Jirau Hydropower Plant and Clean Development Mechanism

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Abstract: The worldwide concern with the climate changes made various countries assume goals of reducing the emissions of greenhouse gases (GHG). The Clean Development Mechanism (CDM) was designed in the scope of the Kyoto Protocol to help the signatory developed countries to fulfill these goals. Brazil has the largest part of its electric matrix formed by renewable sources. The Jirau Hydropower Plant (HPP) Jirau is one of the largest hydropower projects of Brazil and is registered in the CDM. In this paper, the authors analyze the importance of the Jirau HPP for mitigating the emission of GHG and contributing to clean expansion of the Brazil energy matrix. The analysis details the project's social-economic benefits, as well as it approval in the CDM. At the end, it proves the importance of the Jirau HPP as a vector for sustainable development and environmental conservation and its role in reducing the emissions of GHG.

1. Introduction

The global climate change caused by the anthropic emissions of greenhouse gases (GHG) is a theme of great relevance in the last few years. In this context, the Kyoto Protocol, created in 1997 and in force since 2005, has established reduction goals for the developed countries (5% of the emissions verified in 1990), to be achieved between 2008-2012, corresponding to the first commitment period. In 2012, during the XVIII Conference of the Parties (COP-18) of the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol was extended until 2020. However, in this occasion, a few countries opted for not signing this extension.

Brazil, in spite of not having the legal obligation of reducing the GHG emissions, as established in the Kyoto Protocol, has made efforts to mitigate its emissions. In 2009, during the XV Conference of the Parties (COP-15), the country announced its voluntary goal of reducing, between 36.1% and 38.9%, its GHG emissions projected until 2020.

In 2015, during the XXI Conference of the Parties (COP-21), a new global agreement was adopted, seeking to fight the effects of climate change and to reduce the GHG emissions. The agreement, titled "The Paris Agreement", was ratified by the 195 parties of the UNFCCC and by the European Union, including developed and developing countries, with the purpose of limiting the rise of global temperature below 2ºC or up to 1.5ºC.

In this scenario of fighting the climate changes, the renewable energy sources, especially the hydropower plants, play an essential role in mitigating the greenhouse gases emissions, because they replace the necessary power generation from fossil fuels to fulfill the energy demand.

The relevance of the hydraulic source as a technology of mitigating the GHG is recognized by the Intergovernmental Panel on Climate Changes, as present in the Special Report on Renewable Energy Sources and Climate Change Mitigation (IPCC, 2012). The publication identifies that the hydroelectric power plants offer a significant potential for reducing GHG emissions and for promoting sustainable development. However, it is necessary to establish adequate policies and measures to overcome the existing obstacles to hydropower plants implantation. The report discusses the social-environmental aspects of the hydropower plants, highlighting that they are inducers of economic development. The document also brings the description of run-of-river hydropower plants, such as Jirau Hydropower Plant (HPP), object of the present paper, which cause smaller social-environmental impacts.

2. The Clean Development Mechanism

The consideration of the importance of renewable sources in mitigating the GHG emissions, including the hydropower plants, allows framing this kind of project in the scope of the Clean Development Mechanism (CDM). It is essential to highlight that there are specific requirements to be filled by a project to be eligible for the CDM, including: (i) the participation must be voluntary; (ii) the project must count with the approval of the country in which it is implemented; (iii) the project must achieve the sustainable development levels defined by the country in which it is implemented; (iv) the project must reduce the emissions of greenhouse gases in an additional manner to what would happen in the absence of the CDM project activity; (v) the project must account, if applicable, the increase of the emissions that take place outside the project activity boundaries and which are measurable and attributable to these activities; (vi) the project must consult and take into consideration the opinion of the stakeholders; (vii) the project must provide long term measurable benefits relating to mitigating

climate changes; and (viii) the project must be related to the gases and sectors defined in the Kyoto Protocol or related to the activities of reforestation and forestation (FGV, 2002).

In general, the proposal of the CDM consists in that each ton of equivalent CO_2 (tCO_2e) that is not emitted or is removed from the atmosphere by a project activity in a developing country results in Certified Reduction of Emissions (CER's), which can be traded in the carbon credit world market. The CER's represent credits that can be used by the developed countries as a form of partial fulfillment of their goals of reducing the emission of greenhouse gases, according to the Kyoto Protocol. The project must undergo specific steps to eligible to receive CER's, which are: (i) Preparation of the Project Design Document (PDD); (ii) validation and approval; (iii) registration; (iv) monitoring; and (v) checking and certification.

