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AFFORDABLE AND CLEAN ENERGY

ITAIPU BINACIONAL

UNDESA - Itaipu Binacional SUSTAINABLE WATER & ENERGY PARTNERSHIP

ENSURING ACCESS TO AFFORDABLE, RELIABLE, SUSTAINABLE AND MODERN ENERGY FOR ALL

CASE STUDY: ITAIPU AND SDG 7

Activities by Itaipu Binacional supporting implementation of the Sustainable Development Goal 7(SDG 7) of the United Nations 2030 Agenda for Sustainable Development

Aerial view of the Dam - Alexandre Marchetti | Itaipu Binacional

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Itaipu is a binational entity created in 1974 by Brazil and Paraguay in order to utilize the Parana River, along the border of the two countries, to generate hydropower. The Itaipu Hydropower Plant is the largest generator of renewable power in the world (ITAIPU, 2018 a). By the end of 2018, Itaipu had generated a total of over 2.6 billion Megawatts-hours (MWh) since the beginning of its operation in 1984 (ITAIPU, 2019 a).

Since its conception, Itaipu Binacional has followed sustainable development principles as reflected by its integrated actions and programs supporting social well-being, economic growth and environmental protection, contributing to regional prosperity in Paraguay and Brazil. Itaipu's activities in the region have been recognized as outstanding examples of "Best Practices" in the effective implementation of the United Nations 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs).

The spillway - Alexandre Marchetti | Itaipu Binacional

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AFFORDABLE AND CLEAN ENERGY

SDG7: ENSURE ACCESS TO AFFORDABLE, RELIABLE, SUSTAINABLE AND MODERN ENERGY FOR ALL

Target 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services

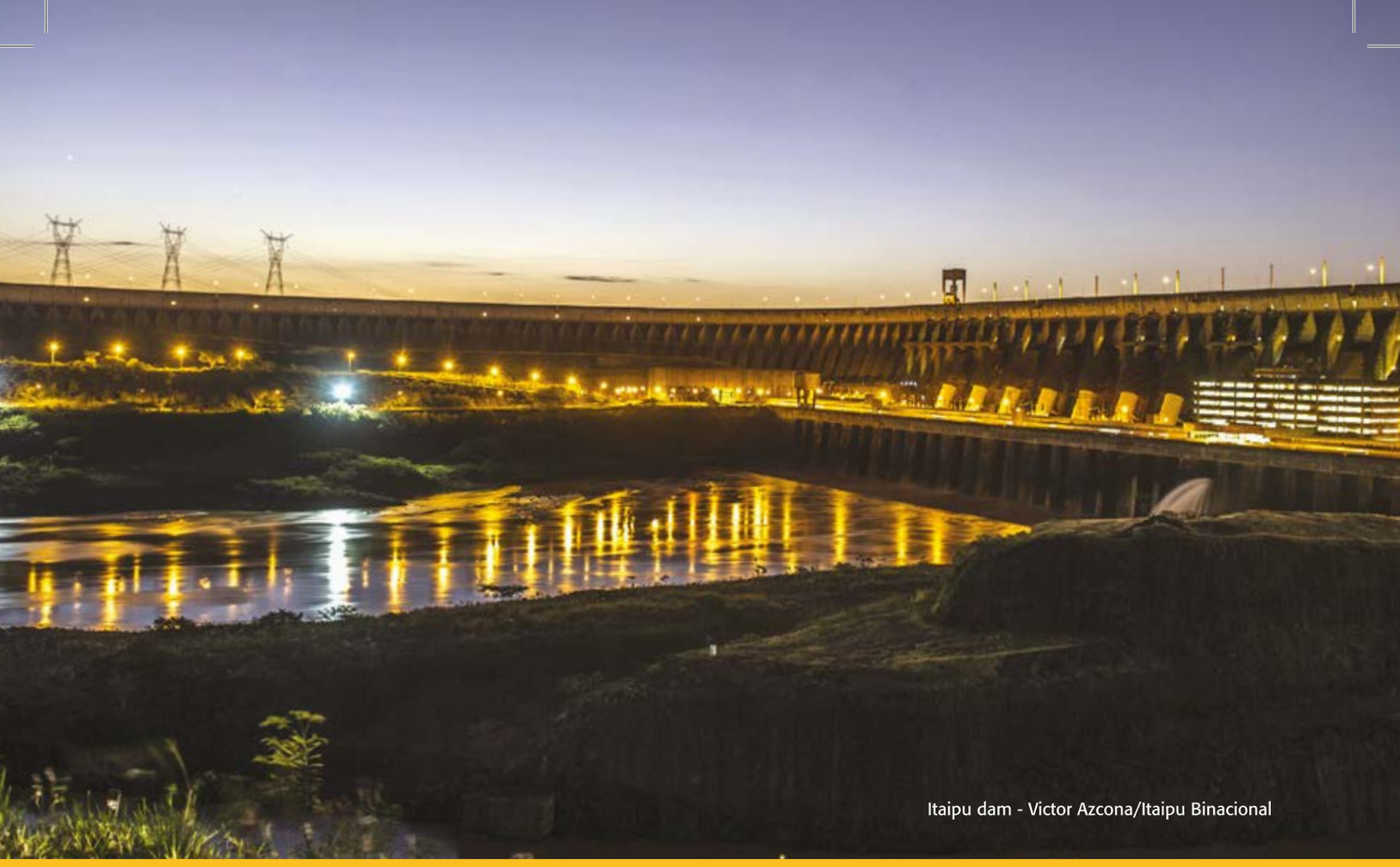
Target 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

