Ex post evaluation – Mongolia

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Sector: Energy policy and administrative management 23110
Programme: Energy efficiency II, BMZ no. 2010 65 424
Implementing agency: Power plant company Combined Thermal Power Plant IV

Ex post evaluation report: 2020

All figures in EUR million	Project (Planned)	Project (Actual)
Investment costs (total)	12.96	11.46
Counterpart contribution	4.46	2.97
Funding	8.50	8.49
of which BMZ budget funds	8.50	8.49

*) Random sample 2019

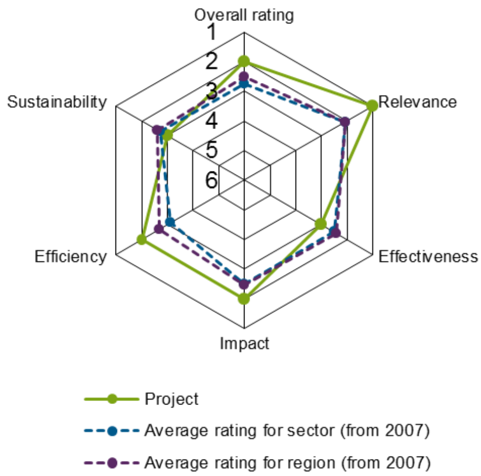
Summary: The aforementioned project included three separate modernisation measures to increase the energy efficiency and environmental and climate-based compatibility of Mongolia's largest power plant IV (703 MW), which is located in Ulan Bator. The specific modernisation measures were: 1) Retrofitting of a pipe cleaning system for the condensers in all seven steam turbines and the installation of two cooling water filters; 2) Installation of a new boiler feedwater pump; 3) Replacement of an outdated water treatment system with a reverse osmosis system. As a result of this measure, the power plant's specific coal consumption for power and heat production has been reduced, thus increasing the plant's efficiency. The increases in efficiency corresponded to the addition of 11.7 MW in new power plant capacity.

Development objectives: The programme's objective (outcome) was to contribute to the energy-efficient operation of power plant IV and thus making a contribution to a more economically sustainable energy and heat supply with reduced emissions, to support supply security in Mongolia, and to contribute to global climate change mitigation (impact).

Target group: The target group were the private and commercial energy consumers in the catchment area of Mongolia's central grid system's as well as the users of Ulan Bator's district heating network, thereby in particular, the population of the country's capital Ulan Bator, whose power and heat supply is primarily ensured by the power plant.

Overall rating: 2

Rationale: The programme addressed a very important core problem in Mongolia with the right measures. Even though the intended reduction in specific coal consumption and specific CO_2 emissions in the area of heat production was only just missed and there is still need for improvement regarding the maintenance budget in view of sustainability, the programme and its overarching developmental impacts impacts are considered good overall. Thanks to the reduction of other harmful emissions (mainly particulate matter, SOx and NOx) as well as large quantities of ash, and thanks to savings in chemicals previously used to treat water (sulphuric acid and salt), further positive environmental impacts were achieved beyond the CO_2 savings, particularly in relation to air quality. The good allocation efficiency and very cost-effective prevention of CO_2 are also worth highlighting.



Highlights: Ulan Bator is growing by around 30,000 inhabitants per year and it is also the world's coldest capital city with temperatures often dropping below -40°C. The city's fast-paced growth via areas known as ger (yurt) districts makes it difficult to supply heat to the population, who burn raw coal in inefficient furnaces. This form of heat supply is responsible for 80% of the air quality problems, which are highly dangerous to health; in this context, the power plants are responsible for up to 6% of air pollution.

Rating according to DAC criteria

Overall rating: 2

Ratings:

Relevance	1
Effectiveness	3
Efficiency	2
Impact	2
Sustainability	3

Relevance

At the time of the programme proposal (PP) in 2010, 79% of the power and heat generated in Mongolia came from seven coal-fired combined heat and power plants, which were built by the Soviet Union between 1961 and 1991. The power plants were highly inefficient and, as a result, recorded a high level of harmful emissions. High economic growth since the political "turnaround" in 1989 and fast-paced urbanisation led to continuous growth in the demand for power (from 3.5 GWh in 1990 to 8.3 GWh in 2018) and heat (from 3.9 million Gcal in 1990 to 7.7 million Gcal in 2018) (MoE, Energy Sector of Mongolia, Country Report, August 2018). The PP assumed that there would be a supply shortage in 2012, which is why the programme focused on supply security, an issue that was both important for survival and from a development policy perspective.