There are specific methodologies in the CDM for renewable sources projects. One example is the methodology ACM0002: *Grid-connected electricity generation from renewable sources*, which purpose is to guide the determination of the baseline scenario for projects connected to the electric grid that generate electric energy from renewable sources. This methodology establishes a few conditions for its use. Specifically for hydropower plants, it contemplates, for instance, installation of a hydropower plant with a new run-of-river reservoir, hydropower plants which reservoirs have a power density greater than 4 W/m^2, among other conditions.

3. The Brazilian Electric Matrix

The Brazilian electric energy matrix is comprised in its greater part by renewable projects. According to updated information from the Generation Information Bank (BIG), of the Agência Nacional de Energia Elétrica (ANEEL) [*The National Electric Power Agency*] (Table 1), the renewable sources, comprised by biomass, wind, hydro and solar, currently represent around 76.8% of the entire generation of electric energy in Brazil. As it can be observed, the hydropower plants have a prominent role in the matrix, with around 61.3% of the total installed capacity, excluding from this percentage the imported energy.

Table 1 – Brazilian electric energy generation matrix.

Source	Installed Capacity (MW)	Participation (%)
Biomass	14,169	8.86
Wind	10,526	6.58
Fossil	26,941	16.8
Hydric	98,083	61.3
Nuclear	1,990	1.25
Solar	24	0.01
Imported	8,170	5.11
Total	**159,903**	**100**

Source: Adapted from BIG (ANEEL, 2017).

The expansion planned for the Brazilian Electric System must continue to remain focused on renewable sources in the next few years. According to the Ten-Year Energy Expansion Plan (MME/EPE, 2015), until the year 2024, the participation of renewable sources, mainly hydroelectric plants, shall remain the majority in the country's energy matrix (Figure 1). In the period of 2014-2024 a growth of 28,300 MW is expected, distributed in 22 hydropower plants in Brazil. The greater part of these plants is located in the Amazon Region and presents a low social and environmental impact if compared to the benefits that they can generate to the region and its surroundings.

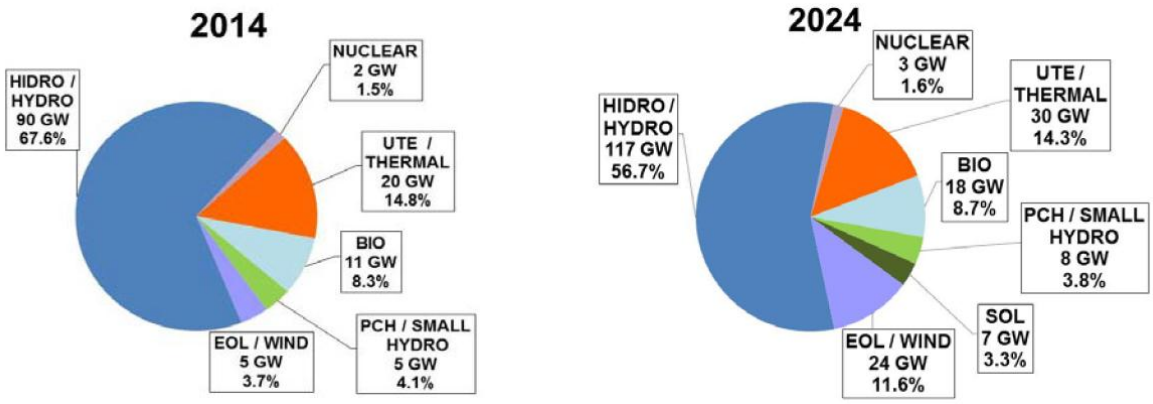

Figure 1 – Brazilian Energy Matrix in 2014 and forecast for 2024 (MME/EPE, 2015).

