Ex post evaluation – Kenya

Sector: Hydroelectric power plants (CRS code 23220)
Project: Programme for renewable energy sources and energy efficiency, refurbishment and upgrading of Kindaruma hydropower plant, BMZ no. 2008 65 121*
Project-executing agency: Kenya Electricity Generation Company Ltd. (KenGen)

Ex post evaluation report: 2021

		Project (Planned)	Project (Actual)
Investment costs (total)	EUR million	42.50	53.33
Counterpart contribution	EUR million	12.50	14.23
Funding	EUR million	30.00	39.10

*) Random sample 2016

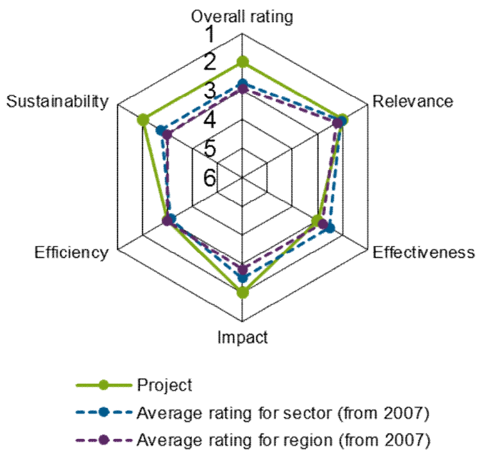
Summary: The project "Refurbishment and upgrading of Kindaruma hydropower plant" involved the refurbishment and expansion of the existing Kindaruma hydropower plant, which is located roughly 170 km north-east of Nairobi on the Tana River. It was implemented in two phases. Phase I covered the refurbishment of and performance-increasing measures for the two existing machines, which were commissioned in 1968 (new output roughly 48 MW), with corresponding ancillary systems. In phase II, the hydropower plant was expanded to include a new machine unit (output roughly 24 MW). As such, the entire hydropower plant of around 40 MW was expanded to reach an installed capacity today of about 72 MW.

Objectives: The programme objective was to produce reliable and climate-friendly electrical energy and feed it into the national interconnected grid (outcome level). As such, the goal of the project was to contribute to national development strategies to promote the Kenyan economy ("Vision 2030") and to contribute to global climate action (impact level).

Target group: The measure's target group was the entirety of customers connected to the power grid.

Overall rating: 2

Rationale: The power plant's refurbishment and expansion were needed from a technical perspective and were highly relevant due to their significance for stable, reliable and climate-friendly electricity production in the country, particularly during peak load periods. However, only some of the project objectives could be reached as the geothermal power production plants developed in parallel to this project are currently prioritised to cover base load demand. For this reason, the volume of electricity fed into the grid does not meet the targets. Due to its flexibility, the hydropower plant is used primarily to cover peak load periods and as a form of control energy to balance out fluctuations in supply and demand. As a result, consumers enjoy a reliable energy supply at all times. The power plant therefore makes an important contribution to Kenya's economic growth and climate action. Given the well-functioning electricity production process, the anticipated future demand for electricity, and the still-relevant situation of hydropower being the only source of energy able to cover evening peak load periods and the need for controlled output, good sustainability can be assumed.



Rating according to DAC criteria

Overall rating: 2

Ratings:

Relevance	2
Effectiveness	3
Efficiency	3
Impact	2
Sustainability	2

General conditions and classification of the project

The general conditions in the Kenyan energy sector are some of the most developed in Sub-Saharan Africa. Using an extensive reform programme, the government has spent the past fifteen years breaking up the energy sector, driving the sectoral focus towards full cost coverage, and creating a market for private investors in electricity production. Now, as many as 11 independent power producers (IPPs) with an installed capacity of 690.5 MW (roughly 29.5 % of the total capacity) contribute to the country's electricity production.

