216,000m^3/d), the total projected groundwater utilisation proposed is in the order of 170,000m^3/d. Groundwater availability is demonstrated with a listing of established groundwater reserves that provide a total estimated established resource – in various categories and thus, levels of confidence - of ~167,000m^3/d.

The premise of groundwater availability to the levels required for the proposed scheme is not challenged, although there appear to be some errors in the summation of the quoted reserves, some values are outdated and the listing is incomplete. The 2030 WRG assessment of groundwater availability within the smaller Tavan Tolgoi (TT) study area identifies established reserves with a capacity in the order of 86,000m^3/d and additional potential in the range 95,000-164,000m^3/d. The reserves quoted for Gunii Hooloi (~75,000m^3/d) and Khurmen Tsagaan (~30,000m^3/d) – both outside the TT study area and thus, not included within the 2030 WRG estimates – would augment resource potential.

The scheme assumes that groundwater development will be capped at current (2013) levels. The proposed allocation of the groundwater resources is 14,292m^3/d for urban areas, 88,128m^3/d for mining and industries and 71,640m^3/d for agriculture (livestock, agronomy and environment). The logic associated with these allocations is not presented and warrants further consideration, given that:

- The limited allocation for mining necessitates the allocation of ~50% of the potable quality Orkhon surface water to mine/industrial use.
- Most of the established local reserves (~146,000m^3/d) comprise brackish (industrial quality) water and are associated with, and may be sufficient alone to meet, mine demands.
- Some of the mining developments (e.g. OT and UHG) have already located and developed groundwater reserves sufficient to meet their demands.
- Water treatment, to varying levels, will be required with re-allocation of local groundwater resources to urban and agricultural use.

2.3. Summary

The scheme will abstract water from the Orkhon River which is the main surface water resource of central Mongolia. The Orkhon is the most affected river basin in terms of human influences from agriculture, mining, deforestation, and urbanisation and is also being impacted by global warming. As a result, the natural flow regime is changing with the water resources decreasing, as seen that the mean annual flow of 13.4m³/s in the 10 year period from 2000-2009 is well below 50% of the long term mean (1945-2008) of 41.5m³/s.

The viability of an off-take of 2.5 m³/s is largely dependent upon the proportion of flow regulated for environmental flow purposes. Where this is established at the desirable norms of at least 80% of the natural river flow, the reservoir storage required would be significant and a period of some years may be anticipated where only partial re-filling of the reservoir occurs. This is likely to get worse with climate change.

It is recognised that the scheme is still at a scoping stage and further definition and assessment of the proposed water use is required including taking into account local groundwater. Further, hydrological analysis is also necessary to support the extent of environmental flow regulations and to assess the downstream environmental impacts from the introduction of an impoundment reservoir.

3. Cost Evaluation

In this section, firstly, an evaluation of the design principles of the Orkhon-Gobi water transfer is made and secondly, an evaluation of associated costs.

3.1. Evaluation of design principles

The team has undertaken an evaluation of the design as well as the assumptions that have been made, with reference to the supplied reports, cost estimate spreadsheets, and responses to design queries. The scheme is at the scoping stage and exact details cannot be defined until a fully developed engineering solution is prepared. As such, there has been a reliance on knowledge derived from previous schemes in the area. Even though the design will have to be considered further, it is appropriate to derive assumptions from previous experience to undertake a high level strategic study.

3.1.1. Design principles impacting costs

3.1.1.1. Capital costs

Material and embedment costs are based on the use of ductile iron cement mortar lined (DICL) pipes. The "Orkhon-Gobi project pipeline assessment" document states that the pipeline will be GRE (glass reinforced epoxy). Either material would be suitable for the proposed pipeline; however, the selection of material will have an impact on the subsequent design approach and decisions, as well as the cost of the project.