4. The Jirau Hydropower Plant

The Jirau Hydropower Plant (HPP) is inserted in the Brazilian context of a strong presence of hydropower plants and of search for mitigating the GHG emissions. It is one of the country's largest hydropower plants, with an installed capacity of 3,750 MW (50 Bulb turbines). The project is located

on the Madeira River, 120 km from the city of Porto Velho, in the state of Rondônia. Connected to the National Interconnected System (SIN) by three transmission lines, the plant is capable of providing energy for more than 10 million residences, increasing the system's stability and ensuring the necessary energy for the country to grow based on a renewable expansion. The plant's construction was initiated in November 2008 and concluded in November 2016, after all the generating units going into commercial operation.

To minimize the social-environmental, the Jirau HPP was designed as a run-of- river hydropower project, with a reservoir with considerably reduced dimensions. The plant operates with a variable water level, between the elevations 82.5m and 90.0m, with the purpose of following the river's natural hydrology. The established rule results in an annual variation of the reservoir area, as demonstrated in the Table 2. The project has a minimum power density of 10.37 W/m^2, while the Brazilian average power density is around 1.96 W/m^2 (ESBR & GDF Suez, 2012).

Table 2 – Annual variation of reservoir water level and area

Operational level under normal conditions	**Reservoir water level at the dam (m)**	**Total Reservoir area (km^2)**	**Increased Reservoir surface (km^2)**
Minimum	82.5	174.90	21.04
Average	85.0	229.29	75.43
Maximum	90.0	361.60	207.74

Source: PDD (ESBR & GDF Suez, 2012).

The project is a result of the Brazilian policy to promote the use of hydropower plants and other sources of clean and renewable sources to supply the addition of future demand without increasing the emissions of GHG to the atmosphere.

There are no doubts, therefore, that the energy from the Jirau HPP allows a greater participation of the hydraulic generation in the country's electric energy matrix, reducing the emissions of GHG and displacing the generation of electricity from plants that use fossil fuels. To calculate the volume of reduction generated by the project, the Brazilian Government calculates the weighed emission factor from the integrated electric system, which makes the projection and effective monitoring on the course of the plant's operation period easier.

The supply of clean and renewable energy by Jirau HPP brings an important contribution to sustainability, minimizing the emissions of GHG that would take place in the absence of the project.

The importance of the Jirau HPP to prevent the emissions of GHG from growing and contributing to the country's sustainable development was pointed out since its conception and construction. The Environmental Impact Assessment of the project, approved by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) [*The Brazilian Institute of the Environment and Renewable Natural Resources*], highlighted the relevance of the hydroelectric projects in the Madeira river, Santo Antônio and Jirau HPP's, for a clean expansion of the country's electric energy matrix (FURNAS et. al, 2005).

> *"The hydropower stations must, upon generating renewable electricity, maintain Brazil as a country with low carbon emissions, thereby contributing to the reduction of the global emissions of greenhouse effect gases and contributing to the nation's sustainable development. Anyhow, the Certified Reduction of Emissions generated by the Projects, in accordance with the rules of the Clean Development Mechanism, as defined by the Kyoto Protocol and by the Marrakesh Agreements, must help to make the projects viable".*

The ANEEL, when analyzing the project changes proposed by the entrepreneur, which enabled an anticipation on the schedule of energy generation, also pointed out the relevance of the Jirau HPP as a form of substituting the installation of new fossil fuel stations, and, with that, avoiding the emissions of GHG (ANEEL, 2008).

> *"On repeating what was verified in auction A-5, held on 08/30/2009, this "substitute" energy (628 $MW_{average}$) would be generated essentially by the burning of fuel oil in thermal plants with an installed capacity of 1,083 MW. This would mean, in terms of expected amount, the burning of 200 thousand tons of oil in 2012 (supposing a plant actuating of only 10% of the time and specific consumption of 0.21 ton/MWh). It is equal to the emission of about 600 thousand tons of CO_2 (0.628 ton/MWh)."*

5. The Jirau Hydropower Plant in the Clean Development Mechanism

As a consequence of its implantation, the Jirau HPP is contributing to the reduction of approximately 6 $MtCO_2e$ per year that would be emitted in the absence of the project by fossil fuels power plants in operation or by the addition of new thermal power stations to the SIN.

In this context, it is verified that the Jirau HPP incorporates the main objectives of the Clean Development Mechanism (CDM) to mitigate the GHG emissions and to support the host country (developing country), Brazil in this case, in its pretensions related to sustainable development.