At present, the total installed production capacity corresponds to roughly 2,341 MW[1] and has thus risen by around 60 % since 2010 thanks to an intensive expansion policy. At the same time, demand during peak periods has risen by 50 % to a current 1,670 MW. Due to substantial investments in electrification, the number of grid connections between 2010 and 2017 has now quadrupled to around 6 million customers.[2] Despite demand for electricity rising more slowly than anticipated, the Kenyan government has continued its commitment to expanding renewable energy sources. At present, 1,793 MW of production capacity is in the pipeline. According to ambitious government plans, geothermal potential in particular is to be developed by 2031 so that up to 5,500 MW in production capacity is provided from geothermal heat. The current installed capacity amounts to 663 MW.

Future challenges include connecting the planned power plants to the national transmission grid and upgrading the grids so that the high losses in the distribution system of 19.4 % are significantly reduced.

One of the Kenyan government's current top two priorities in the energy sector is to massively reduce tariffs for end users. The two main strategies for achieving this goal are substituting thermal production units with renewables and expanding cross-border transmission lines for regional electricity exchange. The government's second priority is to achieve a comprehensive electricity supply by 2020. At present, around 70 % of all households are supplied with electricity. However, power connection rates in remote rural areas remain particularly low at an average of 30 %. Here, diesel-based island grids are frequently used.

Relevance

At the time of the project appraisal (PA) in 2009, Kenya's electricity supply was inadequate and unreliable. The main reasons for this were low and inefficient production, transmission and distribution capacities (PP dated 31 March 2009). At that time, the installed production capacities were just 1,314 MW.[3] At peak times in particular, there were regular power cuts, failures and load shedding, while diesel-powered back-

[1] Figures for 2017: 35.0 % hydropower (previous year 36 %), 34.8 % thermal power plants (previous year: 34 %), 27.0 % geothermal (previous year: 27 %), 1.2 % biomass and 1.1 % wind power (previous year: 1.1 % each). Furthermore, there is another 0.8 % of production capacity from island grids (primarily diesel plants).

[2] Number of customers in 2009/2010: 1,463,639.

[3] Gross production: 6,507 GWh, from hydropower: 2,160 GWh, from geothermal energy: 1,293 GWh;
net production: 6,468 GWh; final energy consumption: 5,767 GWh; electricity losses: 1,052 GWh; gross demand: 6,480 GWh
Source: UNdata (www.data.un.org).

up generators were often used. This had negative economic consequences because all power consumers – private households, industrial operations, commercial operations, service businesses, agriculture and administration – suffered losses in income and the deficit in the power supply had a hampering effect on Kenya's economic development.

Thanks to the storage function, the production of energy from hydropower is suitable for balancing out fluctuations in supply and demand in the electricity system, particularly for electricity demand in Kenya which is characterised by peak load periods in the evening. For this reason, the refurbishment and expansion of Kindaruma hydropower plant was fundamentally suited to contributing to a reduction in planned power cuts and making a direct contribution to a stable and reliable electricity supply to consumers connected to the power grid. As a result of this, it was assumed that the project had a positive impact on reducing the use of thermal energy and diesel-powered back-up generators and – by establishing additional production capacities – also facilitated the current grid expansion and future expansion plans as part of Kenya's comprehensive electrification strategy.

In view of global priorities, the project was therefore suited to making a positive contribution to the United Nations' Millennium Development Goal 7 ("Ensuring environmental sustainability"). It also complemented investments made by other multilateral and bilateral donors, such as AFD, World Bank or JICA, in the energy sector and was in line with the Federal Ministry for Economic Cooperation and Development's (BMZ) sector paper "Sustainable energy for development".

At the time, the project corresponded to KenGen's most urgent priority of substituting environmentally harmful diesel generators, reducing dependence on expensive imported electricity in favour of local renewable resources, and securing the quantity and quality of the power supply.

From the perspective at the time, the project was therefore highly relevant.

The impact relationships underlying the project appraisal – rehabilitating and expanding an existing hydropower plant to secure affordable and ecologically compatible electricity production, thereby contributing to economic growth and climate action – are coherent, even from today's perspective.

Following the liberalisation of the energy sector by a comprehensive piece of corresponding energy legislation in 2006, Geothermal Development Company Limited (GDC) was founded in 2008 to accelerate the expansion of geothermal resources. At the time of the project appraisal, neither the findings from the advanced exploration processes initiated as a result of this nor the Kenyan government's decision made on the basis of these findings in the years that followed – to step up the expansion of production capacities using geothermal energy and use this capacity for base-load operation – were foreseeable. Since both flexible load balancing in the system and the rapid provision of energy during peak demand periods still address a core problem in the Kenyan electricity system, the project exhibits a sufficiently high level of relevance, even from today's perspective.