At the time of the project appraisal (PA) in 2010, 1.1 million people lived in Ulan Bator (UB) (around 40% of the total population). At the time of the EPE (2019), this had risen to around 1.5 million people, which is roughly half of the population of Mongolia. The city has grown at a very fast pace in recent years, with around 30,000 people per year. In view of the cold temperatures, which often drop below -40 degrees Celsius during the eight months of winter, maintaining the power and heat supply was and still is vital for survival and is also a prerequisite for the social and economic development of the region and the country.

The city's unregulated growth was and still is the source of huge problems, particularly when it comes to supplying the population with heat. Growth in areas known as "ger" districts (yurt districts) was particularly rapid. At present, around 60% of people live in these ger districts. Housing here consists of traditional felt yurts and simple timber houses that are heated with inefficient furnaces powered by the cheapest fuel,raw coal. The other 40% of UB's population is connected to the district heating network. In 2018, 80% of the air pollution in UB was attributed to heating in the ger district, 10% to traffic, around 6% to power plants, and around 4% to rubbish and soil erosion (WHO Policy Brief 2018, Air Pollution in Mongolia). In the winter months, air pollution in UB is between six to nine times higher than the WHO's permitted values for particulate matter, NOx and SOx. According to WHO calculations (WHO Policy Brief 2018), 4,133 people in Mongolia die every year from diseases that can be traced back to air pollution, particularly lung cancer, chronic obstructive pulmonary disease (COPD, which includes various irreversible chronic lung diseases), heart failure and strokes. Of these, 3,010 fatalities were attributed to the air pollution in coal-burning households themselves. As such, the mortality rate caused by air pollution is 132 deaths per 100,000 inhabitants. Mongolia therefore ranks among the countries where air pollution has the worst impact on health (global average 92/100,000). Air pollution is particularly dangerous to children, an above-average number of whom have to battle asthma and other respiratory problems. In Mongolia, pneumonia is the second biggest cause of death for children under the age of 5; children from the ger districts have up to 40% less lung capacity than children from rural areas. In March 2017, the government declared air pollution a national emergency and passed the National Programme for Reducing Air and Environmental Pollution (NPRAEP). To summarise, the air pollution in UB – as predicted in the programme proposal (PP) – has continued to deteriorate significantly since the PA in view of the conditions described above and is now one of the main problems of life in the city.

In 2018, 93% of energy generation was based on coal (79% as at PA) and 7% on renewable energy. Since the PA, power plant capacities have been expanded from 794 to 1,239 MW. However, the (very expensive) electricity imports from Russia rose at a continuous rate and now cover 20% of electricity demand (only required during peak load periods at the time of the appraisal).

At the time of the EPE (2019), the evaluated power plant IV (Combined Heat and Power Plant 4 – CHPP-4) generated 61.4% of Mongolia's power (67.2% as at the PA) and 55% of UB's heat supply (no information provided on this in the PP). In 2016, the three existing heat plants used to supply heat to the UB population connected to the district heating network were joined by the Amgalan heat-only plant with 110 MW. With a current output of 703 MW (580 MW during the PA), CHPP-4 remains by far the largest power plant in Mongolia. The installed capacity at CHPP-4 currently makes up 57% of the national installed capacity; at the time of the PA, this figure was 73%. The average usage rate for CHPP-4's installed capacity is 63.3%, though this can rise to 94% during peak load periods in the winter. CHPP-4 is a base load power plant and is the only power plant that can also be used to control the grid and cover peak loads. This demonstrates how vitally important it is for the supply security of the central region (roughly 2 million inhabitants) and for the heat supply to the population of UB. The power plant feeds into the central CRIPG grid, which is the most important of Mongolia's three electric integrated grids and covers around 95% of the country's electricity demands.

