SOCIOECONOMIC COST-BENEFIT ANALYSIS IN INFRASTRUCTURE DECISIONS

Proof of the unfeasibility of hydropower plants in the Tapajós River Basin using the Federal Government's CBA Guide

Island of vegetation near Santárem, in Pará

SUMMARY

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1.

INTRODUCTION

WWF-BRAZIL AND THE INFRASTRUCTURE AGENDA

WWF-Brazil is an organization committed to sustainable, fair and inclusive development, which has been working for 27 years in defense of the rights and interests of Brazilians in all biomes.

Its mission is to combat trajectories of environmental degradation and build a future in which people live in harmony with nature, preserving biodiversity and rational use of natural resources, for the benefit of current and future generations.

From this perspective, one of WWF-Brazil's strategic pillars is the promotion of infrastructures that respond to contemporary development and sustainability challenges, committing to encouraging development that harmonizes with communities and brings positive effects to Brazilian society.

WE NEED RELIABLE AND EFFICIENT INFRASTRUCTURE

A reliable and efficient infrastructure network in quantity and quality is essential to sustain a country's economic, social and environmental development, which requires significant public and private investments in new assets and renewal of existing ones. In the case of Brazil, the gaps that still exist in terms of stock and quality of infrastructure require increasing rates of investment in the industry in the coming decades.

The **NEW CLIMATE ECONOMY REPORT** (2016) estimates that global investments in infrastructure need to change from the current USD 3.4 trillion to **USD 6 trillion** annually in 2030.

Santarém, in Pará


Sunset at Seringalhinho Lake, Jaú National Park, near Manaus, Amazonas, Brazil

BRIDGING RATIONALITY GAPS IN CHOOSING PROJECTS

The country has a known history of inefficient and impactful implementations of large infrastructure projects. This includes everything from unfinished works and unjustifiable projects with little dialogue with the directly affected populations, to the widespread deficiency in compliance with socio-environmental safeguards in the execution of projects. In addition to other factors, this highlights the vulnerability of the investment decision process prior to the implementation of works in all industries, whether energy, transportation, hydraulics, etc.

Thus, given the inconsistency in the decision-making process of infrastructure projects, WWF-Brazil has been contributing to improving decision-making prior to the investment stage, in order to guarantee positive socio-environmental and territorial impacts from the preliminary stage of infrastructure planning.

The emphasis is on prioritizing project goals and choosing more sustainable strategic alternatives, overcoming solutions that only mitigate known implementation impacts.

This effort aims at building a bridge between strategic planning and execution, providing a more comprehensive and targeted approach to enterprise choice for the well-being and sustainability of society, while avoiding local political influences or industrial interests. From this perspective, as well as encompassing more integrated, strategic visions of the future that question the role of infrastructures, we began to look at the **Socioeconomic Cost-Benefit Analysis (CBA)** method. The CBA Method, which is still in its infancy in Brazil, is a potentially strong and crucial tool for improving the investment decision process in the country. It allows for a more conscious and well-founded analysis of the project, essential for considering socio-environmental and territorial impacts, performance risks, climatic and technological factors and compliance with socioeconomic projections, among other aspects. We understand that expanding its reach becomes essential for the construction of a qualified debate.

This study used the methodological recommendations of the **FEDERAL GOVERNMENT'S CBA GUIDE**, macroeconomic parameters set out in the Federal Catalog for use in CBAs, and industrial estimates brought by EPE.

Construction of the Belo Monte HPP

SOCIOECONOMIC ASSESSMENT OF THE TAPAJÓS PLANTS AS A CASE STUDY

WWF-Brazil developed a socioeconomic CBA with the purpose of assessing the proposal to build four large hydropower plants (HPPs) projected in the Tapajós River Basin (Jatobá, Cachoeira dos Patos, Cachoeira do Caí and Jamanxim HPPs), (THA & STUCCHI , 2023).

HPP São Luiz do Tapajós is not part of this study because its environmental licensing process was archived by IBAMA in 2016.

This analysis has two primary focuses: the assessment of these projects and checking the relevance of using this planning tool upstream of investment decision-making.

METHODOLOGICAL CONTRIBUTION AND THE END OF THE DEBATE ON THE TAPAJÓS HPP

With this study, WWF-Brazil hopes to make a concrete contribution, using available and official tools, to the methodological and procedural debate on investment decision-making in the country. We understand that the use of socioeconomic assessment tools in the early stages of investment decisions, such as the preliminary Cost-Benefit Analysis developed herein, allows for a more conscious and well-founded analysis of the project.

Furthermore, the specific case applied to the large hydropower plants designed for the Tapajós Basin, based on a purely economic rationale and argument, hopes to definitively put an end to any energy plan of this nature and size for the region and similarly for the Amazon. **The results of this study emphasize the economic unfeasibility of the proposed HPPs.** The economic losses imposed on Brazilian society estimated by the CBA when choosing to build the Tapajós HPPs is at least BRL 11.81 billion, with the prospect of negatively impacting up to BRL 34 billion. This diagnosis contrasts with the alternative of a non-hydro renewable energy mix, consisting of sources such as wind, solar and biomass, which would provide benefits in equivalent quantity, quality and stability to the country.

When the high risks of hydropower plants are observed alongside the perspective of destruction of social value associated with their externalities, there is sufficient evidence for changes to be made in relation to what was planned for hydroelectric projects in the Tapajós River Basin: their timely rejection.

The **FULL REPORT** strictly follows the model of a classic CBA and is

AVAILABLE HERE

This publication presents a synthesis and reflections based on the original report.

2.

WHY A SOCIOECONOMIC CBA FOR THE TAPAJÓS HPPS?

© Fábio Nascimento / Greenpeace

Construction of the Belo Monte HPP

WHY A SOCIOECONOMIC COST-BENEFIT ANALYSIS (CBA)?

AN APPROPRIATE METHOD THAT BRINGS RATIONALITY TO INVESTMENT PRIORITIZATION

Socioeconomic CBA is a method used to assess an investment project based on the incremental effects to be produced throughout its entire life cycle, compared to a scenario without the project. It considers costs (including externalities) and benefits (including intangibles) expressed in a common monetary metric. It has a long-term horizon and helps to calculate feasibility indicators that express the opportunity cost for society.

It is an established method in public policies and widely used in countries such as Chile, the United Kingdom, Australia, South Africa, and South Korea, as well as in multilateral institutions. CBA is an important tool to report the decision-making process for public investments in infrastructure – regardless of the form of implementation –, as it reduces subjectivities, classifies alternatives and highlights risks and uncertainties to qualify conflicting choices.

The application of CBA, especially when it occurs in the strategic phase (upstream planning), when it is called **Preliminary CBA**, helps in the design and prioritization of projects, as it allows considering risk effects (such as those imposed by climate change), testing different designs and technological assumptions, measuring the effects of ecosystem services and addressing demand perspectives and sensitivities to important variables. Projects evaluated by a Preliminary CBA have a greater degree of maturity and robustness, increasing their chances of success in delivering the expected socioeconomic results.

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HOW TO ADDRESS THE CONFLICT OF CHOICE?
The study is motivated by answering the following basic questions:

? Given the legitimate social need to increase electrical energy generation, is it appropriate to seek this increase through the construction of HPPs in the Tapajós River Basin?

? Considering the serious socio-biophysical-cultural impacts involved, do we believe that the benefits of generating electrical energy are sufficient to justify choosing dams?

? If the increase in electrical energy generation were to come from alternative sources, such as non-hydro renewable sources, would these be more expensive, or would they bring even greater impacts?

Construction of the Belo Monte HPP

FROM THE PERSPECTIVE OF BRAZILIAN SOCIETY AND NOT FROM THE PROJECT OWNER

Socioeconomic assessment differs from financial assessment (or private, from the project owner's perspective), when comparing projects – sometimes quite different – that meet society's requirements. In this regard, **the logic of evaluating social interest before choosing the best way to meet it prevails.** CBA is the method that allows you to systematize this assessment, ranking which alternatives add the greatest benefits with the lowest costs.