Relevance rating: 2

Effectiveness

The project covered the refurbishment, performance increases and expansion of the existing Kindaruma hydropower plant roughly 170 km north-east of Nairobi on the Tana River. It was implemented in two phases. Phase I covered the refurbishment of and performance-increasing measures for the two existing machines, which were commissioned in 1968 (new output roughly 48 MW), with corresponding ancillary systems. In phase II, the hydropower plant was expanded to include a new machine unit (output roughly 24 MW). As such, the entire hydropower plant of around 40 MW was expanded to reach an installed capacity of about 72 MW today. While the work was being carried out, training measures were implemented to ensure that KenGen's operating team can run the plant in a sustainable manner.

The project's outcome-level objective was to produce electricity reliably and in an environmentally friendly manner, and then feed the electricity into the national interconnected grid. Since commissioning (2012/2013), the target achievement can be summarised as follows on the basis of the indicators defined at PA:

<table>
<tr><th>Indicator</th><th>Status/target value PA</th><th>Ex post evaluation</th></tr>
<tr><td>(1) Average amount of electricity fed into the interconnected grid</td><td>Status PA: 200 GWh/a
Target PA: 240 GWh/a</td><td><table><tr><td>12/13</td><td>13/14</td><td>14/15</td><td>15/16</td><td>16/17</td></tr><tr><td>252</td><td>202</td><td>166</td><td>209</td><td>202</td></tr><tr><td colspan="5">Average for 2013–2017: 206 GWh/a</td></tr></table></td></tr>
<tr><td>(2) Availability of the three 25* MW turbines:</td><td>Status PA: min. 40 %
Target PA: min. 80 %</td><td><table><tr><td>12/13</td><td>13/14</td><td>14/15</td><td>15/16</td><td>16/17</td></tr><tr><td>67</td><td>94</td><td>96</td><td>95</td><td>90</td></tr><tr><td colspan="5">Average for 2013–2017: 88.4 %</td></tr></table></td></tr>
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*The output of 25 MW per machine unit used as a basis in the project appraisal was reduced to 24 MW each during the detailed planning stage.

Even when taking into account the natural fluctuations in annual water resources, it can be ascertained that the amount of electricity produced and fed into the transmission grid always remained below expectations and did not reach the respective target (see table, indicator 1). The large downturn in the volume of electricity fed into the grid by Kindaruma hydropower plant in 2014 can be attributed to the commissioning of the expansions to geothermal projects Olkaria I and Olkaria III and the newly constructed Olkaria IV, which suddenly doubled the electricity production capacity for geothermal energy to around 470 MW. Since the distribution grid operator KPLC gets to decide when and how much electricity should be utilised from the production capacities available to it and since it currently prioritises geothermal-based production to cover base load needs, KenGen cannot be blamed for the failure to reach the annual electricity volume targets from Kindaruma hydropower plant.

The figures provided by the executing agency prove that the indicator for technical availability was significantly exceeded, apart from in the period 2012/2013 (see table, indicator 2). The failure to reach the targets in the initial documented periods was the result of extensive acceptance tests for machine units 1 and 2.

With the national installed capacity, KenGen is able to cover peak load demand and also provide control energy to balance out fluctuations in supply and demand. The well-maintained and up-to-date power plant Kindaruma makes an important contribution to this.