Looking beyond the issue of air pollution, the sharp rise in demand for power and heat and the outdated pool of power plants mean that supply security remains a key topic for Mongolia.

As outlined above, the core development problems of a supply shortage and harmful air pollution identified during the PA still persist and remain priority issues, even from today's perspective. The programme's concept included measures to increase efficiency, which were designed to help reduce specific coal consumption and cut emissions of CO_2 and other pollutants. It was a suitable approach to solve the core problems. The underlying impact logic was plausible.

As was previously the case, the project fits into the DC programme objective of making an effective contribution to the more economically and ecologically sustainable provision and use of energy and to the improvement of supply security; it also conforms with the Mongolian Energy Act and with all other key strategic sector papers. The mid-term strategy for implementing the "State Policy on the Energy Sector" envisages the further expansion of capacity at the CHPPs and in the field of renewable energy. In relation to the CHPPs, the measures relate particularly to increasing efficiency and improving emissions. Coordination in the energy sector takes place between the largest donors (ADB, World Bank, JICA, Germany), and sector policy coordination is organised by the Ministry of Energy at irregular intervals.The previous task force for the energy sector was renamed the task force for clean air in 2019 and also expanded. However, in light of the Paris Agreement (2015), power plants based primarily on coal have generally been excluded from German FC financing since mid-2019.

Relevance rating: 1Effectiveness

The outcome-level objective set for the EPE is to make a contribution to improving the energy-based and economic efficiency of operations at power plant IV. Target achievement is assessed based on the following indicators:

Indicator	Status at PA[1)]/ Target value at PA (kg/MWh / kg/GJ)	Ex post evaluation (kg/MWh / kg/GJ)
(1) Reduction of specific coal consumption[2)] a) By 9.1 kg/MWh in electricity production b) By 1.91 kg/GJ in heat production	a) 305.9 / 296.8 b) 41.9 / 39.99	a) 285.7 b) 41.39
(2) Reduction of specific CO_2 emissions[3)] a) By 37.9 kg/MWh in electricity production b) By 7.96 kg/GJ in heat production	a) 937.65 / 899.75 b) 128.52 / 120.56	a) 858.23 b) 125.01

1) The PA values are initial values prior to the project. They are based on the year 2013, see footnote 3) for an explanation

2) Based on standard coal

3) Since the method used meant that data for the power plant's CO_2 emissions cannot be compared with the data from the time of the PA, the CO_2 emissions value from before the project was recalculated. (Calculation method as per EU Directive 2003/87/EC, based on energy production, specific standard coal consumption, and average calorific value of natural coal). The data from before the project is based on the year 2013; the data as at the ex post evaluation is based on data from 2018.

The reduction of specific coal consumption by 20.2 kg/MWh (goal in PA: 9.1 kg/MWh) compared to the status at the PA significantly exceeded the target value. However, the target value regarding the reduction of specific coal consumption in heat production was not achieved (0.51 kg/GJ compared to the target of 1.91 kg/GJ). In principle, it is difficult to allocate energy consumption to the areas of electricity and heat production for combined heat and power plants. Furthermore, there is no universally recognised methodology for this. The method used to calculate the base values during the PA was not documented. The values and allocation used here are based on information provided by the operator. In light of this, a trend towards target achievement can still be derived from the quantification of the indicator objectives, though the reliability of the exact figures is limited.

In the interim period, CHPP-4 implemented further efficiency-enhancing measures that were not financed by the project. These include the installation of the additional, modern turbine 7 and the upgrading of the coal pulverizing mills and control technology. The FC project enabled the new turbine to be installed in the turbine room, which saved costs; this was possible because the new space-saving water treatment plant and the removal of the previous condensers freed up space.

On average, the power plant's total efficiency gains between 2015 and 2018 led to annual standard coal savings of 58,271 t compared to 2013 (before the project); this corresponds to 125,457 t of natural coal from the Baganuur and Tavan Tolgoi mines, from which power plant IV procures its coal. The power plant company credits the programme with total efficiency gains of around 60%. The calculations performed during the evaluation to determine the savings that could be attributed to the programme suggest that efficiency gains of almost 40% can be ascribed to the programme. Based on this figure, an average of 22,631 t/year (PP 24,596 t/y) of standard coal is saved as a result of the FC measures.

