Ex post evaluation – Brazil

Sector: Energy generation, renewable sources - multiple technologies (CRS code: 2321000)
Project: Renewable energy investment programme
Project-executing agency: Energy Company

Ex post evaluation report: 2020

All figures in EUR million	Project (Planned)	Project (Actual)
Investment costs (total)	64.4	82.8
Counterpart contribution	27.2	20.1
Funding	37.2	62.7
of which BMZ budget funds	37.2**	62.7**

*) Random sample 2019
**) Grants, HH loan and IVF

Summary: At the time of the project appraisal, the project involved the construction of four small hydropower plants in the southern Brazilian state of Santa Catarina with a total capacity of 53 MW. Ultimately, two small hydropower plants (run-of-river power plants) were built with a total capacity of 34 MW, consisting of a dam, intake conduit/tunnel, lock, power house, transformer station/switchboard plant and a high-voltage line to transport the energy produced.

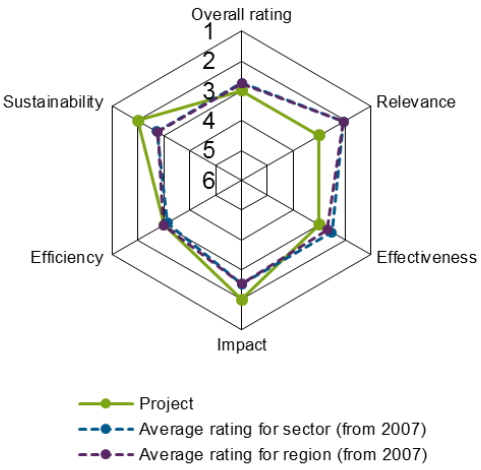
Objectives: The project's objective at outcome level was to contribute to an efficient and reliable energy supply from (non-conventional) renewable energy sources that would be secured over the long term. As a result, the project was intended to help protect the environment and climate by preventing carbon emissions (objective at impact level).

Target group: The project's direct target group was the project-executing agency through the expansion of its generation capacities and the users of energy services, particularly users who consume energy for production purposes.

Overall rating: 3

Rationale: The project tackled a core problem in Brazil – repeated shortages in the energy supply – with relevance for development. However, the project's concept was found to have weaknesses when it came to cost estimates. For this reason, less capacity was installed than originally planned, thus resulting in lower annual power generation and fewer carbon emissions prevented. Since starting operations, the annual power generation of the two small hydropower plants implemented has remained below the targets derived from the actual installed capacity over a six-year average. Hydrological data suggests that the annual generation rates are likely to remain below the planned annual generation figures, even in the future. However, no conclusive assessment can be provided on this at the time of the EPE due to the strong and naturally occurring flow fluctuations. The weaknesses described above lead to the project being rated as satisfactory despite its positive and sustainable impacts.

Highlights: Operations and maintenance are performed to a very high standard in line with best international engineering practice.



Rating according to DAC criteria

Overall rating: 3

Ratings:

Relevance	3
Effectiveness	3
Efficiency	3
Impact	2
Sustainability	2

Relevance

At the time of the programme appraisal in 2007, the total installed power generation capacity in Brazil was around 100 GW. Hydropower accounted for 77 % (around 77 GW) of this total (with only around 1.8 GW coming from small hydropower), thermal power for 21 % (including 4 % biomass) and nuclear power for 2 %.[1] The dominance of hydropower in terms of installed capacity also affected power production. In 2007, hydropower produced around 89 % of the electrical energy generated. National power consumption amounted to 377,030 GWh in 2007, roughly 24 % of which was used by private households and around 46 % by industrial operations.[2]

In response to a drastic shortage of energy in 2001 and radical rationing plans, the Brazilian government at the time of the programme appraisal in 2007 was pursuing the goal of increasing generation capacities to cover increasing demand and avoid another energy crisis. According to the project proposal (PP), demand forecasts for the period from 2006–2015 assumed that demand would increase by 5.1 % p.a. to a final level of 567,000 GWh in 2015 (335,000 GWh in 2005) and an additional 39 GW in power plant capacity would be needed to be able to satisfy the anticipated growth in demand. In view of this situation, public entities were called upon to (re)develop or increase their own production capacities given the government's aim to raise capacities following the initial phases of liberalising the energy market. When adding new capacity, the goal according to the development plan was to rely on more renewables, the use of which had been neglected until then, with the exception of the construction of large-scale hydropower plants.