Effectiveness rating: 3

Efficiency

It was possible to adhere to the framework for timing and costs set out for the project. The costs per installed capacity (in €/MW) were appropriate for both the refurbishment and the addition of the third turbine. The specific costs for the newly installed machine unit (unit 3) were EUR 0.895 million per MW. For comparable hydropower projects in Africa financed by KfW, the range of investment costs spans from EUR 0.5–1.0 million per MW depending on the location, technical design and steel price valid at the time of the contract conclusion, meaning that the electromechanical equipment for the third unit in Kindaruma falls within expectations. A total of EUR 12.74 million from the loan and EUR 6.34 million from KenGen's capital was spent on refurbishing the two original machine units, resulting in specific costing needs of EUR 0.4 million per MW. An evaluation of a number of refurbishment projects has revealed that costs of around 60 % of those for a comparable new investment must be anticipated for a comprehensive extension of a hydropower plant's service life. Applying the aforementioned range for KfW-financed new projects would result in a range of EUR 0.3–0.6 million for refurbishments, meaning that the project costs for the two old units in Kindaruma are plausible.

Due to the large investments made in additional production capacities in recent years – driven primarily by the expansion of geothermal energy in parallel to the expansion of hydropower – the current level of demand for electricity is met by production capacity that tends to be on the high side and thus is sometimes left unused. Under the current compensation system within the Kenyan energy sector, KenGen is not remunerated per generated unit of output, but per installed capacity unit. The electricity price for end consumers is calculated to achieve full cost coverage. If the capacity is too high and left unused, this will ultimately lead to raised tariffs. Since electricity tariffs in Kenya are already above the regional average as it is and are not subsidised – even for vulnerable end consumers – excess capacity leads to increased financial burdens for private households on the one hand, while also potentially reducing Kenya's appeal as a business location on the other. However, capacity created from hydropower is essential for the purpose of supply security, meaning that the causes of possible negative impacts arising from high production capacities lie in the current compensation system.

In comparison to alternative sources of power (including photovoltaic, wind, fossil, thermal, diesel-powered engines), the investment concept pursued at the time of the project appraisal was the most cost-effective scenario. Even from today's perspective, the investment strategy used in the project was the most suitable choice of technology, particularly in terms of covering peak demand: photovoltaic power cannot make a major contribution because peak load periods do not set in until evening, wind is not reliable enough due to the fluctuating production levels, geothermal energy is fundamentally unsuited to cover peak load periods or grid fluctuations due to the lack of control options, and systems based on fossil fuels (mainly diesel) would not be taken into account on the grounds of cost and environmental friendliness. While hydropower plants play a dominant and almost irreplaceable role in the provision of peak load in Kenya, geothermal plants produce unbeatably cheap electricity during base load periods. As such, Kindaruma hydropower plant is able to provide peak electricity for a few hours a day with a high level of availability and with high utilisation of the installed capacity, but it then has to be heavily throttled during base load periods and give priority to geothermal electricity. Due to the reservoir's low volume, Kindaruma hydropower plant must emit a portion of its incoming water into the lower-level hydropower waterfall through the weir system during base load periods, meaning that it is able to use only a portion of its energetic potential.

The priority given to the use of geothermal electricity for the purpose of base load coverage therefore currently limits the usage rate and, with that, the economic efficiency of Kindaruma hydropower plant.

Under the current market conditions, it is likely that a different decision would be made as to whether to expand Kindaruma hydropower plant by adding a third machine unit, particularly in the form of a propeller unit with simple regulation and limited flexibility.

One positive aspect worth noting is that the increased transmission line capacities to neighbouring countries in the East African Energy Association generate new opportunities for imports and exports.

Efficiency rating: 3

Impact

The project's main goal was to contribute to Kenya's economic growth and to global climate action.

Kindaruma hydropower plant contributes to these goals by allowing consumers connected to the power grid to benefit from a reliable and adequate electricity supply. Thanks to a direct connection to the grid, this applies particularly to the urban centre of Nairobi. Even during peak load periods, there is no longer any need for the rationing measures that were often used prior to the project's implementation. This has a direct positive impact on the underlying economic conditions for businesses in Kenya and encourages investors to choose Kenya as a location for industry.

Kenya's GDP has risen by an average of 5.6 percent per year since the third turbine was commissioned in 2013. It is impossible to assign an exact share of this to the functioning power plant, though research has identified a very high correlation between electricity supply and economic growth.[4] It is presumed that a reliable electricity supply and the amount of electricity produced by the power plant had a positive impact on growth within this scope.