With regard to the reduction of specific CO_2 emissions in the production of electricity, the targets were also significantly exceeded: 67 kg CO_2/MWh instead of the envisaged 37.9 kg CO_2/MWh. However, the target value for heat production was once again missed by a significant extent (3.5 kg/GJ compared to 7.96 kg/GJ). Based on calculations during the EPE, an average of 90,492 t CO_2/year are prevented as a result of the programme.

The indicator objectives relating to the reduction of specific coal consumption and CO_2 emissions were significantly exceeded for electricity production. However, the targets for heat production clearly fell short of expectations. For this reason, effectiveness is assessed as satisfactory overall.

Effectiveness rating: 3

Efficiency

The total implementation period was 48 months compared to the planned 30 months. The delays were primarily caused by the tendering process for supplies and services. The pipe cleaning system (measure 1) and the replacement of the water treatment system (measure 3) were put into operation with a delay of six months. However, two failed tendering processes caused significant delays in the tender for the boiler feedwater pump and two speed-regulated drives (measure 2). For this reason, a decision was made to use the funds for measure 2 to expand the pipe cleaning system to turbine 7 and then use the remaining funds to procure a new water pump with equipment and two motors (not speed-regulated) (as an "emergency stand-by"). This decision appears to be necessary and sensible, even from the ex post perspective.

The investment costs amounted to EUR 11.46 million (88.4% of the value anticipated in the PA). Due to the changes required in relation to measure 2, the implementation period was delayed, which meant that the consultancy contract had to be extended three times. However, at EUR 660,039 (5.75% of the total costs) the total costs for the consultant are deemed reasonable. The project measures represented important modernisation measures for bringing the power plant into line with the current international state of the art. The implemented measures were the most profitable and closest in technical terms to five energy-efficiency measures examined during the feasibility study.

CHPP-4's efficiency increased from 40.19% in 2013 to 43.01% in 2018. In this regard, it must be taken into account that the use of heat power plants in Mongolia is driven heavily by the demand for heat, which is based around the demand peaks in winter; while power plant capacity is underused in the summer. During the same period, CHPP-4 reduced its internal energy consumption from 12.83 to 12.38%. The increase in the power plant's efficiency as a result of the energy-efficiency measures is equivalent to an additional capacity of around 10 MW at the time of the EPE (assumed to be 11.7 MW in the PA). This can mainly be traced back to the limited implementation of measure 2. The investment costs per additional kW are around EUR 1,140 (assumed to be EUR 930 at PA) and therefore still around 50% below the costs for constructing a new power plant with the same capacity. The production efficiency is evaluated as good overall.

The allocation efficiency of the invested funds is assessed as good: an internal interest rate (FIRR) of 19% was assumed in the PP. The same figure calculated during the EPE was 20%. The total economic cost calculation also results in an EIRR of 21% (PA 22%). The calculation assumed an average global market price for coal of EUR 86/t (same as PA, still regarded as realistic); the external effects on the environment and health, which are difficult to quantify, were not factored into the calculation as per the PP. At EUR 8.35 per saved tonne of CO_2, the programme's CO_2 prevention costs calculated in the EPE (same calculation method as the PP) were slightly higher than the value of EUR 7.7 per saved tonne of CO_2 estimated in the PA. Taking into account the coal and chemical savings, the prevention costs are then significantly lower than the PA value. As such, the investment was cost-effective, even with regard to the CO_2 prevention costs of EUR -5.10 per saved tonne of CO_2.

Efficiency rating: 2

Impact

The objective at impact level set out in the EPE was to contribute to a more economically sustainable energy and heat supply with reduced emissions, to support supply security in Mongolia, and to contribute to global climate change mitigation.

In light of CHPP-4's installed capacity, which makes up 57% of the national installed capacity, the energy-efficiency measures contributed to economic and ecological effects related to the impact at various levels.

CHPP-4's efficiency rose by a total of 2.82% (see Efficiency). As was previously the case, CHPP-4 is by far the most efficient power plant at 43% and, under the current general conditions, is already relatively close to its optimum for the capacity utilisation of the combined heat and power plant. Five of the other seven Mongolian power plants are between 20.3% and 39.5%. Only CHPP-3 achieves an effectiveness rate of 41%. Thanks to the programme's measures, CHPP-4 is currently Mongolia's most modern power plant and has thus become an example for other power plants in the country.