The core problem of a renewed deficit in Brazil's power supply was correctly identified. The project approach – investing in small hydropower plants, resulting in an increase in capacity – to help solve the core problem was appropriate at the time and from today's perspective. The underlying causal links are equally plausible: investments in non-conventional renewables → efficient, reliable power supply from renewables that is secured over the long term → protection of the environment and climate by avoiding carbon emissions in the newly created capacity.

The project's relevance is also assured at the time of the ex post evaluation (EPE). Although the total installed production capacity increased to around 163 GW (2018)[3], further growth in the demand for power of 3.6 % p.a. up to 2027 is forecasted at the same time.[4] To cover this growth, plans are in place to add new capacities of almost 61 GW by 2027.[5]

The project's concept exhibited weaknesses in its cost estimates and therefore in relation to the installed capacity and annual production figures possible within the scope of the project. In retrospect, it is clear that positive underlying conditions (geological and hydrological) were assumed during the planning process. The only source available at the programme appraisal was the Projeto Básico created by a private project developer in 2006. In-depth studies were not planned until a later point in the project within the

[1] Source: Balanço Energético Nacional (BEN) 2007, Empresa de Pesquisa Energética (EPE) – Energy research company

[2] Source: Consumo nacional de energia elétrica por classe: 1995 - 2018, EPE

[3] Source: BEN 2018, EPE

[4] Source: Projeção da demanda de energia elétrica para os próximos 10 anos (2017–2026), EPE

[5] Source: Plano Decenal de Expansão de Energia 2027, EPE

scope of an EPC contract (Engineering, Procurement, Construction, i.e. the rendering of turnkey services by a general contractor). While contracting the work out under an EPC contract was the right approach given the programme executing agency's limited experience with project development for small hydropower generation capacities at the time, these contracts tend to lead to higher prices compared to other types of contract due to the risk being transferred to the contractor. In retrospect and against this background, the (specific) costs were set too low in the programme appraisal (see Efficiency). With the funds available, it was therefore impossible to build 4 small hydropower plants with a capacity of 53 MW – as originally planned in the PP – and achieve the target of a secured annual production level of 252.5 GWh and prevent 66,000 t of CO_2 per year. More developed and more in-depth planning documents at an earlier stage of the project could have created a more reliable basis for the project planning (particularly for costs and time). However, documents of this level tend not to be available in the early stages of this kind of project, and are therefore not available for the programme appraisal.

The project supported the Brazilian government's efforts to promote the creation of additional production capacities using non-conventional renewable sources of energy to cover Brazil's rising energy demands. In its 2007–2026 development plan, the Brazilian government set itself the goal of increasing the proportion of installed production capacity from renewable sources of energy (such as small hydropower, wind and solar power) from 2.9 % (2007) to 7 % (2016). Furthermore, the project complemented German-Brazilian cooperation and the plans for a German-Brazilian energy partnership in the field of renewables and energy efficiency set out in the programme appraisal as a priority area of their cooperation.

Due to the conceptual weakness concerning the estimates for specific costs as described above, and their extensive impact on the scope of the project's possible results (just 2 of the 4 small hydropower plants), the relevance is rated as just about satisfactory.

Relevance rating: 3

Effectiveness

The outcome-level objective used as a basis for the EPE was to contribute to an efficient and reliable energy supply from (non-conventional) renewable energy sources that would be secured over the long term.

Due to the weaknesses in the cost estimates for the programme appraisal described under Relevance, it was not possible to build four small hydropower plants. Consequently, the potential installed capacity by the project and the secured annual generation figures were reduced.

The following indicators were used to assess the target achievement, the targets for which relate to the two contracted small hydropower plants of João Borges (JB) and Barra do Rio Chapéu (BRC):

Indicator	Target value PA	Actual value at EPE
Installed capacity (MW)	Total 34.15 - 19 (JB small hydropower plant) - 15.5 (BRC small hydropower plant)	Total 34.15 - 19 (JB small hydropower plant) - 15.5 (BRC small hydropower plant)
Secured annual power generation (gross) (GWh/a)	Total 164* - 89 (JB small hydropower plant) - 75 (BRC small hydropower plant)	Total 131** - 65 (JB small hydropower plant) - 66 (BRC small hydropower plant)
System availability (%)	Target value: > 95	> 90 94.6 (JB small hydropower plant) 93.1 (BRC small hydropower plant)

*) The target value is based on the power plants' Garantia Física (GF), which is set for each hydropower plant by the Mines and Energy Ministry (MME) and is intended to map sustainable energy production in the power plant's dry periods.
**) Average for the years 2014–2019.