Target 7.3 By 2030, double the global rate of improvement in energy efficiency

Target.7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

Target.7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support

Source: United Nations, 2015.



Itaipu dam - Victor Azcona/Itaipu Binacional

The Hydropower Plant has an installed capacity of 14,000 megawatts (MW) with 20 generating units of 700 MW each. In 2016, Itaipu generated 103.1 million MWh, which represents a world record of annual generation for a hydropower plant (ITAIPU, 2018 a). In 2018, it generated 90% of the electricity consumed in Paraguay and 15% of the electricity consumed in Brazil (ITAIPU, 2018 b).

In relation to its overall efficiency, Itaipu adopted a management model in 2012 that has resulted in higher productivity. The model considers strategies for possible adaptation to climate change impacts, including changes in rainfall patterns already being observed in the region.

Itaipu has played a major role supporting sustainable development in Paraguay and Brazil by providing access to reliable, sustainable and clean electricity that has powered prosperity for the people of both countries (Sória, 2012). The Binational is a major contributor to the share of renewable energy use in South America, generating, in 2016, about 14 % of its renewable electricity (IRENA, 2017).

Itaipu Binacional promotes prosperity by implementing programs focused on environmental conservation, improvements in infrastructure, public health, income generation, education, and respect for human rights, which contribute to the constant improvement of the quality of life of the people in the region. This commitment is part of its Binational Sustainability Policy and is included in its Strategic Plan since 2003.

As part of this commitment, in 2008, a Renewable Energy Advisor Office was created in both countries to promote the implementation and research of alternative energies, distributed generation technologies and energy efficiency practices.

In addition to these initiatives, Itaipu distributes royalties to the governments of Brazil and Paraguay and stimulates the hiring of local suppliers in bidding processes.

Transmission lines at Itaipu dam - Victor Azcona/Itaipu Binacional

SUSTAINABLE DEVELOPMENT STRATEGY OF ITAIPU

Itaipu's sustainable development strategy recognizes that water security[1] and territorial development in the influence area require optimum environmental management besides social, economic, cultural and technological development.