CHPP-4, as a baseload power plant that is also used for grid control, also makes an important contribution to security of supply. The increase in efficiency through the efficiency measures also results in the production of additional power and heat, which corresponds to a power plant capacity of around 10 MW at the time of the EPE.

In view of the savings of harmful emissions, the following annual savings of harmful emissions can be assigned to the project (average of 2015–2018, source CHPP-4):

Substance	Unit	Quantity (annual)
CO_2	t	90,492
Fly ash (15%)*)	t	7,421
Dust (0.015%)	t	743
NOx (0.21%)	t	141

SOx (0.47%)	t	233

*) Percentage based on natural coal

The power plant's total prevented annual CO_2 emissions amounted to an average of 254,337 t CO_2 between 2015 and 2018 compared to before the project (the power plant's average annual emissions were 5.1 million t CO_2 in the same period). CO_2 savings of 96,850 t per year are attributed to the programme. Beyond reducing CO_2 emissions, the programme (see table) also made an important contribution to reducing further emissions that are harmful to health (SOx, NOx, particulates and fly ash). The reductions in these harmful emissions are very important to UB's air quality and therefore to the health and living standards of the half of the Mongolian population who live there. Furthermore, the project measures have meant that large quantities of toxic chemicals did not have to be used in the water treatment plant (100 t of sulphuric acid and 300–400 t of salt per year). CHPP-4 is the only power plant to have an electrostatic precipitator (ESP) to remove particulates from the flue gas, though its effectiveness is now so reduced that it requires urgent replacement.

Despite CHPP-4's positive effects, the power plants' contribution to reducing air pollution is currently relatively low in view of the severe air pollution in UB caused by open hearths and unregulated ash disposal (see Relevance). The WHO ascribes 6% of environmental pollution to the power plants (see Relevance). A recent feasibility study by the World Bank attributes just 1% of air pollution to the power plants (SRS, "Feasibility Study to Reduce Dust and SO2 Emissions from CHP2, 3 AND 4, and Ash Ponds in Ulan Bator (Mongolia)" on behalf of the World Bank and UBCAP, 2015). However, due to the ban on burning raw coal and the better quality lignite briquettes made available to households, the power plants' percentage-based contribution will increase slightly.

Furthermore, overarching economic and social impacts are derived from CHPP-4's large contribution to the heat and power supply. The power plant's contribution forms the basis for any economic and social development in the densely populated region around UB and also enables the survival of around 800,000 people in winter. For the operating staff, the measures also directly lead to better working conditions in relation to occupational safety and manual work.

The impacts outlined above also contribute to the achievement of the DC programme objective (effective contribution to the more economically and ecologically sustainable provision and use of energy and to supply security). With regard to the DC programme objective, however, in a transitional phase in which more and more renewable energies are added to the energy mix, analogous measures to fully utilise the efficiency potential of the other power plants would be appropriate.

Impact rating: 2

Sustainability

The installed systems work well and are in a good, well-maintained condition. The technical measures implemented during the programme increase the power plant's availability as the routine cleaning processes take place during operation. Furthermore, a self-designed solution for using the water treatment system's membranes multiple times was also installed. Thanks to an upstream cleaning phase in which the cleaned membranes are reused, the service life of the expensive membranes for the reverse osmosis system can be extended.

The power plant's employees are able to complete operating and maintenance work to a satisfactory extent and will be able to do so in future as well: the good training provided by the suppliers and manufacturers has so far enabled the already well-trained and motivated staff to operate the state-of-the-art technology correctly, which is also due to be used in other Mongolian power plants. There is a clear awareness of the need for regular routine checks and preventive maintenance within the power plant. The employees are also aware of the power plant's importance for the population of UB and are proud of its good condition and good operating results. There is great interest among management and staff in the modernisation of the power plant.