For this reason, the project was developed in strict conformity with the requirements and rules of the CDM, with engagement and consultation to the stakeholders and with a high standard of sustainability, in order to ensure that all the process phases, including validation, registration and monitoring, could be conducted in an efficient manner.

As mentioned before, without the implementation of the Jirau HPP, the electricity generated by the project and dispatched in the SIN would have been generated by fossil fuels power plants. Thus, the project was developed based on the methodology approved in the scope of the CDM ACM0002: *Grid-connected electricity generation from renewable sources*.

As a first stage of the CDM, the Project Conception Document – PDD (Portuguese and English versions) was prepared in accordance with the CDM rules and methodologies, containing the description of the project and the respective participants, technical, financial and social-environmental information, baseline methodology (ACM0002), calculation methodology used to determine its potential for reducing the GHG emissions in the scope of the Brazilian electric sector, definition of the credits obtaining period, monitoring plan, justification for the additionality of the project activity, among other data. It is worthwhile to stress that the monitoring plan includes the form of gathering and storing all the necessary data for calculating the reduction of the GHG emissions, to be checked and certified in a later stage.

As part of the process, the project was submitted to local public consultation in March 2012, involving environmental agencies from all spheres (federal, state and municipal), non-governmental organizations (NGO's), Federal and State Attorney Offices, research institutions, local community, among others. After concluding the local consultation, the project was published on the UNFCCC website and underwent a global stakeholder consultation in April 2012, which lasted 30 (thirty) days.

The following stage was the validation by the Designated Operational Entity (DOE)[1], which ensured that the documents and project development and implementation procedures were in

[1] The Designated National Entities are national or international entities accredited by the MDL Executive Board, with the following attributions: (i) validate the MDL project activities; (ii) check and certify the reductions of greenhouse gas emissions and CO_2 removal, among others.

conformity with the CDM requirements, attesting that the project fulfills the eligibility criteria and that there is an additional reduction in the emission of GHG due to its implantation.

After this phase, successfully concluded in September 2012, the project was submitted for the approval of the Brazilian National Designated Authority, represented by the Inter-ministerial Committee on Global Climate Change (CIMGC), composed at the time by representatives from 11 ministries of the Brazilian Government.

In December 2012, after a detailed analysis, the Letter of Approval for the project was issued by the CIMG, which confirmed that Jirau HPP contributed for the Federative Republic of Brazil to achieve sustainable development, based on the criteria established by the Brazilian Government, enabling the project's submission for approval from the United Nations, which took place in the same month.

After this submission, the United Nations secretariat conducted a sequence of conformity and content analyses, before forwarding the project for approval from the Executive Board of the CDM. The Jirau HPP was registered in the CDM in May 2013, but with effectiveness of December 2012. The Jirau HPP became, therefore, the largest renewable energy project registered as a CDM project in the United Nations.

This registration represented an important milestone for the Brazilian policy of incentive to renewable energy generation sources, mainly in regard to hydroelectricity, and for the National Policy on Climate Change. It also demonstrated the importance of the Jirau HPP to the clean growth of the Brazilian energy matrix and mitigation of the GHG emissions, as well as its role as an inducer of sustainable development of the region where the project is located. In addition, it confirmed that the Jirau HPP is being implemented based on principles of sustainability, with high social-environmental performance and applying the best practices in implantation of hydropower plants.

Since its registration, the Jirau HPP became eligible for receiving carbon credits, and, later, for trading these credits (Certified Reduction of Emissions – RCE's) in the world market or for donation them. To receive the RCE's, however, the project must pass through the checking and certification stages, in which the DOE checks if the reductions of GHG took place as a result of the project, according to the monitoring plan previously established in the PDD.

The first carbon credits emission of the Jirau HPP was successfully concluded in August 2016. This process included field inspections, interviews, data gathering and measurements, observation of

monitoring practices, checking of the monitoring equipment, among others. As a result, 1,699,285 RCE's were issued, corresponding the period from July 2014 to February 2015. It is worthwhile to highlight that the project has the potential of reducing 6 $MtCO_2e$ per year. The quantitative issued in August 2016 was lower due to the fact that the first verification considered a period of only 8 months when the Jirau HPP was still in the motorization phase.

Two percent of the total RCE's were destined to the Adaptation Fund, created by the United Nations Organization to finance concrete adaptation projects and programs in developing countries (Parties do the Kyoto Protocol) that are particularly vulnerable to the adverse effects of global climate changes.