This comprehensive and impartial vision goes beyond the interests of the project owner when considering non-monetary **BENEFITS** (such as improvements in public health, reduction of accidents, appreciation of natural and cultural heritage, etc.) and **EXTERNALITIES** (emission of greenhouse gases – GHG, variation of ecosystem services, etc.), which are relevant to society, even though they are not traded in markets. Furthermore, socioeconomic CBA considers social costs when deducting taxes and subsidies, as well as fees and tariffs, as they are mere transfers between economic agents (families, users, firms, and government) in the same society.

RATES AND THE PERSPECTIVE OF FINANCIAL RETURN ARE RELEVANT. The change is that these points will be considered after checking the socioeconomic feasibility of the project.

The application of the CBA in the industry follows the recommendation of the Federal Audit Court (TCU, 2017)[2], after assessing the **LESSONS LEARNED** from the development of dams in the Amazon.

!

IMPROVING INVESTMENT DECISIONS IN THE ENERGY INDUSTRY

Planning in the domestic electricity industry is quite consolidated and makes use of a sophisticated investment decision model that takes into account issues of financial and technical feasibility for an optimal minimum cost composition in energy generation solutions. With these indications, the expansion of the industry takes place through generation auctions and related regulatory acts.

Technical and economic feasibility studies (EVTE) are usually required to guide decisions related to development projects. However, EVTEs focus on seeking alternatives TO the project rather than exploring alternatives TO the project, as occurs in cost-benefit assessments.

In this planning gap, the CBA represents the complement in which the evaluation of elements not quantifiable by common industry models (network models) is carried out. This is precisely why the study must take place during the pre-feasibility planning phase, reducing long lists of alternatives to short lists.

Thus, the Preliminary CBA is extremely important for infrastructure projects – such as hydropower plants – as it is developed in the initial phase, the ideal time to assess the investment objectively and consider socioeconomic impacts, ensuring a well-founded decision, free from assumptions.

Especially for energy projects, the application of the Preliminary CBA in the design phase provides efficiency in the distribution of resources and contributes to the reduction of information asymmetries, allowing a fair comparison between projects with a focus on well-being, issues that get past private decisions of investment. The CBA can provide the industry's leading federal bodies with parameters for comparing the socioeconomic returns of different projects, guiding the decision on the types of auctions and which energy sources should be encouraged or regulated, taking into account the socioeconomic benefit they will bring to the society.

USING THE FEDERAL GOVERNMENT CBA GUIDE

Recently, the Federal Government proposed the **Five Dimensions Model (M5D)**[3] to evaluate social investment projects, seeking uniformity and consistency in decisions in order to improve the quality of public investment in Brazil. This model involves a successive process of developing proposals, comprising

compliance with the strategy, | **the cost-benefit ratio,** | **the contracting model,** | **the available resources and** | **the feasibility of deliveries.**

Its **second dimension** explicitly requires a socioeconomic cost-benefit assessment – it is at this stage that long lists of strategic alternatives to meet society's demands are reduced to short lists based on the most promising alternatives.

Alter do Chão Beach, on the Tapajós River

Tapajós River, in Itaituba

To operationalize the CBA in Brazil, the Federal Government published the **General Guide for Socioeconomic Cost-Benefit Analysis of Infrastructure Investment Projects (CBA Guide)**[4], a methodological reference that provides definitions, approach recommendations and a roadmap for carrying out analysis of cost-benefit in Brazil, which is complemented by a toolbox that includes an IPEA Parameter Catalog, industry manuals and specific recommendations for addressing climate risk.

According to the CBA Guide itself, "its main purpose is to provide guidelines and recommendations in order to standardize the methodology for assessing projects and programs, aiming for their systematic application to the selection and prioritization of investments.

This practice is an essential element of a formal investment management system in the public interest, recognized as the main obstacle to the effectiveness and quality of infrastructure investment in Brazil (World Bank, 2017; IMF, 2018)."

Despite its great potential in improving decision-making, the application of CBA in Brazil is still in its infancy, and expanding its reach becomes crucial to improving the investment decision-making process. In this regard, this case study applied to Tapajós HPPs becomes an important contribution to the application of the method.

WHY HYDROPOWER PLANTS (HPPS)?

EXPANSION OF ELECTRIC POWER IS NECESSARY AND LEGITIMATE

Electrical energy is a legitimate human need. Estimates from the Energy Research Company (EPE)[5] indicate that by 2031 Brazil will have a 36% increase in energy consumption, requiring investments of BRL 192 billion and involving operational costs of BRL 145 billion to meet demand. So, the need for discussion gains strength regarding the energy generation model that will be adopted to meet growing demand and guarantee well-being, health, connectivity and economic production provided by electrical energy.

Hydropower plants are the largest source of production, having generated 55.3% of the country's electrical energy in 2021. Although it is a widely disseminated model, its expansion is discussed due to climatic factors and restrictions related to other uses of water that can directly impact the amount of energy delivered to the National Interconnected System (SIN).

ELECTRICITY

By 2031

36%

increase in energy consumption

Investments of

BRL 192 billion

Operating costs

BRL 145 billion

DO WE NEED TO GENERATE ENERGY WITH NEW LARGE HYDROPOWER PLANTS IN THE AMAZON?

The need to expand energy generation in Brazil is unquestionable. However, the discussion arises about how to increase energy capacity.

Are hydropower plants (HPPs) really more efficient to meet projected demand? What does the history of these projects reveal?

The Amazon is a large region, with great environmental and social diversity. In proportion to this diversity and magnitude, large infrastructure and development projects emerged in the territory. From this perspective, several territorial interventions took place, with special attention to those promoted by the energy industry, with a certain traction from the 1980s onwards, when it was possible to witness cases such as the Balbina and Samuel HPPs, which caused significant environmental damage and electrical production below expected.

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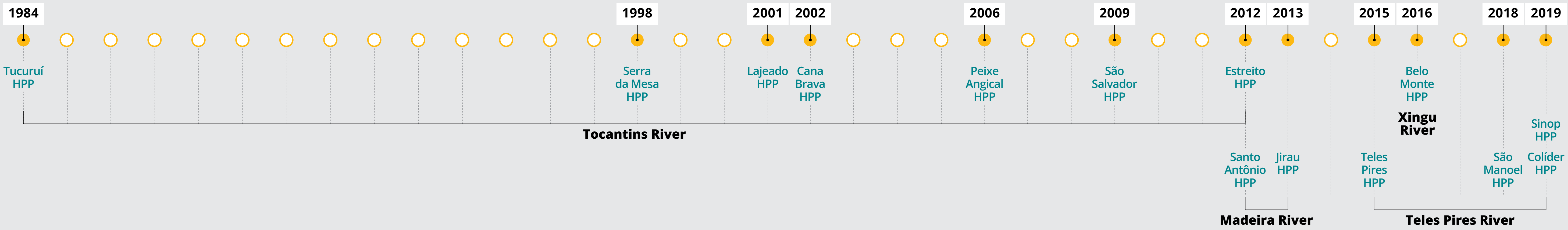
Santo Antônio hydropower plant, on the Madeira River

However, the planning of hydropower developments for the Amazon scene focused on plants on the Madeira, Xingu and Tapajós rivers which, together with those on the Tocantins River, could represent around 40% of the national electrical generating complex. The large hydropower plants in the North region began with the damming of the Tocantins River in 1984 by HPP Tucuruí. After a 14-year hiatus, no less than six plants followed – Serra da Mesa HPP (1998), Lajead HPP o (2001 Cana Brava HPP (2002), Peixe Angical HPP (2006), São Salvador HPP (2009) and Estreito HPP (2012). The Madeira River was also the site of megaprojects such as Santo Antônio HPP (2012) and Jirau HPP (2013). Nothing different happens on the Teles Pires River – one of the main tributaries of the Tapajós River and until then free flowing – blocked by the Teles Pires HPP (2015), to subsequently house the São Manoel HPP (2018), the Sinop HPP (2019) and HPP Colíder (also in 2019). And, finally, the Xingu River, owner of the controversial Belo Monte HPP (2016).