The cost estimate assumes that the embedment requirements for the entire GRE pipeline will consist of a 100mm layer of sand to bed the pipe and as-dug material used for the backfill, including the pipe surround. We acknowledge that the variation in ground is not considered great and groundwater is scarce. However, the embedment design is possibly optimistic as it seems that temporary construction loading may not have been taken into account. This should be further considered at the next stage of design.

The strategy for dealing with thrust issues has been clarified as:

> "Thrust block will be cast in place at pipeline turns. Valves and instruments (Air release valve, pressure surge valve, non-return valve, air tank, and break water tank) to protect from hydraulic thrust are addressed at pump station and manhole."

This strategy is considered appropriate for the proposed installation and material, assuming a pipeline as costed. Should alternative material or design be used in the actual installation, an alternative strategy for thrust restraint can be considered, i.e., a tied pipeline (mechanically restrained joints) with restraint accounted for in the chamber/PS connections. No costs have been allocated for thrust restraint so an additional allowance should be made to the cost estimate.

3.1.1.2. Operating costs

A roughness coefficient of 140 (Hazen-Williams) has been used in the hydraulic calculations. This is appropriate for a DICL pipeline, but would need to be re-assessed for a GRE pipeline. The wall thickness and internal diameter would also vary by selected material (also subject to design load and internal pressure). The use of GRE would likely reduce the calculated head losses; thereby, the required pumping and power consumption.

3.1.1.3. Design principles

No clear basis for selection of the point source and pipeline route have been provided. This is a high-level assessment; therefore, these details will be considered further at the pre-feasibility/feasibility stage. This entails a risk that the scope of work, particularly relating to the dam construction and length of pipeline required, may be subject to change.

It has been clarified that steel and DI pipes are imported to Mongolia from Russia and China. It is assumed that a similar procurement will be required for GRE pipes. Availability of the proposed product (size, material and waiting periods) will have to be confirmed prior to selecting the appropriate pipeline material and, subsequently, developing the design, project programme and implementation plan and increasing confidence in the cost estimate.

No allowance has been made for specific crossings; however, it has been identified that minor roads in three areas will be crossed at a depth below ground level equal to the pipeline diameter, which would be +200mm. This will be appropriate (assuming depth to crown). Road crossings will require closure and/or diversion of the road or, if this is not possible, trenchless installation may be required (large diameter GRE or DI will probably require tunnelling). It is accepted that crossings will be a minor element in the scale of the overall scheme.

The assumptions made regarding pipeline depth below the ground surface are considered appropriate for this stage of study, albeit conservative. Pipeline depth will need to be confirmed at subsequent design stages following geotechnical site investigations and review of hydraulic calculations as well as the overall design.

The requirement for power supply installation will have to be confirmed. No clarity has been provided on the assumption of a requirement for 445 km of overhead power line. In addition, an assessment should be made as to the benefits of pumping the entire pipeline route with consideration of the issues and benefits of providing sections of gravity supply over the route. It appears that the pumping requirements have been over-estimated, however, at this stage, the assumption that the entire route will need to be pumped is conservative, but appropriate. There may be scope to reduce power and operational costs as the design develops.

3.1.1.4. Conclusion

The design principles and assumptions associated with this scheme have not yet been sufficiently developed to provide confidence in the overall design or costs. The design strategy should be agreed upon and enable a more robust cost estimate with an increased confidence.

Evaluation of the engineering feasibility of water transfer pipeline options will consider the details highlighted above when more information (from more detailed investigations) becomes available. This design process is likely to address the uncertainties. In addition, it is likely that there will be scope to introduce value engineering into the scheme. On a scheme of this scale, with the design at this level of detail, there are likely to be changes in the future that could significantly impact the current cost estimate.

3.2. Evaluation of costs

The information provided by Prestige in support of the costs in the scoping stage estimate, is generally appropriate to an estimate of this type; in particular, the cost substantiation provided for the pipeline element has greater detail than would normally be expected for a scoping stage estimate.

3.2.1. Capital Costs

The evaluation of the capital cost estimate for Alternative C is based on information contained in the Screening Report (Prestige, 2014) and the responses to questions posed to Prestige.