Each of these five important objectives unfolds in basic goals, used to better understand and manage the actions carried out by Itaipu (ITAIPU, 2019 b). This approach is intrinsically linked to the overall objectives and specific targets of the SDG in energy (SDG7) and the other SDGs of the United Nations 2030 Agenda for Sustainable Development.

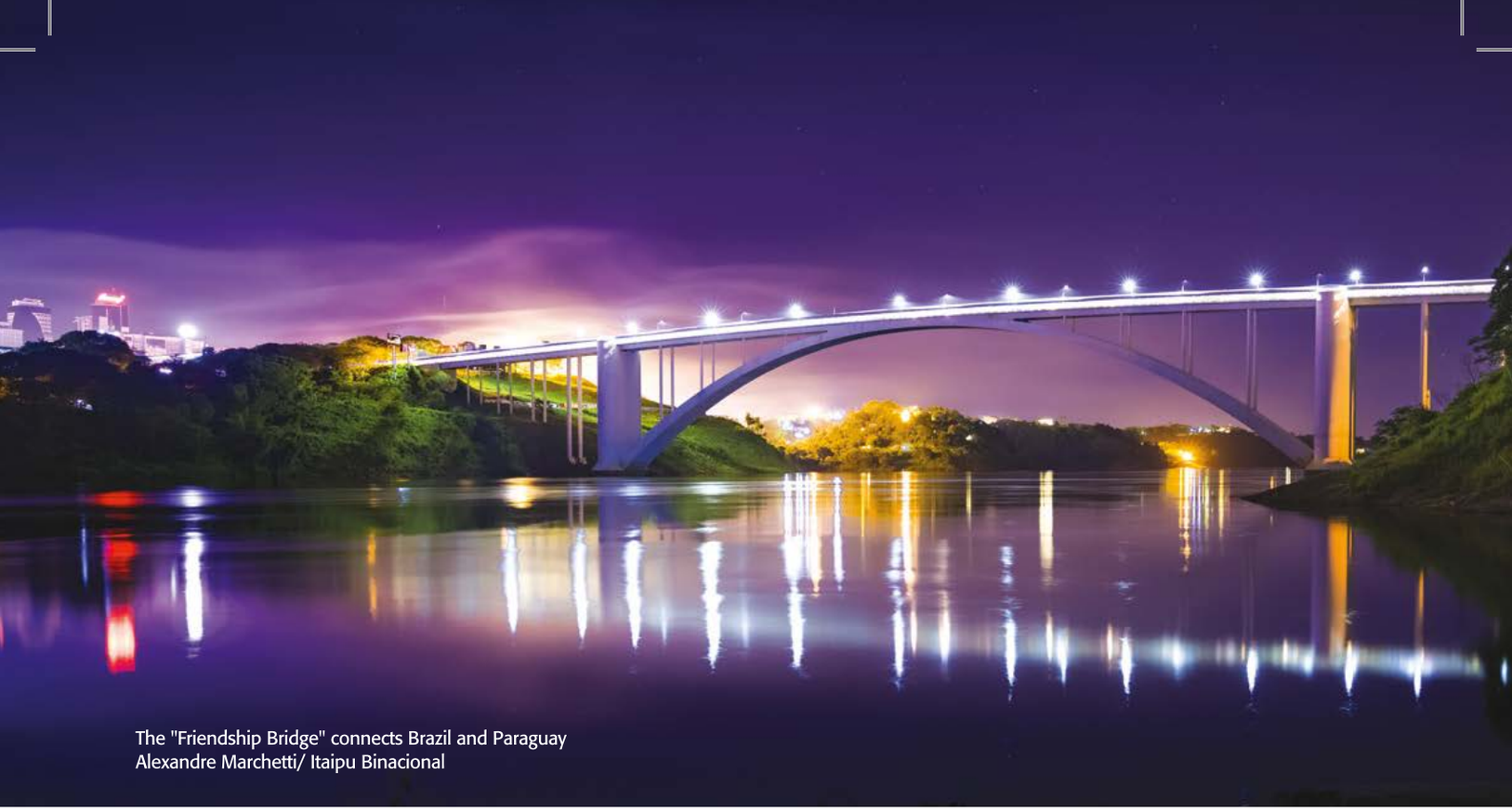
Itaipu's vision for 2020 is to be "the generator of clean, renewable energy with the best operating performance and the world's best sustainability practices, promoting sustainable development and regional integration"(ITAIPU, 2018 c).