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[4] Stern, D. I, Burkes, P. J, and Bruns, S. B. (2017). The Impact of Electricity on Economic Development: A Macroeconomic Perspective. UC Berkeley: Center for Effective Global Action.

Due to the increased hydropower capacities, the extra capacity now available in addition to the base load capacity from geothermal sources substitutes both diesel-powered back-up generators and the use of thermal energy. While thermal power plants still produced 3,047 GWh in 2009, they produced just 1,471 GWh in 2016, despite a rise in total energy production. This has led to a reduction in harmful emissions and thus contributes to global climate action. Furthermore, the generation capacity secured for the next few decades – as a result of the refurbishment and expansion of Kindaruma hydropower plant – results in a significant reduction of carbon emissions. Applying the average amount of electricity fed into the interconnected grid for 2013–2017 of 206 GWh and the grid emission factors transmitted to the UNFCC of 0.5993 tCO2eq5/MWh, the carbon reduction attributed to the power plant's operations is calculated as 123,450 tCO2eq per year.

In addition to the beneficial development policy impacts on the economy and environment, further positive effects from the project's implementation have been identified. During the project's implementation, the inhabitants of Kindaruma and surrounding communities benefited from temporary employment related to the construction work. Even after the project was completed, staff are still needed to run and service the plant, roles which are covered by local workers. As a result, families are able to send their children to school and the increase in employment rates also improves the economic power of Kindaruma and the surrounding area. This in turn has a positive effect on local shop owners. What is more, KenGen invests 1 % of its profits into social projects in the project communities, e.g. developing infrastructure measures such as roads and schools, treating and providing free drinking water, and reforesting areas for the purpose of erosion control. One aspect that is particularly worth mentioning is the annual granting of bursaries to the best pupils in each year from nearby schools, who receive financial support until they graduate from university if they receive good grades, and are then offered a role with KenGen.

There is a negative environmental effect from starting up and shutting down the individual hydropower stations at the waterfalls on the Tana River, as this decision is based exclusively on energy-related considerations. The resulting surges up and down the river and the rapid changes to the water table regularly result in losses in the fish population.[6]

No other positive or negative environmental effects have been identified.

Due to the large number of positive contributions, the project has been awarded a good impact rating.

Impact rating: 2

Sustainability

Thanks to the refurbishment and upgrading of the hydropower plant, KenGen now has three machine units that permit it to produce electricity for a further 25–30 years if they are operated and maintained properly. KenGen is sufficiently qualified to run and maintain the systems. The knowledge imparted to selected service providers during the project implementation period is passed on within the company, thereby ensuring a high level of technical knowledge. According to the current financial situation, sufficient funds are available to operate the plant. Due to the system of compensation by installed unit instead of by generated unit, this situation is likely to persist in the future. One intrinsic risk is the presence of a sufficient water supply for the hydropower plant. However, there is no specific indication of a reduction in the water available beyond normal hydrological fluctuations. In fact, forecasts indicate a slight rise in water volumes.

The overall plant's sustainability is at risk from the advancing sedimentation[7] of the reservoir, though this will not set in until after the now extended technical service life. KenGen is working to counteract the build-up of sediment by means of erosion control measures in the catchment area and dams in the tributaries, thereby decelerating the increasing loss of storage space.

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[5] Tonnes of carbon dioxide equivalent.

[6] The water supply's role is explained in more detail in the next section.

[7] Sedimentation refers to the natural filling of standing inland water with organic material.

From today's perspective, the seamless electricity production process, the anticipated future demand for electricity, and the still-relevant situation of hydropower being the only source of energy able to cover evening peak load periods and the need for controlled output leave us expecting a good sustainability.

Sustainability rating: 2

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 **overarching developmental impact**. The ratings are also used to arrive at a **final assessment** of a project's overall developmental efficacy. 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 efficacy of the project (positive to date) is very likely to continue undiminished or even increase.

Sustainability level 2 (good sustainability): The developmental efficacy 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 efficacy of the project (positive to date) is very likely to decline significantly but remain 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 efficacy.

Sustainability level 4 (inadequate sustainability): The developmental efficacy 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 overall objective ("overarching developmental impact") and the sustainability are rated at least "satisfactory" (level 3).