Prestige provided a high level scoping stage estimate of capital costs of USD 525M (Prestige, 2014) and the breakdown of these costs has been shown in Table 3.

Table 20 Capital costs of the Orkhon-Gobi water transfer scheme Alternative C as per Prestige (2014)

Expense Type	Alternative C (USD Million)

Project management cost	10.235
Design and exploration (including tax and social insurance fee)	17,996
Dam (or well and horizontal water collecting structure)	115.461
Pipelines	173.111
Equipment and materials	81.169
Construction works	92.426
Miscellaneous Erection and construction	1.000
Transportation, petroleum and oil	30.567
Other expenses	3.500
Total	**525.464**

This type of estimate would usually be presented as a three point estimate, rather than a single value. A three point estimate would provide an indication of the level confidence in the data and in the estimate. A wider range in the figures generally means less confidence in an estimate, as compared to an estimate with a narrow range of predicted outcomes.

3.2.1.1. Pipeline Costs

The cost for the pipeline is based on the use of Ductile Iron Cement Line pipes; this is a suitable selection but differs from the design of the "Orkhon-Gobi project pipeline assessment" document which states that the pipeline will be GRE (glass reinforced epoxy). The final selection of material will have an impact on the cost of the project.

3.2.1.2. Cost Base Date

Prestige were asked what the base date for the costs in the Screening Report (Prestige, 2014) was; they confirmed that there were a variety of dates 2Q2010, 1Q2013 and 1Q2015 for the Ductile Iron Cement Lined Pipes (USD173M) . The standard convention is to use one base date within an estimate, usually the current year. The estimate requires to be adjusted to a standard base date, an assessment has been made and shown in Table 21 Revised capital costs of the Orkhon-Gobi water transfer scheme Alternative C, where the base date of 1Q2016 has been used. The consumer prices inflation (annual %) for 2011-2015 is 13.0% (source World Bank). For the assessment of the effect of construction inflation, a figure of 10% has been used to inflate the estimate from 1Q2013 to 1Q2016. This equates to an uplift of USD185M, revising the estimate to USD800M. The Ductile Iron Cement Lined Pipes were also included as there was no evidence to substantiate that the costs used within the Screening Report (Prestige, 2014) were at 1Q2015 prices.

3.2.1.3. Uncertainty and risk

The estimate should take into account the uncertainty of an event that will occur and have more than one outcome and risk, and an event, which may or may not occur at all. Prestige were asked if their estimate had scope for this, but they were not able to confirm if they had. Reviewing the cost substantiation we have received, no evidence could be found that uncertainty and risk have been accounted for. The Institute of Chemical Engineers (IChemE) has a formal but useful structure with 5 "classes" of estimate, for a Feasibility estimate; where a value of + /- 30% to 50% to generate a three point estimate, -15% for the Lower Confidence Level and 40% for the Upper Confidence Level has been used, giving range of between -USD120M to +USD360M.

3.2.1.4. VAT

The scoping stage estimate did not state whether it excluded or included VAT. It is usual for VAT to be shown separately. Prestige stated that it was inclusive of VAT; however, no evidence of the inclusion of VAT could be found within the supporting documents. For the purpose of this evaluation, VAT has been added.

3.2.1.5. Other Costs

Prestige provided spreadsheets that gave additional information on the breakdown of some of the capital costs in Table 4, which was helpful in reviewing the costs in more detail.