Construction of the São Manoel hydropower plant

THE LARGE HYDROELECTRIC POWER PLANTS IN THE NORTHERN REGION



Science accumulates vast evidence that the expansion of this model brings negative consequences, especially in tropical forests like the Amazon. The socio-environmental impacts are considerable and difficult to mitigate or appropriately offset, in addition to the fact that energy generation does not translate into local development.

Moreover, deforestation in the Amazon region and climate change can affect energy production capacity, as observed during the El Niño phenomenon, which can reduce hydroelectric energy generation capacity.

Although the CBA proposed herein does not intend to discuss the expansion of the national energy matrix via HPPs, but rather a specific group of plants in the Amazon region, its results contribute to this larger debate.

It is known that it is crucial to reevaluate the expansion of the hydroelectric model in Brazil, considering more sustainable alternatives with less economic, environmental, and social impact, and the case of the Tapajós HPPs brings concrete elements to the discussion.

WHY THE TAPAJÓS RIVER BASIN HPPS?

THE INTENTION OF BUILDING HYDROPOWER PLANTS IN THE BASIN IS STILL REAL

According to the Generation Information System (Siga) of the Brazilian National Electric Energy Agency (ANEEL), there are 51 hydroelectric projects in operation in the Tapajós River basin and eight plants in the construction phase. However, the scenario could be much more intricate, as the total number of possible new dams identified for the territory exceeds 50.

Out of these, four in particular, the Jatobá HPP, on the Tapajós River, and the Cachoeira dos Patos, Cachoeira do Caí and Jamanxim HPPs on the Jamanxim River, all located in the Tapajós River hydrographic basin, draw attention due to their size and potential for generating impacts. , such as the flooding of an extensive area of more than 100 thousand hectares, the release of more than 100 million tCO_2 into the atmosphere, the transformation in the way of life of indigenous and traditional communities, the loss of traditional means of subsistence, in addition to imposing new movement patterns in the territory.

TAPAJÓS RIVER BASIN

51

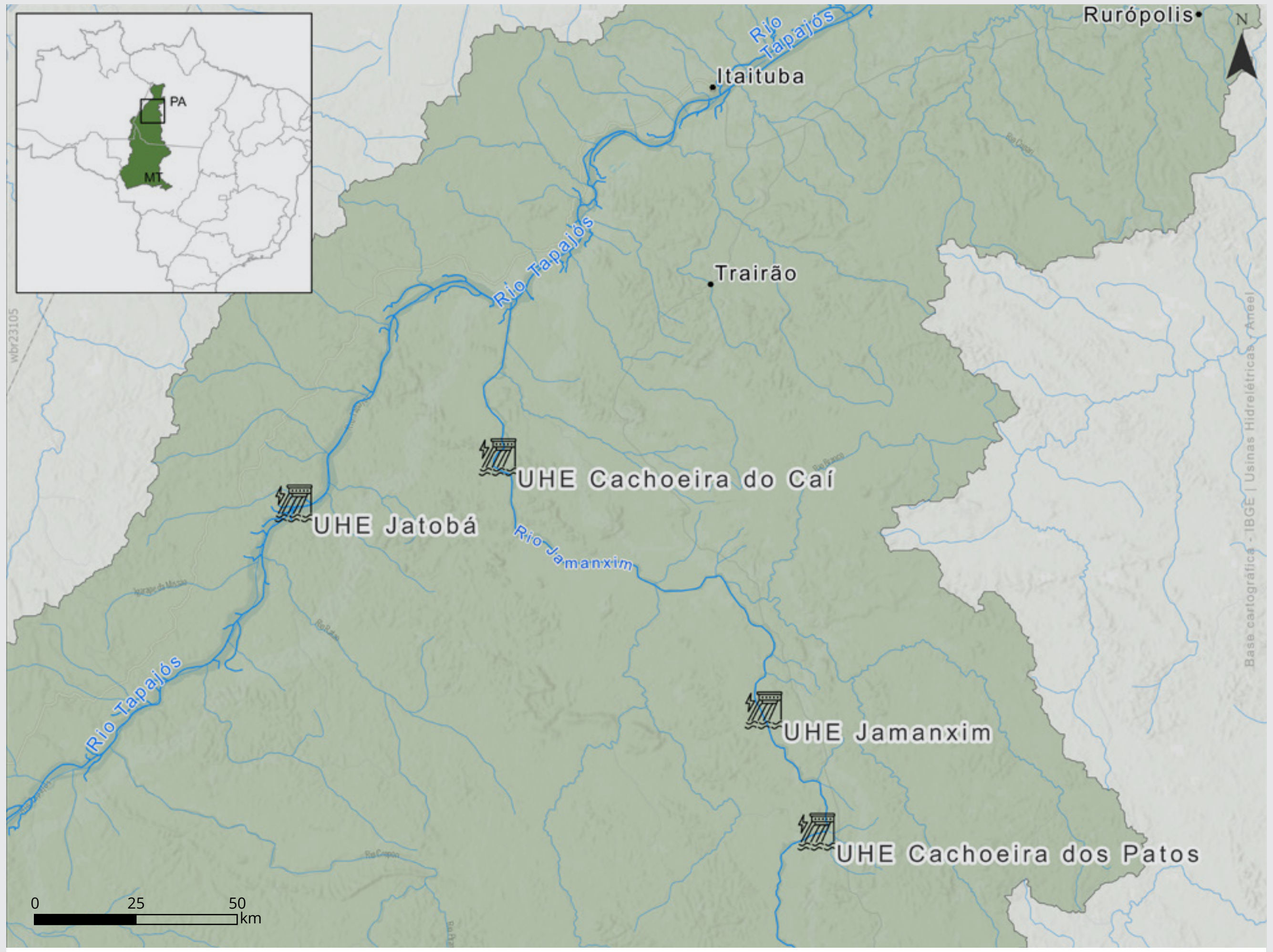
hydroelectric projects in operation

9

plants under construction

Santarém, in Pará

© Adriano Gambarini / WWF-Brazil



The Jatobá HPP (1,650 MW) had its feasibility studies completed in 2017 and is active in the ANEEL database with "EVTE accepted"; in other words, it could be included in energy auctions, and it is in the PDE 2031 studies alongside 15 other plants.

The National Electric Energy Agency (ANEEL) extended the deadline for the technical and economic feasibility studies (EVTE) of the three plants on the Jamanxim River to the end of 2023 – Cachoeira dos Patos HPP (528 MW), Cachoeira do Caí HPP (802 MW) and Jamanxim HPP (881 MW.

- Cities
- Hydrography
- Hydropower Plants
- Tapajós River Basin

!

CHALLENGES OF THE ELECTRIC INDUSTRY AND THE ROLE OF NON-HYDRO RENEWABLE SOURCES:

The growing need for dispatchable energy (the ability of a source to be activated according to demand) in the electricity industry faces challenges due to the high costs and environmental impacts of thermoelectric plants powered by fossil fuels. New hydroelectric projects with reservoirs are socioeconomically unfeasible, and plants without reserve dams (run-of-the-river) do not provide dispatchable energy and face the risk of lower-than-expected production (as occurs with Belo Monte and would occur with the Tapajós HPPs). The free energy market, of increasing importance, favors sources of rapid implementation and lower risk, but which do not add dispatchability to the system. In this context, the government aims at guaranteeing a reliable supply to the detriment of primary energy suppliers, with the integration of renewable sources and exchange between systems being the challenges to minimizing the seasonality of these sources.