The overall result for the indicator target achievement at outcome level is mixed: the planned capacity of 34.15 MW for the two contracted small hydropower plants was achieved. However, their secured annual power generation levels are significantly below target, and therefore were not achieved. Annual power generation (average for the years 2014–2019) is 20 % below the target level (João Borges small hydropower plant around 27 % and Barra do Rio Chapéu small hydropower plant around 12 % below the target). The operating period of almost 7 years (2013–2020) at the time of the EPE does not allow for a conclusive assessment to be made in terms of the hydrological situation and its impact on secured annual power generation due to the natural annual flow fluctuations, which have been strong for this area of the river over recent decades. The annual flow figures for the years 2013–2019 were generally below the average annual trend line, apart from the year 2015. Furthermore, the data available at the time of the EPE suggests that, due to the hydrological conditions, annual generation from the capacity installed under the project is likely to remain below the planned annual generation figures in future too, even if the two power plants are run at the optimum level. The annual generation figure used for the planning process and based on the flow duration curve used for planning was confirmed by the EPE using the Barra do Rio Chapéu small hydropower plant as an example. The design of the small hydropower plants is also deemed correct in retrospect.

On the whole, the small hydropower plants exhibit acceptable availability of > 90 % (average since they were commissioned in 2013), which is just below the international availability target of > 95 %. This can be attributed to factors including extensive maintenance work in individual years, which had to be carried out due to damage (material weaknesses).

From an international perspective, the plants are operated at a very high standard of quality (see Sustainability). The systems are controlled by a central load dispatch centre in Florianópolis and are serviced on site by mobile deployment teams if required or should faults arise that cannot be rectified remotely. This process is highly effective in terms of operation.

Given that the secured annual power generation is significantly below the target, the effectiveness is rated as satisfactory.

Effectiveness rating: 3

Efficiency

Overall, the project costs from the initial estimates (2006) had risen by 167 % by the time the construction work was finished (2013). This is due to the following reasons:

In the aforementioned period between 2006 and commissioning in 2013, the accumulated inflation rate in Brazil was roughly 44 %, which is reflected by indexation clauses within the contracts – concluded in BRL – and also in the final contract values. Beyond the increased inflation, the project took place during an economic upswing with rises in prices within the Brazilian construction industry as a result.

The contract value of the construction orders (EPC) was already 39.3 % (around 24 % adjusted for inflation) above the original cost estimates in the Projeto Básico (2006) for the small hydropower plants drawn up by a private project developer. This increase and the final specific costs, which were still at an acceptable level (see below), suggest that the specific costs set at the beginning of the project were too low.

While the construction work was being carried out, the project was confronted with further unanticipated geological and hydrological challenges (João Borges small hydropower plant: difficult geology for the foundations and flooding of the excavation pit as a result of an extraordinarily high flood; Barra do Rio Chapéu small hydropower plant: failure in the dam and instable tunnel ceiling areas), which resulted in further cost increases. Compared to the order value when the contracts for the construction orders were signed, the final costs rose by a further 91.7 % (around 67.5 % when adjusted for inflation).

The specific costs in the Projeto Básico were initially estimated at BRL 3.22 million per MW. The actual specific costs after completion of the construction work in 2013 were BRL 8.59 million per MW. Despite the significant increase in specific costs, this figure, which was equivalent to EUR 2.99 million per MW in the year of completion (2013)[6], was still of a similar magnitude to other small hydropower plants built in

[6] Average exchange rate in 2013: EUR 1 = BRL 2.87

the region during the same period (EUR 2.5–3 million per MW) albeit at the upper end of the range. Even in comparison to two other larger hydropower plants built by the programme executing agency in the same period with specific costs of BRL 8.1 and 10.9 million (these projects tend to have lower specific costs than small hydropower plants), the specific costs appear to be within an acceptable scope.

At just under 7 %, the internal rate of return (IRR) based on the energy commercialised in accordance with the Garantia Física (GF)[7] is, as expected, slightly below the 8 % standard rate for the sector due to the cost increases. In the programme appraisal, the IRR for the four small hydropower plants originally planned was specified as 12.8 %.