The costs would normally be expected to be presented as a 3 point estimate to allow for uncertainty and risk. In addition to the changes to the costs highlighted above, some further amendments to the detailed costs have been listed below:

- The cost of USD 115M for the dam, from the level of detail provided, looks low. Particularly of concern is the allowance made for fill material at USD 0.10/m^3, USD 0.20/m^3 and USD 0.50/m^3, and this has been adjusted to USD 10/m^3, which corresponds to an additional +USD 35m. Given the uncertainty related to the environmental flows required for regulation, a significant change in dam size could be required and therefore a major element of cost uncertainty.
- Design and exploration (including tax and social insurance fee), the Screening Report Study Cost of USD5M has been missed due to an error in the formulae in the spreadsheet.
- Pipeline supply costs for the 1100mm and 1000mm diameter appear lower than expected. The cost has been adjusted for this + USD43M.
- Within the Pipeline spreadsheet, there is an error in the calculation of topsoil volume, total trench depth has been used, a cost adjustment of – USD4M
- Excavation of topsoil, including a 25% allowance for rock, has been included. There does not appear to be any allowance for replacing the topsoil or any reinstatement, so made adjustment of + USD1M.
- Despite Prestige stating that for temporary roads and easements, a rough estimate had been included, no evidence of this could be found, Allowance of USD10/m would add + USD9M; and
- Prestige have stated that thrust would be dealt with the pump station and manhole etc. We have been unable to locate this cost allowance within the estimate. Ductile iron pipes will require more thrust blocks; therefore, an allowance of 1,800 30m^3 concrete blocks every 500m has been made. At a cost of USD150/m^3, this corresponds to an additional cost of + USD8M.

The result of these adjustments have increased the capital cost which can be seen in Table 4.

Table 21 Revised capital costs of the Orkhon-Gobi water transfer scheme Alternative C

Capital Expenditure	**Confidence Level**		
	Lower	**Mid**	**Upper**
Prestige Estimate May 2014		**USD525.5M**	
Ductile Pipe Rates		USD43.3M	
Fill material to Dam		USD35.2M	
Allowance for temporary roads and easements		USD9.0M	
Allowance for Thrust blocks		USD8.1M	
Feasibility Study Costs omitted		USD5.0M	
Project Management		USD1.8M	
Replacement of topsoil and reinstatement		USD1.0M	

Topsoil excavation		-USD4.1M	
Sub-Total		**USD624.8M**	
Adjustment from 1Q13 to 1Q16, 10% per annum		USD187.4M	
Sub-Total	USD**812.2M**	USD**812.2M**	USD**812.2M**
Estimate; -15% & +45%	-USD121.8M	USD0M	+USD365.5M
Sub-Total	**USD690.4M**	**USD812.2M**	**USD1,177.7M**
VAT 10.0%	USD69.0M	USD81.2M	USD117.8M
Total (Including VAT)	**USD759.4M**	**USD893.4M**	**USD1,295.5M**

As this is a scoping stage estimate it is suggested the upper limit be used. However, there is still considerable uncertainty related to this overall cost due to design elements, and increased confidence will be obtained once a full feasibility study is undertaken.

3.2.2. Operational Costs

The evaluation of the operational expenditure for Alternative C, is based on information for Option 3 within the Excel file AZ_2010_OP_3_2013 TOR2.xlsx provided by Prestige.

The total Operational cost detailed within this file was USD41.6M per annum at 2013 prices, with a capex cost of USD 527.9M. As part of this review the revised capex figures calculated have been utilized.

Table 22 Operational costs as provided by Prestige.

Item	Total (USD)
1. Total investment	**527,965.104**
2. Operational cost (annual)	
Salary	2,504,160
Social insurance fee	275,458
Electricity	25,050,416
Communication	104,000
Maintenance	158,000
Other	2,000,000
Water resource fee	5,013,621
Sub-total	**35,106,044**
Depreciation	6,493,971
Total Cost	**41,600,015**

3.2.2.1. Annual Operation Costs

On reviewing the Operational costs provided, the following costs would appear to be satisfactory:

- For the Salaries, a good level of detail was provided showing the numbers of staff and their annual salaries.