Both Paraguay and Brazil have gained much from the development and operation of the Itaipu Binational Hydropower Plant. This source of electricity has helped reduce dependence on coal and oil, and in the avoidance of substantial quantities of GHG emissions, and has resulted in a more connected relationship between the two countries through their joint partnership. Itaipu is considered an economic, fiscal, political and interregional success (Tommy, 2011).

[1] Water security refers to the recovery, conservation and preservation of watersheds and reservoirs through permanent and integrated actions that promote the sustainable use of natural resources, better socio-environmental conditions and the best availability of water in quantity and quality for different applications (ITAIPU, 2018 c).

1.

ACCESS TO ELECTRICITY: ITAIPU'S ROLE AS A PROVIDER OF RELIABLE ELECTRICITY TO PARAGUAY AND BRAZIL



The "Friendship Bridge" connects Brazil and Paraguay
Alexandre Marchetti/ Itaipu Binacional

Objective and description

Itaipu has played a key role in the accelerated increase in electricity access that has been observed in Brazil and Paraguay in the last decades. The total current access of electricity to the population in these countries stands at 100% in Brazil and 99.3% in Paraguay as of 2017 (World Bank, 2019). The reliable electricity access that Itaipu has been providing for over three decades has been translated into an economic boom for the region, characterized by accelerated expansion of cities, rapid economic growth, thousands of jobs, new roads and other public services, prosperity and sustainable development.

Currently, it is estimated that Itaipu Binacional provides electricity access to the equivalent of about 37 to 48 million people based on the per capita consumption of electricity (International Energy Agency, 2017). The modern economies of Paraguay and Brazil depend on the reliable and secure electricity supplies from Itaipu.

This reliance on efficient and clean electricity has greatly contributed to the relatively decarbonized economies of Brazil and Paraguay. As of today, the Plant is contributing to the leading position that Brazil and Paraguay maintain as countries with energy systems highly dependent on renewable energy and, consequently, avoiding large volumes of GHG emissions. The relatively clean energy systems of Brazil and Paraguay translate into highly valuable global benefits, reflected in the avoidance of negative impacts from climate change.

As Itaipu generates the highest amount of hydroelectric power on the planet, it has the capacity to produce approximately six times Paraguay national electricity requirements. Paraguay currently generates the highest percentage of renewable energy per capita in the world, and is the fourth-largest electricity exporter worldwide, surpassed only by France, Germany and Canada (Leading Edge, 2018).

The Brazilian and Paraguayan governments receive financial compensation, called royalties, for Itaipu's use of the Paraná River hydraulic potential to generate electricity. Royalty payments are based on the use of hydraulic potential and the amounts are calculated based on the energy generated.

The amounts transferred as royalties to Brazil and Paraguay provide an increase in the capacity of the two countries to achieve their goals, mainly by the municipalities in the entity's area of influence, with undeniable benefits for the population. This effect can be evidenced by the increase in the HDI (United Nations Development Program's Human Development Index) of several municipalities in the region (Sória, 2012).

So far, Brazil and Paraguay have received more than 11 billion dollars in royalties. Each country has its own legislation to regulate the distribution and internal use of this resource. The funds are destined to both countries, which establish the criteria for distribution of values among municipalities, states and agencies, allowing royalties to be applied in health, education and security, among others (ITAIPU, 2018 a).

Related SDG 7 targets

This activity relates to Target 7.1 on access to affordable, reliable and modern energy services.