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Tapajós River,
in Novo Airão

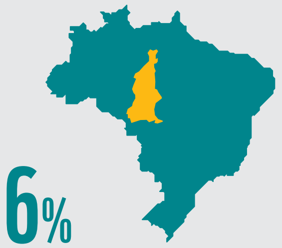
IMPORTANCE OF PRESERVING THE TAPAJÓS BASIN

The Tapajós Basin represents almost 6% of the Brazilian territory, crossing four states, 30 Conservation Units, 34 Indigenous Lands and more than 36 million hectares of forests. It stands out for its domestic and worldwide importance and its crucial role in preserving biodiversity. Its reserves and indigenous territories make it even more relevant for the conservation of the region.

However, the future vision for the Tapajós Basin is threatened by the imminent impacts not only of hydropower plants, as previously mentioned, but also by other large infrastructure projects, such as railways and waterways, as well as the expansion of agricultural activities, mining illegal, logging and land grabbing. These activities can compromise the way of life of regional communities, including indigenous peoples, traditional communities, *quilombolas* and fishermen. **The preservation of the Tapajós Basin is extremely important to mitigate the negative impacts of these activities.**

Furthermore, the basin has significant potential to foster sustainable economic development, boosting low-impact activities such as community-based tourism and the sustainable use of diverse and rich socio-biodiversity products, generating wealth for present and future generations.

TAPAJÓS BASIN



6%
of the national territory

4
states

30
conservation units

34
indigenous lands

+than 36
million hectares of forests

The Tapajós Basin is fundamental to ensuring the well-being of local communities, the preservation of biodiversity and the integrity of ecosystems. Furthermore, it represents an opportunity to think about development in a way that avoids significant impacts on society as a whole.

3.

FOR THE COUNTRY, INVESTING IN THESE HPPS IS LOOSING (A LOT OF) MONEY: MAIN RESULTS

Construction of the Belo Monte HPP

WHICH PROJECTS DO WE COMPARE AND HOW DO WE COMPARE THEM?

FAIR COMPARISONS: HPP VERSUS MIX OF NON-HYDRO RENEWABLES

According to the CBA method (as well as the CBA Guide), the assessment of the socioeconomic feasibility of a project is given by its incremental effect, that is, the evaluated alternative (in this case, the 4 HPPs in Tapajós) compared to other ways of meeting the same underlying social objectives: delivering energy to the National Interconnected System (SIN). Thus, a combination of alternative generating sources was established, consisting exclusively of non-hydro renewables (called Mix).

The **COMPLETE CBA REPORT**, especially its annexes, compares not only Mix, but several other combinations of generating sources, in addition to individual sources – all results reinforce the same conclusions presented herein.

For simulation purposes, a **mix is considered to inject exactly the same amount of net energy into the SIN and with the same reliability**, as it addresses the same energy demand and serves the same users connected to the regulated market distribution network (residential consumers, commercial, industrial and institutional). To this end, it must operate from the same start year and during exactly the same period of operation as the HPPs.

COMPARING TWO DIFFERENT PROJECTS THAT DELIVER EXACTLY THE SAME BENEFIT TO SOCIETY

HPPs in the Tapajós River Basin and their transmission lines (LT) versus Mix of non-hydro renewable energies and their transmission lines

WHY ARE THESE PROJECTS COMPARABLE?
The concept of a SELF-SUFFICIENT Unit of analysis

According to the CBA Guide, the compared projects must form self-sufficient units of analysis – that is, they must contain all the elements that are necessary to make the generation of the desired benefits possible.

In the case of the electrical energy industry, this means that both HPPs and Mix include the transmission lines necessary for the delivery of this energy to the SIN (also including the losses that occur in this transport). Additionally, in the case of Mix, it means considering the inclusion of a sufficient Power Reserve to cover any intermittency of these sources.

HPP OF THE TAPAJÓS BASIN – 30 years operating

They operated without storage tanks: they cannot be dispatched

Project	Installed power
Jatobá HPP	1,649MW
Jamanxim HPP	881MW
Cachoeira do Caí HPP	802MW
Cachoeira dos Patos HPP	528MW
TOTAL INSTALLED POWER	**3,861MW**
FIRM POWER	2,124MW

55% of the total potential according to the capacity factor set forth by EPE

\+ **TRANSMISSION LINE** – **~2,400 km,** *equivalent to that of the Belo Monte HPP*

→ **EFFECTIVE DELIVERY TO SIN**

16.70 **million MWh/year** *when deducting transmission losses*

95% **guarantee**

Social welfare

≠ =

NON-HYDRO RENEWABLE ENERGY MIX – 30 years operating

Generic projects (without specific location), whose size is calculated "backwards" from the generation of the Tapajós HPPs

Given the intermittency of renewables, an additional 10.5% of operational power reserve (RPO) was considered, mirroring the simple average between that required for wind farms in the Northeast (6%) and South (15%), following Technical Note from ONS (DPL–REL–267/2020)

Project	Installed power
Solar Photovoltaic	2,956MW
Wind (onshore)	2,086MW
Biomass UTE *(sugarcane bagasse)*	723MW
Biogas UTE *(sugar-energy waste)*	101MW
TOTAL INSTALLED POWER	**5,870MW**
FIRM POWER	2,062MW

Given its composition – arbitrary, but credible – the Mix requires the installation of 5,870 MW due to the lower weighted capacity factors

\+ **TRANSMISSION LINE** – **~1,500 km,** *for wind farms and 10% of that for others*

→ **EFFECTIVE DELIVERY TO SIN**

16.70 **million MWh/year** *when deducting transmission losses*

95% **guarantee**

Social welfare

Amounts with 2021 price database (as in the EPE notebook).

Planning base date (year 0): 2022.

Year 1 of the monetary flow of costs, benefits and externalities: 2023.

Average construction period for a HPP = 3.3 to 3.6 years according to EPE, considered as 4 years in the Tapajós case (2023–2026).

Shelf life of 30 years, starting in the year following implementation, 2027 (according to EPE for HPPs).

Start of implementation of hydropower plants in year 1 and Mix in year 3. Start of operation of both in year 5 and operating time of 30 years. The Mix has a shorter shelf life, which requires reinvestment that begins with enough time for another energy generation cycle to begin one year after the end of the shelf life of the original investment.

SOCIAL DISCOUNT RATE (TSD): To reduce the flow of costs, benefits and externalities, which extends over 30 years, into a single current amount that can be compared to any other investment options (net present value), it must be discounted at a rate that represents the opportunity cost of alternative application of the resource. In the case of CBA, the Social Discount Rate (TSD) is used, estimated specifically for the assessment of investments in infrastructure, as defined by the Federal Government.

The TSD is 8.5% per year, with a threshold of 5.7% per year in an optimistic scenario and 11.4% per year in a pessimistic scenario. It bears emphasizing that the PDE 2031 (EPE, 2022) uses the discount rate of 8% which, even though it does not represent the social rate itself, is quite close.

Optimistic scenario
5.7% per year

SOCIAL DISCOUNT RATE **8.5%** per year

Pessimistic scenario
11.4% per year

Source: IPEA, 2022

Among the main feasibility indicators of a cost-benefit analysis, the **Comparative Net Present Social Value (ΔVSPL)** stands out. This is the difference between the VSPL of the project scenario (HPPs) and the base scenario (Mix of non-hydro renewable energies) and can be defined as being the sum of the net benefits and costs calculated in each period over the entire analysis horizon, brought to present value through the **SOCIAL DISCOUNT RATE (TSD)**. In other words, comparative net social present value is the sum of discounted net flows, for which a negative value means that the project is socially unfeasible when compared to the base scenario.

Therefore, according to the CBA Guide, to obtain the ΔVSPL, it is necessary to calculate the flow of benefits, costs and externalities (positive and negative) throughout the established shelf life of the project and its alternative. In order for it to be a socioeconomic (and not financial) assessment, it is also required that the values be in **SOCIAL PRICES**.

Another relevant indicator in CBA analysis is the ratio between benefit and cost (B/C). When the result of the B/C ratio is less than 1, that is, the costs are greater than the benefits, the project must be rejected. Costs exceeding benefits represent the subtraction of limited resources that could be used in alternative projects. In the case of ΔVSPL, negative results indicate the discarding of the analyzed project to the detriment of the alternative.