Observations and amendments have been made for the following elements:

- Salaries appear to be at 2013 prices. These have been uplifted by 30% to 1Q2016 to USD 3.3M from the previous USD 2.5M;
- The costs for Vehicles could not be located so an allowance of 10% of the salary cost was added;

- Electricity costs are at 2013 prices (USD 25,050,416). The cost per kilowatt hour was ~ 99 MNT. In July 2013, Mongolia increased this by 30% for mining sector to reach at 130 MNT and for other industries to 105.60 MNT. Currently, we understand costs are in the range of 190 to 200 MNT. As a result, electricity costs have been increased by USD8.8m to USD33.9M;
- Maintenance of USD 158,390 per annual seems very low at 0.03% of the Capital costs, particularly as this is an annualized value and does not appear to allow for the periodic replacement of mechanical and electrical equipment. The life expectancy of these elements would be 20 to 30 years depending on the level of maintenance. To address this, maintenance costs are assumed as 0.5% of Capital Costs;
- Other Operational costs of USD 2,000,000; does not state what this covers uplift by ~30% for inflation over 3 years; and
- Depreciation is USD 6,493,971. Although there is no clear indication of the number of years the assets are being depreciated over; however, it appears to be 80 years. Eighty years is greater than what would be expected, particularly as mechanical and electrical components would need replacing several times in this period. Forty years for the depreciation has been assumed; this increases the cost by USD 22.9M to USD 29.4M.

The result of these adjustments have increased the operational cost from USD41.6M/per annum to a 3 point estimate of USD65M, USD68M, and USD79M which can be seen in Table 6.

Table 23 Revised operational costs of the Orkhon-Gobi water transfer scheme Alternative C

Operational Cost (annual)	Lower (USD M)	Mid (USD M)	Upper (USD M)
Capex (Excluding VAT)	**690.4**	**812.2**	**1,177.7**
Operational Expenditure (annual)			
Salary	3.3	3.3	3.3
Operational Vehicles	0.3	0.3	0.3
Social insurance fee	0.4	0.4	0.4
Electricity	33.9	33.9	33.9
Communication	0.1	0.1	0.1
Maintenance 0.5% of Capex	3.4	4.4	5.9
Other	2.6	2.6	2.6
Water Resource Fee	3.4	3.4	3.4
Sub-Total	**47.4**	**48.1**	**49.9**
Depreciation 2.5% (40years)	17.3	20.3	29.4
Total Operational Cost	**64.7**	**68.4**	**79.3**

3.3. Summary

3.3.1. Design Evaluation

At the current scoping stage, there is limited information on the exact design and related assumptions associated with the water transfer scheme and there has been a reliance on knowledge derived from previous schemes in the area. With the level of design at this stage, there are considerable uncertainties associated with the cost estimates. The design process, as part of a more detailed feasibility study, should address these uncertainties and lead to a more robust cost estimate.

3.3.2. Cost Evaluation

A reviewed and adjusted capital and operational cost estimate for the Orkhon River water transfer scheme is summarised below in Table 7, following the review of the cost estimates presented in the Screening Report (Prestige, 2014), the substantiation provided by Prestige and based on the limited (and uncertain) design that has been developed at this stage. The information provided by Prestige in support of the costs in the scoping stage estimate, is generally appropriate for an estimate of this type.

Table 24 Revised operational costs of the Orkhon-Gobi water transfer scheme Alternative C

Cost Type	Confidence Level		
	Lower (USD M)	Mid (USD M)	Upper(USD M)
Capital Expenditure	690.4	812.2	1,177.7
VAT 10.0%	69.0	81.2	117.8
Capital Expenditure Total (Including VAT)	**759.4**	**893.4**	**1,295.5**
Operational Expenditure (Annual Excluding VAT)	**64.7**	**68.4**	**79.3**

As this is a scoping stage estimate, it is suggested the upper limit be used, as the cost certainty would increase after a feasibility estimate had been provided. A summary of the key points of the review is provided below.