Challenges

One of the greatest challenges for Itaipu has been to maintain an integrated approach to the generation of hydropower always taking into consideration the optimum management of water resources, and terrestrial and water ecosystems. In the past, the major challenge for Itaipu was to implement all the necessary construction programs and activities to keep expanding the capacity of the hydropower plant, increasing electricity access for the population.

Lessons learned

Much has been learned in 35 years of reliable operation and generation of electricity from renewable resources. A critical issue is the cooperation with stakeholders, such as municipalities, government and social organizations, in order to assure Itaipu´s role as a provider of reliable electricity and strong supporter of territorial development in Paraguay and Brazil.

Therefore, Itaipu Binacional recognizes that in order to reach sustainable development, all stakeholders need to participate actively in the overall process. In consequence, all the programs and activities promoted by Itaipu have been guided by sustainability principles.

In terms of history and diplomatic issues, the cooperation between Argentina, Paraguay and Brazil was also key for the successful construction and operation of the hydropower plant. In 1979, they signed the Agreement on Technical-Operational Cooperation, which established that the fluvial border zone of the three countries had to mantain a previously established level so as to be in accordance with internacional practices (Sória, 2012).

Results

Itaipu has been able to provide reliable and clean energy in the form of electricity for Brazil and Paraguay for over 35 years. The electricity supplied by Itaipu has achieved record values in the last several years and, in 2018, was 96,585,596 MWh, providing an important contribution to the sustainable development of Brazil and Paraguay.

Paraguay's national electrification rate increased from 80.42% in 1990 to 99.3% in 2017, while Brazil's national electrification rate rose from 87.48% to 100% in the same time period (World Bank, 2019). Itaipu has contributed greatly to this growth in electricity access, with its rural electrification programs coupled with social development and life quality improvements programs.

High-voltage network - Alexandre Marchetti | Itaipu Binacional

2.

IMPROVING RURAL COMMUNITIES ACCESS TO MODERN COOKING TECHNOLOGIES

Objective and description

Firewood is the main source of energy for more than half of the population in Paraguay, especially in rural households.

Around 85% of rural households use firewood as the main fuel for cooking (Viceministerio de Minas y Energías, 2018). This level of consumption increases the loss of native forest in the country and it exposes the population to the health risk caused by the wood smoke.

The objective of the project is reducing the use of native wood for cooking in rural and indigenous communities by increasing the biomass energy efficiency. Itaipu distributes Eco stoves that use less amounts of wood due to a technology powered by solar energy.

The Eco Stove has a solar panel to charge a battery that powers a ventilation system, contributing to having a greater efficiency when generating combustion.

The project contributes to the conservation of forest remnants in the Alto Paraná Atlantic Forest corridor, through the adoption of a plan to reduce biomass consumption for cooking, covering six departments of Paraguay.

Besides distributing the stoves for free, Itaipu invests on training the people on how to use such technology. This initiative is considered a pilot activity, but it could be expanded to other isolated communities.

Eco Stove - Ever Portillo/ Itaipu Binacional

Related SDG 7 targets

This activity relates to Target 7.1 on access to affordable, reliable and modern energy services.