Expedition through the Amazon, in 2021

SOCIAL PRICES AND APPLICATION OF CONVERSION FACTORS: By adopting society's perspective, the CBA uses social prices (also called shadow prices), and not necessarily market prices (observed prices). Social prices: i) **correct distortions embedded in market prices, which include taxes, subsidies, fees and tariffs (transfers between economic agents in the same society);** ii) **consider users' willingness to pay for increases in well-being** and iii) **include externalities, positive or negative.**

To consider the direct economic costs of projects (capital (Capex) and operational expenses (Opex) of HPPs and Mix, including transmission lines and intermittency, consulted with EPE's PDE 2031) to the detriment of market values, the factors conversion parameters contained in the IPEA[6] Parameter Catalog, calculated for this purpose, were applied.


Fordlândia, on the Tapajós River

COMPOSITION OF THE COMPARATIVE NET PRESENT SOCIAL VALUE (ΔVSPL)

The ΔVSPL consists of the difference between the project's VSPL (HPPs) and its alternative (Mix). The VSPL of each project is obtained from its economic benefit minus its direct costs and externalities. The negative value of ΔVSPL indicates the unfeasibility of HPPs in relation to Mix

HPP OF THE TAPAJÓS BASIN

BENEFITS

BRL 48.33 billion

Economic value of 16.7 million MWh/year

–

DIRECT COSTS

BRL 36.73 billion

- ● **Capex** (investment)
- ● **Transmission lines**
- ● **Opex** (operation and maintenance)
- ○ **Fuel** (UTE required)
- ○ **Repex** (equal shelf life – 30 years)
- ○ **Intermittency** (additional for renewables)

–

EXTERNALITIES

BRL 6.06 billion

- ● **GHG emissions** (loss of C stock due to vegetation suppression in lakes and LT, deforestation)
- ● **Loss/gain of economic activity**
- ● **Loss of Ecosystem Services**

=

BRL DISCOUNTED FLOW

30 years of operation

BRL 5.54 billion

Net Present Social Value (VSPL)

↓

Comparative Net Present Social Value (ΔVSPL)
=
- BRL 11.81 billion

↑

NON-HYDRO RENEWABLE ENERGY MIX

BENEFITS

BRL 48.33 billion

Economic value of 16.7 million MWh/year

–

DIRECT COSTS

BRL 30.34 billion

- ● **Capex** (investment)
- ● **Transmission lines**
- ● **Opex** (operation and maintenance)
- ● **Fuel** (UTE required)
- ● **Repex** (equal shelf life – 30 years)
- ● **Intermittency** (additional for renewables)

–

EXTERNALITIES

BRL 0.64 billion

- ● **GHG emissions** (loss of C stock due to vegetation suppression in lakes and LT, deforestation)
- ○ **Loss/gain of economic activity**
- ○ **Loss of Ecosystem Services**

=

BRL 17.35 billion

Net Present Social Value (VSPL)

Social Discount Rate: **8.5%/year**
(IPEA, 2022)

BENEFITS

The valuation of benefits was based on the increase in energy supply to the SIN (16.70 million MWh/year), considering the willingness to pay of users in its regulated market.

There are BRL 6,232 million annually, with a temporal allocation between the 5th and 30th year.

In present social value (through application of the Social Discount Rate – TSD), **the valuation of the benefits results in BRL 48.33 billion that each of the projects** (HPPs and Mix) generates.

BENEFITS

Valued at

BRL 48.33 billion

for each of the projects

−

DIRECT COSTS

Costs at market prices estimated based on sectoral parameters, largely compiled from the notebook called “Cost Parameters – Generation and Transmission” of the PDE 2031 (EPE, 2022), and subsequently converted into social prices based on the Catalog of IPEA parameters.

Given that the social benefits are the same, the most advantageous option from a social point of view (with the best benefit/cost ratio) is decided by the set of costs and externalities.

Direct social costs (Capex and Opex) vary significantly between HPPs and Mix. In present social value:

HPPs: Capex of BRL 23.82 billion; Opex of BRL 0.62 billion; LT with a cost of BRL 12.29 billion. TOTAL = BRL 36.73 billion.

Mix: Capex of BRL 17.35 billion; Higher opex, of BRL 1.26 billion; The cost of LT is lower, at BRL 4.90 billion, and the costs of fuel for UTEs, biomass and biogas are BRL 2.40 billion. The power reserve, given the greater intermittency of the sources, is BRL 4.42 billion. TOTAL = BRL 30.34 billion.

Mix has direct costs lower than those of HPPs at BRL 6.39 billion.

DIRECT COSTS

of Mix are lower than those of HPPs at

BRL 6.39 billion

−

EXTERNALITIES

Although several externalities are recognized, the most renowned and with available information were considered, estimated based on academic literature and government data:

Greenhouse gas emissions: loss of carbon stock in biomass due to forest suppression in the area of lakes and TL, in addition to induced deforestation; emissions relating to operational greenhouse gas emissions.

Losses and gains from economic activities: losses in fishing activities, agricultural production, opportunities to extract timber and non-timber products. Gain opportunities for economic activity in legally deforested areas.

Loss of ecosystem services: regulation of the hydrological cycle and provision of habitat.

The externalities of HPPs total, in present social value, BRL 6.06 billion.

For Mix, two externalities were considered that are independent of specific installation locations: greenhouse gas emissions (includes full life cycle emissions), and water consumption in UTEs.

Mix generates BRL 0.64 billion in externalities considered.

Incremental results and sensitivity tests make up the analysis of externalities between the HPPs and the Mix *(see Probabilistic Analysis, pg 37)*.

=

INDICATOR OF (NON) FEASIBILITY

Comparative Net Present Social Value (ΔVSPL)

With the estimates of the benefits, direct costs and social externalities of the Tapajós HPPs and the Mix of non-hydro renewables, it was possible to evaluate the comparative economic return between them.

The result indicates that implementing HPPs to the detriment of the Mix of non-hydro renewable sources generates a negative **ΔVSPL of BRL 11.81 billion**.

Furthermore, the Benefit/Cost ratio is 0.72. According to the CBA Guide, **projects with negative ΔVSPL and a B/C ratio less than 1 must be rejected**.

Therefore, these results point to the unfeasibility of HPPs.

INDICATOR OF (NON) FEASIBILITY

Negative ΔVSPL of

BRL 11.81 billion

Construction of the Belo Monte HPP

© Fábio Nascimento / Greenpeace

BUT WHAT DOES THIS MEAN?

The CBA indicators (ΔVSPL and B/C ratio) prove the unfeasibility of HPPs in the Tapajós Basin and present the Mix of non-hydro renewable sources as the best option to generate the demand that will be delivered to the National Integrated System.

Furthermore, the indicators reveal the inability of the HPP project to meet the criteria of added social value to the point of enabling compensation between beneficiaries and the affected parties.

According to the opportunity cost guideline, the alternative project (in this case, Mix) must be implemented, allowing the distribution of scarce resources to what achieves more appropriate results for society.

INDICATOR OF (NON) FEASIBILITY

The ΔVSPL indicates that **investing in HPPs and not in Mix generates a loss of social value of approximately BRL 11.81 billion.**

This difference in values represents approximately 38% of the costs and externalities of the Mix itself, that is, **38% more electricity can be generated with non-hydro renewable sources for the same social cost as the Tapajós HPPs.**

SOCIAL COST

The **direct social cost** (before externalities) of HPPs is BRL 36.73 billion, while that of Mix is BRL 30.34 billion. This means that, even before externalities are taken into account, society gains BRL 6.39 billion by choosing the Mix of non-hydro renewables.

EXTERNALITIES

The suppression of forest vegetation to form the HPP ponds makes the option a net emitter of CO2, an externality valued at BRL 3.79 billion (present social value).