3.3.2.1. Capital Expenditure

The total capital expenditure has risen from USD 525M to USD 1,295M (including VAT) at the upper confidence level. This increase is attributed to revision of costs in the following key areas:

- Cost base date: All costs have been updated to a standard based date of 1Q2016. This has the impact of increasing the cost by USD187M.
- Uncertainty and risk: The cost estimate should take account for uncertainties and risks. A three point estimate approach has been taken, providing a mid to lower confidence (-15%) and upper confidence (+40%). The upper confidence level adds an additional USD 365M.
- VAT: VAT has been added, which adds an amount of USD118M to the total revised cost estimate.
- Pipeline costs: Pipeline costs for diameter 1100mm and 1000mm appear lower than expected, therefore added USD44M.
- Dam costs: The envisaged cost of the dam looks low. For the fill material alone, an additional cost of USD35M has been added. At this stage, there is uncertainty in the size of the dam and as a result considerable additional costs could be incurred. This is a key area of uncertainty.

3.3.2.2. Operational Expenditure

The annual operational expenditure has risen from USD42M to USD79M (excluding VAT) at the upper confidence level. This increase is attributed to revision of costs in the following key areas:

- Electricity costs have been increased from 2013 prices to current rates, increasing the costs by USD 8.8M.
- Maintenance costs have been increased to reflect 0.5% of total capital costs, an increase of USD5.69M.
- Depreciation has been reduced down from 80 years to 40 years, which resulted in an increase in the cost by USD 22M.

3.3.2.3. Summary

At the scoping stage, there is large uncertainty in the design elements of the water transfer scheme. These changes could considerably impact the associated cost estimate. Whilst, the revised cost estimate above addresses some issues, the remaining uncertainty would need to be addressed at the pre-feasibility/feasibility stage.

4. Financial, economic, environmental and social impacts

This Section provides a summary of how the financial cost-effectiveness has been updated in light of the revised cost estimates from Section 3, to be incorporated in the hydro-economic assessment tool developed by the 2030 WRG. It also investigates how economic, environmental and social impacts for the water transfer scheme, previously estimated by Prestige, can be integrated.

4.1. Financial cost-effectiveness assessment: derivation of cost-effectiveness ratio

The financial evaluation undertaken in Section 3 has resulted in amendments to the project's capital investment and annual operational and maintenance cost estimates. The updated financial cost estimates (expressed as Equivalent Annual Cost (EAC)) were then used in conjunction with the project's technical effectiveness value (expressed in million cubic metres of water per year) to derive an updated cost-effectiveness ratio (expressed in USD per cubic meter of water supplied per year). The lower the ratio, the more cost-effective the project is; in other words, less (financial) effort needs to be made in order to increase water availability by one unit, which in the case of this project can be done through augmenting the supply.

The revised capital investment costs of the project are estimated at about USD 1.30bn and operational expenditure USD 0.08bn (high estimate) with total water supply of 216,000 m^3/day. Updated cost-effectiveness ratio for the project is 2.68USD/m^3.

4.2. Economic, environmental and social impacts: review and evaluation

The screening report on initial economic, financial, environmental and social screening (Prestige, 2014) has been reviewed with the aim to identify and incorporate key relevant impacts associated with the recommended option (Alternative C) in the hydro-economic assessment tool.

Evaluation of financial costs (capital, operational and maintenance) is presented in the previous section and the updated cost estimates are used in the hydro-economic assessment tool.

The report presents and discusses the regional economic baseline including regional economic growth (GDP) and development of mining, agricultural, and other business sectors. The report also highlights anticipated **economic impacts** associated with the project, including, among others:

- Contribution of the scheme to GDP growth;
- Improved productivity of farming (as a result of irrigation) and uninterrupted development of mining operations (as a result of additional water supply);
- Development of small and medium enterprises along the pipeline route.

However, the initial screening covers only qualitative and semi-qualitative assessment of anticipated economic impacts using a scale from 1(low significance) to 3(high significance) and distinguishing between positive and negative impacts. No quantitative estimates, e.g. on additional employment generation or GDP growth have been presented in the report.