Since they were commissioned, the average take-off price achieved on the free market8 for both power plants for the energy commercialised under the GF was BRL 234 per MWh. Based on the existing contracts for 2020, the programme executing agency expects an average take-off price of BRL 235 per MWh; this is an attractive take-off price compared to the regulated market. As explained under Effectiveness, it appears as though the secured energy generation rate assumed in the GF will not be achieved, even in the future. From a commercial perspective, this tends not to be critical for the programme executing agency as the small hydropower plants are permitted to commercialise the energy specified in the GF in off-take agreements, even if their production rates are below this level. The difference between the GF and the plants' own energy generation levels is purchased at a very favourable rate via the structured redistribution mechanism (MRE[9]), and at the prices defined in the off-take agreements, which are significantly higher than the purchase price. From a sectoral perspective, this would not be efficient as a permanent condition. Furthermore, it would call the function of the MRE into question if generation were permanently below the GF at the majority of the hydropower plants participating in the MRE and therefore the temporary under-production of some hydropower plants could not be balanced out by the temporary over-production of others.

Based on the secured annual power generation figures determined in the GF, the small hydropower plants' prime costs are around BRL 198 per MWh for João Borges and BRL 181 per MWh for Barra do Rio Chapéu (base year 2009). In comparison to the results from the energy auctions (BRL/MWh) in the same period, these prime costs are appropriate. At the time of the programme appraisal (2007), conventional hydropower (large-scale hydropower) was the most affordable regenerative alternative. However, the project's goal was to increase energy production from alternative (non-conventional) renewable energy sources. Further alternative renewable energy sources, such as biomass, wind and photovoltaics, did not begin to play a more dominant role until 2009/2010. In recent years, the costs for generating power from solar and wind farms in particular have fallen heavily. Nowadays, at BRL 70 per MWh (auction price in 2018, adjusted for inflation against base year 2009), wind is the most affordable source of energy.

According to the final inspection, there was no indication of any misappropriation of funds.

Against the following background, the efficiency is rated as just about satisfactory: Despite considerable cost increases over the course of the project, the specific costs are still in line. The further development of the hydrological conditions and the future annual generation figures achieved as a result are decisive for the plants' profitability, which has remained below expectations to date. However, it is not possible to provide a conclusive assessment on these factors at the time of the EPE.

Efficiency rating: 3

[7] Hydropower plants are permitted to commercialise no more generated energy than the amount specified in the GF. The GF defined by the MME is due to be adjusted every five years, though only by 5 %, or no more than 10 %, over the entire term of the concession.

[8] Ambiente de Contratação Livre (ACL) and Spot

[9] The Mecanismo de Realocação de Energia (MRE) serves to protect the hydropower plants from hydrological risks. Participation is voluntary for small hydropower plants. The MRE considers all Brazilian hydropower plants in a pool as an aggregated GF. The complementary hydrological conditions nationwide enable hydropower plants to exchange under/over-production.

Impact

The objective at impact level used as a basis for the EPE was to contribute to protecting the environment and climate by preventing carbon emissions. The following indicators are used to assess target achievement; the indicator targets relate to the two implemented power plants as it was not possible to build four power plants using the funds available (see Relevance):

Indicator	Target value PA	Actual value at EPE
Carbon emissions prevented (t/year)	38,193*)	47,814**)

*) CO_2 coefficient calculated based on IGES (period 2006–2008, combined margin CM: 0.233 t CO_2/MWh)
**) CO_2 coefficient calculated based on IGES (period 2015–2017, combined margin CM: 0.364 t CO_2/MWh)

Even though the secured annual power generation of the two small hydropower plants has been lower than planned since commissioning (see Effectiveness), the target for the prevention of carbon emissions (t/year) was still achieved; this is because the latest CO_2 emissions reduction factor (2015–2017) has risen compared to the original value (2006–2008). Without this rise, the target would not have been achieved.

Through the addition of new power generation capacities using renewable energy sources, the project contributes to the prevention of carbon emissions and thus to the overarching development objective of protecting the environment and climate, even though the prevention of carbon emissions remains, as expected, significantly below the target of 66,000 t of CO_2/year planned in the project proposal. This would only have been attainable had four small hydropower plants been constructed.