The comparative emission of GHG from the Tapajós HPPs in relation to the Mix of non-hydro renewables completely inverts the logic of "clean" energy commonly associated with water sources and proves that it is not a strategy for mitigating climate change – at the same time. On the contrary, **investing in HPPs is contributing significantly to the worsening of the climate crisis.**

The valuation of some of the ecosystem services that risk being lost with HPPs helps to reveal the risks associated with damming the last large free-flowing river in the Brazilian Amazon, home to unique socio-biodiversity.

INVEST IN HPPS GENERATES

BRL **11.81** billion

in social value loss

38%

less electrical energy than **non-hydro renewables** for the same social cost

Direct social cost of

BRL **36.73** billion

BRL **6.39** billion

more than the Mix of non-hydro renewables

BRL **3.79** billion

in net CO_2 emissions *(present social value)*

4.

MUCH WORSE THAN EXPECTED: WHAT DO EXTERNALITIES AND RISK ANALYSIS SHOW US

The socioeconomic CBA methodology presupposes the consideration of externalities, but even before their inclusion, the unfeasibility of HPPs with regard to Mix is already observed. The transmission lines and other aspects of the composition of the self-sufficient analysis unit (intermittency and shelf life compatibility) reveal that **HPPs have a much higher cost than non-hydro renewables in the 30-year energy generation cycle.**

The inclusion of externalities increases the comparative cost of HPPs, as by causing the suppression of forest areas (99 thousand ha in the formation of ponds alone), they generate the loss of stored carbon that is converted into CO_2 in the atmosphere. Throughout their life cycle, Mix's non-hydro renewable sources also emit greenhouse gases, but in very small proportions. In the comparative balance of emissions over the 30 years of operation, hydropower plants emit 129 million tCO_2 more, and clearly cannot be deemed "clean".

The standard result of the CBA also includes other local and regional externalities, such as variations in productive activities in the affected areas, losses in fishing activity that affect upstream and downstream riverside communities, in addition to imposing losses on commercial fishing, promoting the loss of regional ecosystem services on livestock and soybean farming activities and the loss of ecosystem services from habitat provision.

In addition to externalities, the CBA methodology also assumes **risk analysis**: in the Amazon, one of the most notable is performance. **Climate change** and deforestation affect the hydrological cycle, with prospects of reducing the firm energy capacity factor in the Tapajós River Basin, as revealed by hydrological modeling.

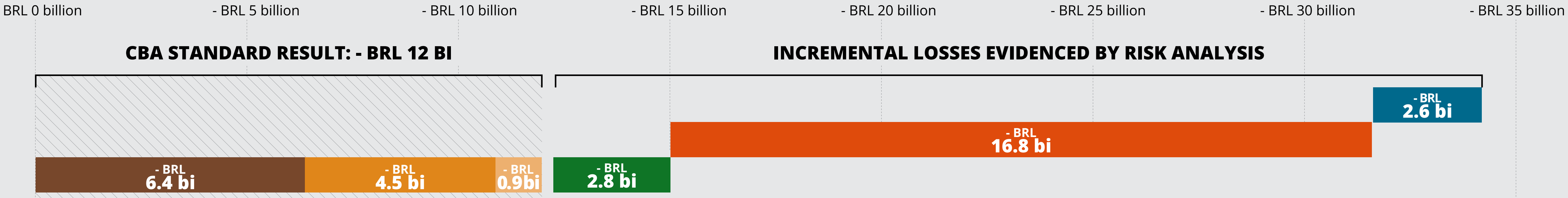
The risk of **overcost** and **delays** are also typical and tend to materialize for all energy generating sources. However, historically the HPPs stand out for presenting both excess costs and delays that are much higher than those of other sources, such as solar and wind. When the historical behavior of this risk is added for both HPPs and Mix, there is a significant increase in the difference (for the worse) in Amazon dams.

The cumulative effect of the costs, externalities and higher risks of HPPs in relation to Mix reaches negative BRL 34 billion, and points to an order of magnitude that exceeds by BRL 3.7 billion of the direct cost of Mix itself, which is of BRL 30.3 billion.

In other words: opting for non-hydro renewable sources and not HPPs allows you to generate twice as much energy and still save BRL 3.7 billion.

INCREMENTAL VALUES OF ΔVSPL CONSIDERING RISK ANALYSIS

Incremental values of the Comparative Net Present Social Value and risk analysis (provided for in the CBA Methodology), considering the impact of climate change, excess costs and delays in works.



DIRECT COSTS

Result for didactic purposes only!

The methodology assumes the consideration of externalities

PARAMETERS: Capacity Factor, Capex, Opex, fuels... the same ones used in PDE and PNE

CONVERSION TO SOCIAL PRICES: IPEA parameters for national goods and services and labor

INTERMITENCY: 10.5% additional power reserve due to the intermittency of renewables

FUEL: costs for sugarcane bagasse and biomass

RESIDUAL AND REPEX to equal the shelf life in operation for 30 years:

30 years | 25 years | 20 years

EXTERNALITIES

OVERALL:

GHG EMISSIONS: loss of C stock (vegetation suppression of ponds and LTs, induced deforestation) and ACV of the Mix. Valuation for the social cost of carbon HPPs remove > 100 thousand ha of forests (not clean energy).

LOCATIONS AND REGIONS:

- **Variation in productive activities** (losses and gains from livestock, agriculture, and extraction activities).
- **Losses in fishing activity** (affecting riverside communities and commercial fishing).
- **Loss of** habitat provision and regional **ecosystem services** (on livestock and soybean farming activities).

In addition to these, other externalities recognized but not included in the study include changes i) in **the structure of social cohesion**; (ii) in **the flood pulse**; (iii) **river connectivity** and (iv) **hydrological ecosystem services**. Details to follow.

CLIMATE CHANGE

Increases costs by

24%

Modeling of hydrological effects indicates a **reduction in the firm energy capacity factor** in the basin, causing performance risk.

EXAMPLE: Belo Monte has an installed capacity of 11,223 MW, firm power of 4,571 MW and generated, in mid-2021, ~500 MW due to lower rainfall.

ADDICIONAL COSTS

They are typical for all sources but vary greatly among them: **HPPs are notorious generators of additional costs!**

Sensitivity analysis to the **AVERAGE OVERCOST** of the industry

70.6% HPPs

12.6% Mix

HPP budgets must be increased by ~75% to have a 50% chance that final costs will be within projection *(Callegari, Szklo & Schaeffer, 2018)*[7].

DELAYS

Sensitivity analysis to the industry's average delay (2 years HPPs vs Mix)

INDUSTRY AVERAGE DELAYS:

2.5 years | 0.4 years | 0.0 years

EXAMPLE: Belo Monte HPP had its initial deadline doubled.

OTHER RISKS

KNOWN AND RISKS NOT CONSIDERED: [8]

- Social conflicts;
- Judicialization;
- Violation of human rights;
- Differentiated impacts of gender and violence; and
- Destruction of livelihoods and sacred sites.

TOTAL

Considering the effect of **COSTS**, **EXTERNALITIES** and **RISKS** associated with **CLIMATE CHANGE**, **ADDICIONAL COSTS** and **DELAYS**, investing in HPPs brings a

LOSS of approximately **BRL 34 billion** to Brazilian society.

Choosing non-hydro renewable sources allows you to **GENERATE DOUBLE THE ENERGY** and

SAVE BRL 3.7 billion

© Carol Quintanilha / Greenpeace

Construction of the Belo Monte hydropower plant

ECONOMIC EXTERNALITIES: UNDERESTIMATED, BUT WITH LOCAL WEIGHT

Externalities, by definition, encompass all effects generated by the project that fall on third parties and which, when negative, are not properly offset (unlike effects recognized and incorporated into project costs, such as involuntary resettlement). Generating externalities is inevitable, which makes its inclusion in the CBA mandatory: different projects that meet the same objective (as is the case of HPPs vs. Mix) or different alternatives of the same project (route A or B of a railway) can have radically different externalities.