Social baseline included in the screening report presents information on land use, demographics and social conditions (expressed as HDI (Human Development Index) covering areas like life expectancy and health, education, access to resources and services and participation in community life).

Environmental baseline is evaluated and presented in the report by natural zone (Khangai, steppe zone, Gobi and desert zones), eco-region (Khangai, Daurian steppe, Central Asian Gobi eco-region) and by river basins (Orkhon river basin). The assessment of environmental baseline presented in the report is qualitative only with full EIA and SEA to be developed in the future.

In the context of **environmental impacts** the report utilises World Bank's Environmental Screening, Environmental Assessment Sourcebook (1993). In particular, the assessment focuses on the nature and magnitude of anticipated impacts while having regard to the type, location, sensitivity and scale of the project. The sensitivity of the project is highlighted including the issues associated with disturbance of natural grasslands, encroachment on lands and rights of nomadic herders, involuntary resettlement and potential transboundary issues.

The results of initial screening and identification of potential environmental issues associated with the project highlighted the following issues that could give rise to potentially significant impacts.

- Issues related to dam safety, flooding, seismic and other risky conditions
- Modifications to hydrologic cycle associated with consumption of large volume of diverted water to extractive industry in the Gobi region and consequent changes to ecosystems
- Disturbance of natural grassland and encroachment on lands that may affect rights of nomadic herders, resulting in involuntary resettlement and associated conflicts

The screening of potential environmental impacts of project alternatives was based on the following criteria (and applicable range of significance of the impacts):

- Surface and groundwater (significant)
- Seismic threat (significant)
- Climate and air quality (significant or medium)
- Land use (significant or medium)
- Soil, vegetation and wildlife (medium or low)

The initial screening of anticipated environmental impacts distinguishing between positive and negative impacts was carried out using a scale of 1 (low significance) to 3 (high significance) with no quantitative estimates presented in the report. The data received, however, provides information on annual electricity consumption.

Generally, **social impacts** are considered in terms of water supply and water quality indicators, impact on employment, household income, livestock resilience (reduced mortality and increased birth rates) as well as changes in the pastureland. The screening of potential impacts of the project alternatives included the following relevant criteria (and applicable range of significance of the impacts):

- Social impacts (significant, medium or low)
- Indigenous people (significant, medium or low)
- Health and safety (medium or low)
- Cultural heritage (medium or low)

The initial screening results of anticipated social impacts associated with different project alternatives were presented on a scale of 1(low significance) to 3(high significance) and distinguished between positive and negative impacts. No quantitative estimates in relation to social impacts are presented in the report.

Summary of the initial screening results on economic, environmental and social impacts associated with the alternative C are summarised in the table below.

Table 25 Scoring of impacts

Criteria	Potential range of positive and negative impacts	Alternative C Negative impacts	Alternative C Positive impacts	Weight
Area of influence/ change	Significant	3	3	5
Climate and air quality (emissions, dust, noise)	Significant or medium	1	3	8
Surface water	Significant	3	3	10
Groundwater	Significant	1	2	10
Soil	Medium or low	2	2	7
Vegetation	Medium or low	2	2	5
Wildlife	Medium or low	2	2	5
Land use	Significant or medium	3	2	7
Seismic threat	Significant	3	1	5
Economy	Significant, medium or low	1	3	5
Indigenous people	Significant, medium or low	2	3	8
Social impacts	Significant, medium or low	1	3	7
Health and safety	Medium or low	2	2	8
Cultural heritage	Medium or low	2	1	5
Total score (impact multiplied by weight)		187	223	

The results of initial screening suggest that adverse impact on surface water resources in the donor catchment, scale of the project and associated land use changes are the key negative impacts. On the other hand, implementation of the project is anticipated to result in significant positive economic and social impacts. Furthermore, the region will directly benefit from the additional water supply which is the intended purpose of the project.