In addition, 70,000 (seventy thousand) carbon credits were voluntarily donated to the State Government of Rio de Janeiro - Brazil as a contribution to the Olympic and Paralympic Games Greenhouse Gases Compensation Strategy (Selo de Sustentabilidade – Jogos Limpos 2016). With this initiative, it was possible to collaborate to compensate part of the amount of 1.6 $MtCO_2e$ emitted in works and services related to the 2016 Olympic and Paralympic Games, demonstrating the use of compensation mechanisms to promote the sustainability of events and country economy.

6. Sustainability in the Jirau Hydropower Plant

In order to have an independent assessment of the project's sustainability, based on a structured, specific and internationally consistent methodology, the Jirau HPP was assessed in accordance with the Hydropower Sustainability Assessment Protocol.

The Hydropower Sustainability Assessment Protocol is a framework for assessing the sustainability of hydropower projects and a neutral tool for dialogue with stakeholders. The Protocol covers various topics such as climate change, corruption, human rights, gender, grievance mechanisms, integrated water resource management, legal issues, multi-purpose projects, transboundary issues, transparency and all the other subjects related to the sustainability of the hydropower projects.

The Protocol comprises a background document to define all principles for use and application as well as 4 (four) stand-alone assessment tools covering the main stages of hydropower developments: Early Stage, Preparation, Implementation and Operation. The results of a phase can contribute in the definition of additional actions to be executed in this or in the next stages of the project, ensuring its implementation in accordance with the best practices. Inside each tool, there are a number of topics to

be assessed, including the environmental, social, technical and economic/financial issues, to form a vision of sustainability of the project.

Each topic receives a score from 1 to 5, where level 3 defines the criteria for the fulfillment of basic good practices and level 5 defines the level of compliance necessary to meet proven best practices in the hydropower sector.

Score	Description
1	There are significant gaps relative to basic good practices.
2	Most relevant elements of basic good practices have been undertaken, but there is one significant gap.
3	Describes basic good practices.
4	All elements of basic good practices have been undertaken and in one or more cases exceeded, but there is one significant gap in the requirements for proven best practices.
5	Describes proven best practices.

The Jirau HPP was assessed in accordance with the Hydropower Sustainability Assessment Protocol in its implantation phase. According to the methodology for this stage, 20 topics were analyzed in the 4 (four) main areas (environmental, social, technical and economic/financial), in addition to transversal questions (climate change, human right and transboundary issues). The assessed topics were: I-1 Communications & Consultations; I-2 Governance; I-3 Environmental & Social Issues Management; I-4 Integrated Project Management; I-5 Infrastructure Safety; I-6 Financial Viability; I-7 Project Benefits; I-8 Procurement; I-9 Project Affected Communities & Livelihoods; I-10 Resettlement; I-11 Indigenous Peoples; I-12 Labor & Working Conditions; I-13 Cultural Heritage; I-14 Public Health; I-15 Biodiversity & Invasive Species; I-16 Erosion & Sedimentation; I-17 Water Quality; I-18 Waste Noise & Air Quality; I-19 Reservoir Preparation and Filling; I-20 Downstream Flow Regimes.

Verbal, visual and documental evidences were used to assess the project. The assessment team had a competent approach and conducted 132 interviews with multiple stakeholders, such as members of the civil society (for instance, resettled people and workers), local associations, NGO's, municipal and state governments, federal government institutions, including IBAMA, FUNAI, ICMBio and the Ministry for Planning, contracting companies, researchers, and the entrepreneur's team.

During the preparation, auditing and report drafting phase, a total of 1,952 documents were analyzed in order to corroborate and reference the results of the interviews and allow the assessment team to determine the project's sustainability profile, according to the Protocol's methodology.

The results of the assessment were consolidated in the Hydropower Sustainability Assessment Report (available at http://www.hydrosustainability.org/Protocol-Assessments.aspx), which concluded that the Jirau HPP has a very strong performance across its sustainability profile, demonstrating the commitment with the sustainability in the implantation of the Jirau HPP, in addition to the fulfillment of best practices in hydropower plants.