Certain effects, even when recognized, are not compensable or even easily quantifiable and/or valued due to their nature. In this CBA, highly relevant negative effects of HPPs could not be fully included, such as:

- **changes in the structure and social cohesion of traditional populations, not monetarily compensable**
- **changes in the flood pulse, with negative consequences for the entire downstream ecosystem**
- **loss of hydrological ecosystem services "exported" to other regions of the country**
- **changes in river connectivity, generating loss of diversity and biomass, simplification of the trophic structure**
- **interruption of migratory routes and local extinctions of associated fauna**

Of the included effects, the one with the highest value was related to **GHG emissions (BRL 5.12 billion, 84.5% of the total externalities of HPPs in present value):** forested areas in the Amazon biome are responsible for a vast carbon stock (BRL 4.36 billion), in addition to emitting CO2 and CH4 from the lakes (BRL 0.76 billion). The set of externalities of economic activities is subdivided into the opportunity cost of land use (both losses and gains) and the loss of fishing activity. Its monetary value, negative at BRL 0.30 billion, is significantly lower than GHG emissions and represents 5% of the total, although it is highly relevant at the local level – it is greater than the GDP of the municipality of Trairão-PA and affects 13 thousand people.

Two effects on the provision of ecosystem services (ES) could be quantified and valued: i) regulation of the hydrological cycle and ii) habitat provision. In the first, the loss of ground cover was associated with the drop in soybean and regional livestock productivity, in the Amazon itself. Its value (BRL 0.09 billion) is low compared to the others (1.5%), but it is equivalent to the annual agricultural production of Novo Progresso-PA, the municipality with the largest planted area in the region. If the loss of hydrological ES "exported" to other regions of the country had been quantified, it would capture the negative consequences for valuable agricultural production in the Central-West and Southeast.

The provision of habitat was based on 35 studies that value this SE at BRL 2.36 thousand ha/year on average, with a minimum and maximum range of BRL 0.57 and 4.16 thousand ha/year, which is equivalent to the value of regional livestock farming (BRL 1.90 thousand ha/year). As a conservative approach, the minimum SE value was used in the CBA, which resulted in a negative BRL 0.55 billion (9.1% of total externalities) – equivalent to the Opex (operating costs) of the HPPs. If the average parameter were chosen, the externality would be BRL 2.28 billion (3.7 times the Opex and more than half the value of GHG emissions).

EFFECTS INCLUDED

BRL 5.12 billion

GHG emissions

84.5%

of the total externalities of HPPs in present value

Forested areas in the Amazon biome are responsible for a vast carbon stock

BRL 4.36 billion

PROBABILISTIC ANALYSIS: CONSERVATIVE RESULTS AND ROBUSTNESS TO END THE DISCUSSION ONCE AND FOR ALL

The extremely negative result of HPPs compared to the Mix of non-hydro renewables was reinforced by the probabilistic risk analysis (Monte Carlo simulation). After 9,999 random draws of possible variations for various elements of risk and uncertainty in the analysis, it was observed that 50% of the time the HPPs presented losses between BRL 22.6 billion and BRL 33.8 billion. The median pointed to a negative result of BRL 27.7 billion in comparative net present social value. Furthermore, a negligible chance (0.01%) of obtaining a positive result for the HPPs was found, with the Benefit/Cost index being greater than 0.5 only 45.6% of the time.

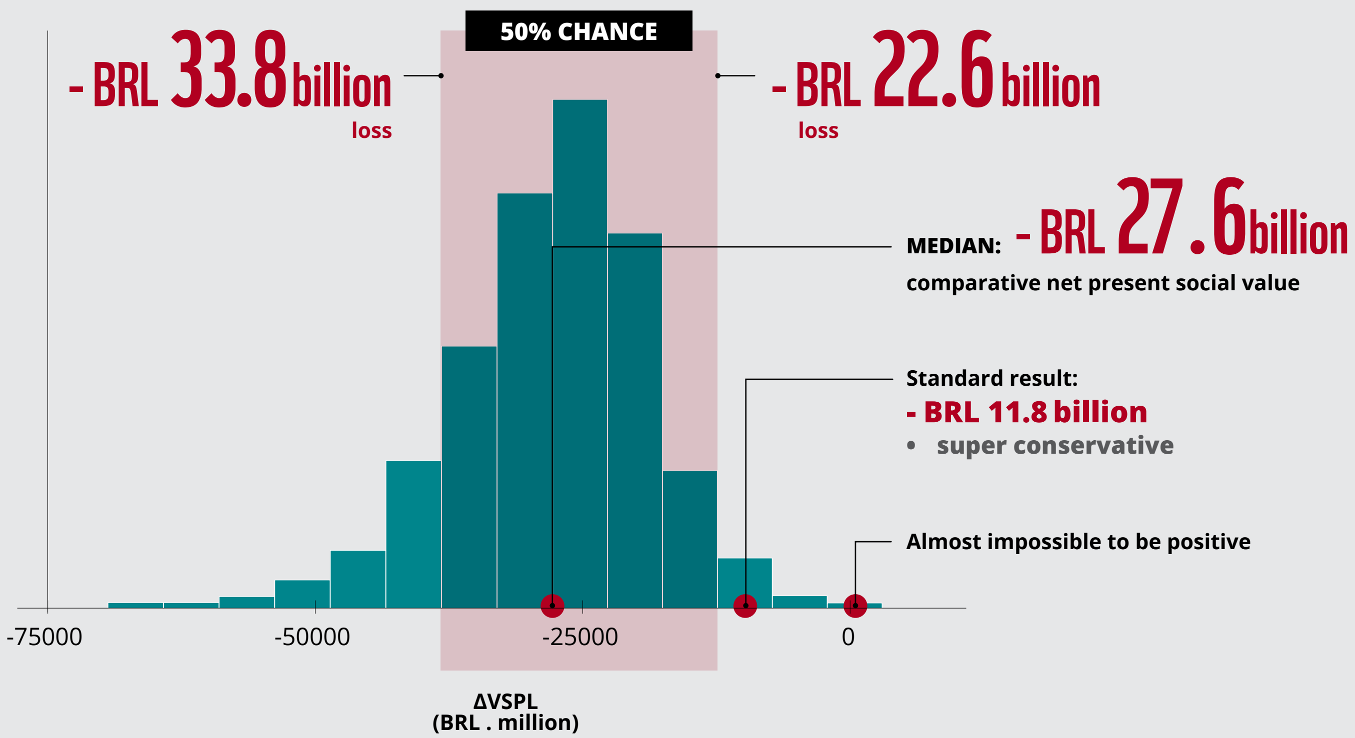
The Monte Carlo analysis included the following elements, both for HPPs and Mix:

MONTE CARLO ANALYSIS is a statistical technique for addressing project uncertainties (in modeling) and (external) risks. Performs several random draws of key variables, respecting their distribution patterns. Based on the integrated reading of its results, it provides robustness to decision making.

The probabilistic risk analysis reinforces the already strong results of the individual assessment of the effects of climate change, additional costs and delays, robustly concluding that investing in Tapajós HPPs is unacceptable.

- **occurrence of delays**
- **occurrence of additional costs**
- **variations in Capex and Opex parameters**
- **variability in future climate (climate change)**
- **capacity factors**
- **carbon stock parameter in the forest vegetation area**
- **CO_2 emission parameter**
- **extent of induced deforestation**
- **parameter for controlling deforestation in the Amazon**

PROBABILITY DISTRIBUTION OF ΔVSPL



Vila de Penedo, in Pará

5.

FINAL CONSIDERATIONS

This analysis can be used as a case study for the incipient application of the Preliminary CBA methodology within the scope of national planning and is evidence of its applicability and relevance.

On the **METHOD** side, the reference provided by the **CBA Guide** and the toolbox produced especially for use in cost-benefit assessments stands out, especially the IPEA **Catalog of Federal Parameters** (which allowed the application of direct cost conversion factors, in addition to establish the Social Discount Rate) and the **Annex to the Climate Risk CBA Guide**[9]. These publications standardize concepts, names, and processes, reduce asymmetries and allow comparability and measurement of results.