With this project, the programme executing agency re-entered the domain of energy generation. As a result, it began to rebuild its expertise in project planning and implementation, and in the operation and maintenance of hydropower plants. The programme executing agency currently operates a total of four of its own hydropower plants with an installed capacity of 159.15 MW (including the two FC-financed plants) and is also involved in three other plants. Its stakes in the investments correspond to an installed capacity of 1,377 MW. Upon commissioning (2013), the programme executing agency's stake in the installed small hydropower plant capacity in the state of Santa Catarina was around 9.6 %. Following the creation of additional capacity in the state, this was 6.4 % in 2019. However, the far larger stake in capacity of 1,503 MW is located in other states. Even though the installed capacity of the two small hydropower plants implemented as part of the project corresponds to around just 0.7 % of the installed small hydropower plant capacity for all of Brazil, the project can be assumed to have a broad effect for the expansion of renewable energy sources. On the one hand, this is can be attributed to the installed small hydropower capacity of the programme executing agency in the state of Santa Catarina, while on the other hand, the project-executing agency as a subsidiary of one of the largest energy companies in Brazil is able to offer up its expertise to its parent company. There is still potential for small and micro hydropower, though according to the programme executing agency it is becoming increasingly difficult to implement small hydropower projects profitably and with low implementation risks. In recent years, the programme executing agency has also expanded its generation capacities into further fields of renewable energy; this relates particularly to wind (158 MW), but also its first ever experience with photovoltaic systems (0.9 MW).

Beyond the impacts described above, the project also had positive effects for the communities affected: Economic activity and the tax revenue of the municipalities in which the two small hydropower plants were built increased, particularly during the implementation phase. Furthermore, these communities have also received tax revenue from energy production since the plants were commissioned.

Despite receiving a category B+ for the ESIA, the project's impact on the environment was relatively low for a hydropower project. Due to the topography, the measures only required a small amount of space and therefore encroached upon the river morphology and flow patterns as little as possible. Since the majority of the banks were steep, the storage basins only required a small amount of space. Furthermore, very little usable space was lost on the banks. Equally, no vegetation or endangered fauna requiring protection were affected, and no neighbours had to be resettled. Mandatory compensation measures for parties temporarily and permanently affected by the area were implemented along with environmental requirements. Environmental licences were updated beyond the project's term as planned. Furthermore, large sections of the banks along the storage basins were reforested with local vegetation and thus

ecologically enhanced. Conversations with the programme executing agency's ESIA managers, site visits and anecdotal information provided by neighbours and community representatives during the EPE did not reveal any contradictory results.

The project's positive impacts set out above generally meet expectations and are therefore rated as good.

Impact rating: 2

Sustainability

The project's two small hydropower plants are of a technically high standard and promise to be effective over the long term.

Furthermore, the approach to operation, maintenance and qualification of staff suggests sustainable operation over the long term: Operation and maintenance are at a very high standard and are carried out in line with best international engineering practice with the required human resources. Employees' level of qualification is high and in line with the qualifications required for operation and maintenance. A training programme has been established for staff. Furthermore, an efficient and effective system for procuring and providing spare parts has been established.

The programme executing agency and its parent company are economically stable and proper operations and maintenance are guaranteed.

No sedimentation effects that could have an adverse impact on operations have been observed to date. Furthermore, the ecological flow quantities have been complied with to date. The ecological flow of the two small hydropower plants is designed so that this flow quantity is also secured even with the minimum operating water level. The flow values of both small hydropower plants have also reflected this since commissioning. As such, the run-of-river power plants have not and will not influence the flow patterns. The environmental impacts are therefore low. Water quality is checked regularly and has not changed. The water's edge has been actively influenced in an ecological manner thanks to the reforestation measures implemented as part of the project.

The natural and strong annual flow fluctuations observed for this area of the river in recent decades do not suggest any changes resulting from climate change. Current climate forecasts tend to assume an increase in rain and the water inventory for the temperate (southern) regions of Brazil by 2085; at the same time, however, an increase in drought periods has been observed for Brazil as a whole in the past. Based on current climate projections and from today's perspective, it is assumed that the sustainability of the impacts will not be limited by a reduction in water availability for the duration of the technical useful life (assumed to be 40 to 50 years from commissioning).

Given the situation described above, the sustainability is rated as good.

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).