Nevertheless, internal and inter-institutional decision-making and acceptance processes can take a long time, which restricts the power plant's effectiveness and efficiency. For instance, the State Commission for Equipment Acceptance did not accept the water treatment system until 2018, which led to delays as

CHPP-4 was not permitted to release any budget for maintenance or operation prior to this. Another critical point is the fact that the new water pump, which was delivered back in January 2016, was not installed until mid-2018. The original plans were to install it as the 9th pump, but ultimately a decision was made to use it as a replacement for the oldest pump. Even though decision-making processes can take too long, the systems' functional capacity was not seriously affected by this and (operating) problems have so far been dealt with successfully, in some cases with the manufacturer's involvement. Nevertheless, there has been a problem with the pipe cleaning system since autumn 2018 (cleaning balls are disappearing during the cleaning process; the cause has yet to be identified). CHPP-4 is currently conducting a study on the causes. However, the problem seems to be taking too long to resolve. The manufacturer was not involved earlier due to a lack of funds.

To avoid politically unpopular tariff increases, the energy regulation commission sets the power and heat tariffs and coal prices on an annual basis. Electricity prices subsidise the price of heat. The tariffs are not dependent on consumption. This results in revenue that does not cover costs. The budget for maintenance and repairs (excluding personnel) is just 10% of the total annual budget available to the power plant, which is insufficient should larger-scale problems occur or if spare parts or expertise have to be procured from abroad. The necessary investments in replacements therefore cannot be financed with the plant's own reserves and large repairs cannot be performed quickly. This fact poses the biggest risk to sustainability. However, CHPP-4 is "too big to fail" and the necessary funds have been covered by state grants where required. It is assumed this will remain the case in future.

According to the State Policy for the Energy Sector, Mongolia is preparing for a transitional phase towards a market-oriented energy sector with more autonomy for power plants and an adjustment of tariffs in line with actual costs. This would gradually eliminate the described obstacles in the field of management and future investments in power plants. However, this process is not expected to be achieved in the near future, particularly in view of the political concerns regarding energy price increases.

Sustainability rating: 3

Notes on the methods used to evaluate project success (project rating)

Projects (and programmes) are evaluated on a six-point scale, the criteria being **relevance**, **effectiveness**, **efficiency** and **impact**. The ratings are also used to arrive at a **final assessment** of a project's developmental effectiveness. The scale is as follows:

Level 1	Very good result that clearly exceeds expectations
Level 2	Good result, fully in line with expectations and without any significant shortcomings
Level 3	Satisfactory result – project falls short of expectations but the positive results dominate
Level 4	Unsatisfactory result – significantly below expectations, with negative results dominating despite discernible positive results
Level 5	Clearly inadequate result – despite some positive partial results, the negative results clearly dominate
Level 6	The project has no impact or the situation has actually deteriorated

Rating levels 1-3 denote a positive assessment or successful project while rating levels 4-6 denote a negative assessment.

Sustainability is evaluated according to the following four-point scale:

Sustainability level 1 (very good sustainability): The developmental effectiveness of the project (positive to date) is very likely to continue undiminished or even increase.

Sustainability level 2 (good sustainability): The development effectiveness of the project (positive to date) is very likely to decline only minimally but remain positive overall (this is what can normally be expected).

Sustainability level 3 (satisfactory sustainability): The developmental effectiveness of the project (positive to date) is very likely to decline significantly but remain more or less positive overall. This rating is also assigned if the sustainability of a project is considered inadequate up to the time of the ex post evaluation but is very likely to evolve positively so that the project will ultimately achieve positive developmental effectiveness.

Sustainability level 4 (inadequate sustainability): The developmental effectiveness of the project is inadequate up to the time of the ex post evaluation and is very unlikely to improve. This rating is also assigned if the sustainability that has been positively evaluated to date is very likely to deteriorate severely and no longer meet the level 3 criteria.

The **overall rating** on the six-point scale is compiled from a weighting of all five individual criteria as appropriate to the project in question. Rating levels 1-3 of the overall rating denote a "successful" project while rating levels 4-6 denote an "unsuccessful" project. It should be noted that a project can generally be considered developmentally "successful" only if the achievement of the project objective ("effectiveness"), the impact on the development objective ("impact") **and** the sustainability are rated at least "satisfactory" (level 3).