4.3. Incorporation of impacts into Hydro-Economic Framework

The outcomes of this review lead to amendments to the data previously derived for the Orkhon-Gobi water transfer scheme in the Hydro-economic assessment tool, including a number of criteria expressed in quantitative terms. In particular, such criteria include:

- Financial costs of the project alternatives (capex and opex)
- Technical effectiveness (water saving or water supply augmentation)
- Cost-effectiveness ratio
- Energy consumption
- Reduced human health risks
- Air quality and climate change
- Impacts on habitats and biodiversity

Furthermore, impacts on employment, water quantity, chemical and thermal pollution of water and land have been considered in semi-qualitative manner (using a scale). In particular, adverse impacts on soil, vegetation and wildlife are largely associated with pollution levels.

Information obtained in the course of this review was used to update the inputs in the Hydro-economic assessment tool. For instance, the results of the initial screening for soil, vegetation and wildlife criteria (assessed at medium impact) were used to amend the chemical pollution and waste criteria values within the hydro-economic assessment tool.

Table 26 Incorporated changes in the HE assessment tool for the Orkhon-Gobi water transfer scheme

Type of criteria	Criteria	Previous value	New value
Financial & technical	Capex [USD]	111,762,821	282,419,000
Financial & technical	Opex [USD]	5,486,539	17,287,400
Financial & technical	Water requirement [m^3/year]	30,000,000	17,198,892
Economic, environmental	Energy for water [KWh/m^3]	0.351	4.4
Financial cost effectiveness	Financial cost effectiveness ratio [USD/m^3]	0.56	2.68
Holistic cost-effectiveness ratio	CE ratio considering economic and environmental criteria [USD/m^3]	0.13	0.79
Economic	Net employment generation	None	None
Economic	Impacts on GDP growth	none	None
Environmental	Impact on available water quantity	4	4 (no change)
Environmental	Chemical pollution (land or water)	1	2
Environmental	Wastes	1	2
Environmental	Thermal contamination: discharge of cooling waters	1	1 (no change)
Total score	Total score inclusive of semi-qualitative criteria	2.13	2.62

5. References

Asian Development Bank, (2014). Demand in the Desert, Mongolia's Water–Energy–Mining Nexus.

Batimaa, P., Myagmarjav, B., Batnasan, N., Jadambaa, N., and P. Khishigsuren. (2011). Urban Water Vulnerability to Climate Change in Mongolia, Ministry of Nature, Environment and Tourism Water Authority/ UNEP, Ulaanbaatar.

Davaa, G., Oyunbaatar, D., Tumurchudur, S., Wim van der Linden, and Z. Munkhtsetseg. (2012). Orkhon River Basin Integrated Water Resources Management Assessment Report, Part 2. Surface Water Assessment.

Kenner, S., Nergui, S., Sodnom, T. and Khurelbaatar, T, (2015). Characterizing Environmental Low Flows in Terms of Magnitude, Duration and Frequency, Proceedings of the Trans-disciplinary Research Conference: Building Resilience of Mongolian Rangelands, Ulaanbaatar Mongolia.

Khishigsuren, P., Tsogzolmaa, Kh., and Ts.Baldandorj. (2012). Orkhon River Basin Integrated Water Resources Management Assessment Report, Part 1. Natural Condition and Land Use.

Prestige (2009). Orkhon-Gobi Project proposal

Prestige (2014). Report on Initial Economic, Financial, Environmental and Social Screening. Preparation of Terms of Reference for Feasibility Studies on Flow Regulation of Orkhon River and Construction of Water Reservoir Complex Project.

Richter, B.D., Davis, M.M., Apse, C. and C. Konrad. (2011). A presumptive standard for environmental flow protection River Research and Applications 28(8): 1312-1321.

Withanachchi, S.S, Houdret, A., Nergui, S., Ejarque Gonzalez, E., Tsogtbayar, A. and A. Ploeger (2014). (Re) configuration of Water Resources Management in Mongolia: A Critical Geopolitical Analysis, The International Centre for Development and Decent Work (ICDD) Working Paper No. 13, Nov. 2014

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