The methodologies, implemented in conjunction with information from industrial planning in electrical energy (systematized by EPE, such as the “Cost Parameters – Generation and Transmission” of PDE 2031), allowed the expeditious preparation of the Preliminary CBA in strict compliance with planning industry with a high degree of reliability of results. This robustness is not due to the “infallibility” of the estimates used – on the contrary, it is due to the recognition of their limits and the application of systematic sensitivity tests and probabilistic risk analysis.

Developing the analysis following the CBA Guide also provides transparency in the evaluation of investment projects, facilitating communication with interested parties and understanding the reasons for choosing one alternative over others.

Igarapé on the Juruena River

Aerial view of the Amazon River

© Nicolas Villaume / WWF-US

As, in addition to parameters that encompasses objectives intended by governments and other decision-makers regarding development plans, the political-institutional context, aspirations for economic growth and the country's social and environmental goals must make up the complex process of choice (trade-offs), especially those related to investments in infrastructure. In turn, these complex discussions not only can but should be shared with those who will be affected – Brazilian society.

The **RESULTS** of the Preliminary CBA applied to the Tapajós HPPs also reveal the benefit of timely application of the method to the upstream planning cycle: **definitively discarding the four hydropower plants in the Tapajós River Basin to the detriment of non-hydro renewable energy generation projects promotes savings of at least BRL 11.81 billion, potentially reaching more than BRL 34 billion.** The amount is enough to generate, with the same sources as the non-hydro renewable energy mix, a total of 38% more electricity.

Even if the resources saved are distributed to other sectors, they represent approximately 6% of the average level of investment in the national economy in recent years. Saving amounts of this nature becomes essential in the face of fiscal restrictions and allows resources to be directed towards alternatives that add legitimate benefits to society. Considerations like this can only be made by contrasting alternatives – it is the opportunity cost that matters.

The **Preliminary CBA brings SOCIOECONOMIC VISION to decision-making**, assessing the feasibility for Brazilian society as a whole before focusing (and committing resources and time) on technical issues (engineering and environmental impact studies) and financial issues (project owner's perspective, which is just one of several members of society). Regional particularities, such as the unique Amazonian biodiversity, also made up the extensive list of attributes evaluated in the CBA: even if partially, **ecosystem services were valued alongside direct investment and operation costs** (expressed at social prices).

This **CBA** directly contributes to meeting the recommendations made by the TCU in Ruling 2,723/2017. In this, flaws in the systemic vision and broad socioeconomic perspective for assessing the feasibility of dams in the Amazon are highlighted.

Aerial view of the Teles Pires dam on the Tapajós River

© Rogério Assis / Greenpeace

The identification, quantification and **monetary valuation of several externalities**, both positive and negative, were possible thanks to the vast knowledge framework available for the project region. The application of CBA in different locations; however, may encounter greater restrictions. Externalities such as pollution of water bodies, soil contamination, atmospheric pollution, degradation of ecosystems and others can be assessed on a regional basis and made available in catalogs for use in CBAs, as is already the case in Chile, the United Kingdom, and others. In order to implement future analyses, it would be essential to increase investments in the systematization of scientific and technical publications that allow the parameterization of social and environmental effects for future comparisons that are gradually more rational and fair.

This Preliminary CBA also contributes to filling the knowledge gap identified by Athayde *et al.* (2019)[10], authors who point out the need to carry out assessments of the costs and socioeconomic benefits of existing and planned dams in the Amazon River systems.

Finally, WWF-Brazil hopes that the monetization now carried out of just some of the provision, regulation, support and cultural ecosystem services provided by the Tapajós River Basin will shine upon the understanding of the breadth, scope and intrinsic value of this last great river of free-flowing waters in the Brazilian Amazon, home to unique socio-biodiversity. No decision regarding this territory, whether for the implementation of infrastructure or the implementation of policies, should be made without this understanding and – ultimately – respect.

Madeira River at the Santo Antônio Power Plant dam

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This document is based on the **FULL CBA REPORT**. Read it for a comprehensive and detailed understanding of the context and conclusions.

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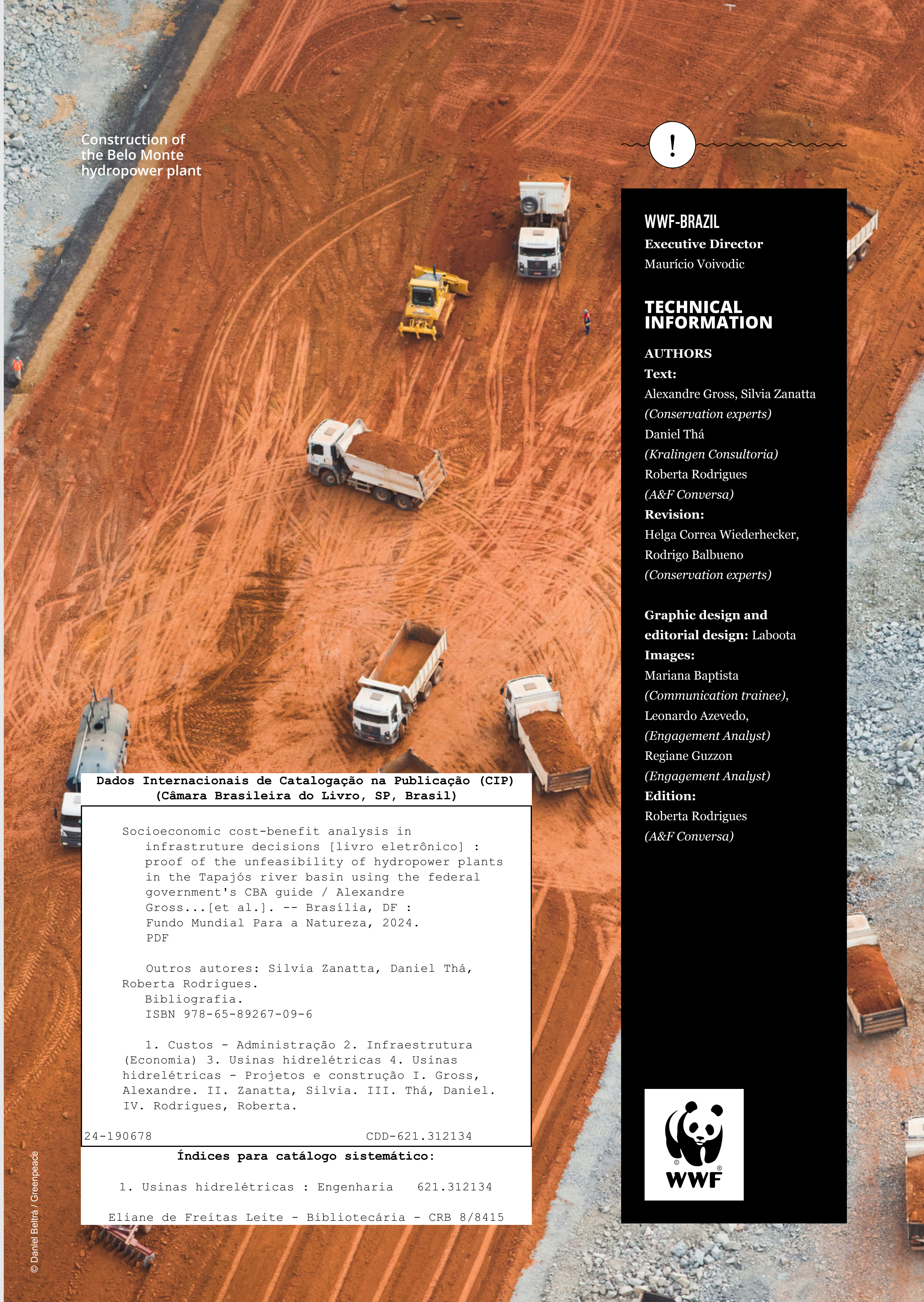

Construction of the Belo Monte hydropower plant

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