Challenges

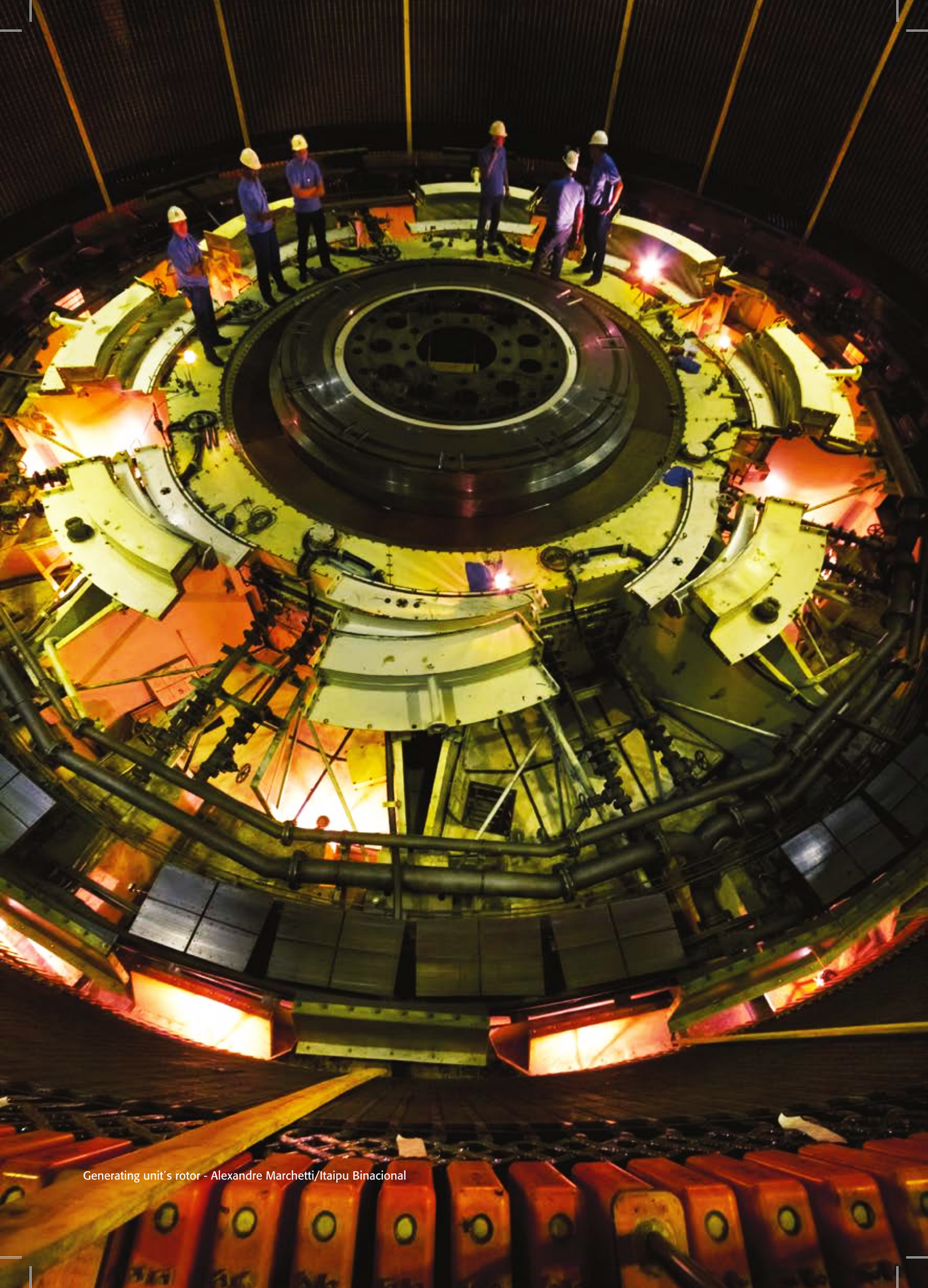
One of the greatest challenges for Itaipu has been to provide the necessary training in using this technology. Also, in some cases, the communities are reluctant to change their traditional firewood cook stoves.

Lessons learned

Much has been learned by working with the community in the process of adapting to new technologies. One of the most important ones is related to continuing the use of the efficient cookstoves until it becomes constant practice. Women and children are usually the ones responsible for gathering biomass for use in cookstoves. With the new technology, their time can be used for more productive tasks and the process of cooking will minimize the negative effects in nature and on the population's health.

Results

Itaipu Binacional has been able to provide modern technologies for cooking to rural and indigenous communities that usually depend on the use of solid unsustainable biomass.



Generating unit´s rotor - Alexandre Marchetti/Itaipu Binacional

3.