The project obtained scores 4 and 5 in almost all the topics (Figure 2), with results particularly exceptional results in technical, environmental and economic-financial areas. According to the report, across all of the topics, the project has implemented impressive policies, management systems, communication channels, grievance mechanisms, programs and procedures which are capable to back the strong sustainability commitments of the project, its shareholders and the financers, as well as those of the regulatory authorities.

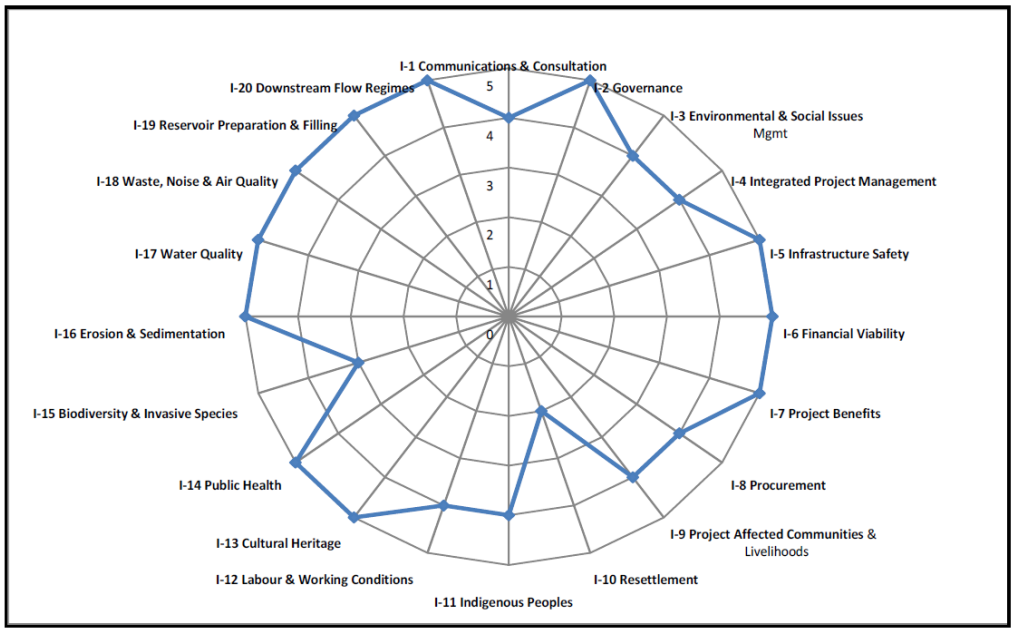

Figure 1 – Sustainability Profile of the Jirau HPP (Locher et. al, 2013)

Although, in general, the results show the adoption of good practices and even proven better practices in the hydropower sector in the project implantation phase, various programs and processes assessed in the audit continue to be implemented in accordance with the Basic Environmental Project (PBA). Consequently, the conclusive results of some social-environmental programs shall only be

available in the future and, therefore, could not be completely assessed during the audit (Locher et. al, 2013).

The independent assessment of the various aspects of project sustainability has demonstrated to have great value not only to identify opportunities of improvements in the social-environmental management practices in the preparation for the operation phase, as well as for viewing the achievements and the future opportunities for increasing the benefits of the project to society and to the environment.

7. Conclusions

The purpose of this paper is to find a correlation between the development of electric energy projects through renewable sources, especially the Jirau HPP, and the efforts for reducing the emission of GHG. Various countries have committed with goals of reducing future emissions which must be fulfilled with investments in clean and renewable technology. The CDM allows that the developing countries help the developed countries in fulfilling these goals.

In the context of the CDM, Brazil stands out for having a predominantly renewable electric matrix, which must be maintained, since its expansion is also based mainly by renewable sources.

The Jirau HPP, one of Brazil's largest hydropower plants, stands out for being the largest project already registered in the CDM. The energy generated by the Jirau HPP avoid the annual emission of 6 $MtCO_2e$, since the energy generated by the project avoid the need of actuating generating plants that use fossil fuels.

Certainly, the Jirau HPP project shall help Brazil in fulfilling the voluntarily goals assumed in the COP-15. The carbon credits generated by the Jirau HPP can also be used to help in the fulfillment of the emissions reduction growth of developed countries and the new agreement established during the COP-21.

It is clear then the importance of the Jirau HPP to the sustainable development and to contribute to climate change mitigation, providing security of supply and minimizing the need for fossil fuel dispatch.

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