ITAIPU'S ROLE IN INCREASING THE SHARE OF RENEWABLE ENERGY IN PARAGUAY AND BRAZIL

Solar water heater in San Francisco Neighborhood - Víctor Azcona / Itaipu Binacional

Objective and description

Itaipu Binacional provides great contribution to Paraguay and Brazil in terms of the overall share of use of renewable energy in these countries. In 2018, it generated 90% of the electricity consumed in Paraguay and 15% of the electricity consumed in Brazil (ITAIPU, 2018 b).

The electricity generation from the Plant replaces the equivalent of 550,000 barrels of oil each day, or 50 million cubic meters of natural gas. In relation to the impacts of climate change, Itaipu is avoiding the emissions of about 87 million tons of CO_2 equivalent if it is replacing coal and 39 million tons if it is replacing natural gas (ITAIPU, 2018 a).

Itaipu promotes the use of different forms of renewable energy including solar thermal, solar photovoltaic, wind and biogas. It has extensive programs for capacity building in the area of renewable energy and has created an International Center for Renewable Energy with emphasis on the development of biogas processes.

Besides the International Center, Itaipu has a representative as the Coordinator of the Observatory of Renewable Energies of Paraguay (OER - PY). The OER is a program of inter-institutional and multidisciplinary technical cooperation that coordinates and promotes sustainable development with the purpose of increasing the use of renewable energies, energy efficiency and the diversification of the energy matrix (ITAIPU, 2019 c).

Solar thermal

During the construction of social housing in Paraguay, the government created the "San Francisco Neighborhood", to which Itaipu Binacional provided a water heating system through the installation of 112 solar water heaters. With this action, it was possible to reduce 76% of the home's electric load.

Solar photovoltaic

Itaipu promotes the installation of solar panels in isolated areas and rural communities where access to electricity is difficult, thus contributing to achieving universal access to energy.

Itaipu, in partnership with the Itaipu Technology Park (PTI) and the Pontifical Catholic University of Rio Grande do Sul (PUC-RS), also invests in promoting knowledge on this field and it encourages the population to learn more about the subject by conducting courses on solar photovoltaic energy technologies and its applications. The courses are offered to people who live in the cities that are members of the Association of Municipalities of West of Paraná in Brazil. Through the courses, participants are able to understand the local and global benefits of using solar energy, including its impacts on climate change mitigation.

Solar and wind

Itaipu Binacional and the Itaipu Technology Park (PTI) developed a mapping of the potential of solar and wind energy available at Itaipu`s regions of interest, which resulted in two different atlas: the Atlas of the Wind and Solar Potential Energy of Paraguay and the State of Parana Solar Energy Atlas in Brazil (Instituto Nacional de Pesquisas Espacias, 2018; ITAIPU, 2019 c).

The objective of the Atlas is to share data about the potential of solar and wind energy in the territory in an interactive way, with easy access and free of cost. The document provides accurate information about solar irradiation and estimated productivity of photovoltaic systems, which promotes greater interest regarding solar energy investments throughout the region from small to large investors. It also encourages research in different areas regarding this source of energy.

The Western Parana Energy Planning program is being supported by Itaipu since 2017. It represents a long-term planning of the region's energy sector including guiding trends and targeting alternatives to expansion of the electric system in the next decade, with an integrated perspective of available resources, including new renewable sources of energy. The planning covers the 54 municipalities linked to the West Development Program.

The action considers 2016 as the base year of information and it develops demand projections for the period 2017-2026. Considering the energy scenario and its impact in the western Paraná, the project aims at contributing to energy security, taking into consideration the region's development and being based on a clean and renewable energy matrix, making the use of local energy resources possible and aiming at reducing overall energy costs and environmental impacts.

Transmission lines at Itaipu
Alexandre Marchetti/ Itaipu Binacional

Related SDG 7 targets

This activity relates to Target 7.2 on increase substantially the share of renewable energy .

Challenges

In the past, the major challenge for Itaipu was to implement all the necessary construction programs and activities to keep expanding the renewable electric capacity of the hydropower plant, until the current level of 14,000 MW in 2007, with 20 units. In terms of electricity generation from a renewable energy source, Itaipu started in 1984 with 277 GWh and achieved a worldwide record in 2016, with 103 GWh (ITAIPU, 2016 a).

Another challenge is to continue promoting the use of other renewable energies in the energy matrix of countries, promoting new technologies, capacity building and pilot projects.

Lessons learned

Itaipu understands the need to maintain an integrated sustainable development strategy to keep achieving very high levels of electricity generation year after year, allowing for the reliable use of renewable energy resources.

Results

The integrated approach followed by Itaipu to electricity generation and natural resource management has allowed sustainable prosperity for the people of Paraguay and Brazil. Itaipu Binacional is one of the largest contributors of renewable energies in the electricity matrix of both countries, and stimulates the use of other sources of renewable energy in the region.

Itaipu at night - Alexandre Marchetti/ Itaipu Binacional

Turbine rotor (Part of the generating unit)
Victor Azcona/ Itaipu Binacional

4.

THE INTERNATIONAL CENTER OF RENEWABLE ENERGY – CIBIOGÁS

Biogas demonstration unit ithe area of influence (Céu Azul, Brazil)
Alexandre Marchetti/ Itaipu Binacional

Objective and Description

Itaipu, along with 26 other institutions, created the International Center of Renewable Energies – CIBiogás, located inside the Itaipu Technology Park – PTI. "The Center's goal is to support the development of public policies that regulate and encourage the use of biogas, while also developing strategies related to the generation of knowledge and the transfer of technology, and which currently boasts 6 demonstration units (ITAIPU, 2019 d).

The reason why Itaipu emphasizes the generation of biogas – "a result of the treatment of residual biomass from livestock farming and a source of initially unperceived income" – is related to the characteristics of the region. The area is dedicated to livestock farming, especially the conversion of plant into animal protein, with the cultivation of maize and soybeans integrated with poultry, pig and dairy farming. These activities have a strong environmental impact, especially in terms of waste generation. If this animal waste is not correctly treated, it accumulates in rivers and, eventually, in the Itaipu Reservoir. This, in turn, contributes to eutrophication of the lake and the generation of greenhouse gases.

In this sense, investment in this source of renewable energy, besides contributing to generating hydropower for a longer period of time (as it increases the average lifetime of the Reservoir), is key to disseminating knowledge and experiences about production and use of biogas in a region of tropical climate that has a vast potential to produce this type of energy, contributing to climate change mitigation and adaptation (ITAIPU, 2019 d).

There is a demonstration unit inside Itaipu, and the others are on the farms in its influence area. Biomass energy generation basically consist of using the biogas released by decomposing organic matter – in biodigestors– to drive motor generators. The energy produced is enough to cover all the farm's energy requirements, or at least guarantee supply during peak hours, when energy costs are higher. Besides generating energy, the byproduct of the biodigestion process is biofertilizers of high quality, another very important advantage.

Related SDG 7 targets

This activity relates to Target 7.2 on increase substantially the share of renewable energy.

Challenges

Itaipu has faced some challenges in the development and use of this fuel, including the need to make people aware of the possibility of using organic waste as a fuel for vehicles and of the fact that cars using natural gas can

also use biomethane without having to make any adaptations. Although the process drastically diminishes the emission of methane gas (CH_4), the generation of biogas as fuel still emits small amounts of CO_2 into the atmosphere, but studies are being conducted to transform emissions into clean fuel using hydrogen.

A challenge related to the demonstration unit constructed inside Itaipu is the green waste that was used to produce biomethane. As it needs pre-treatment, it has a high cost and is no longer used. The long-term goal is to make this treatment economically viable. While studies are being conducted in this sense, Itaipu no longer uses grass and shrubs from its green areas to produce biogas.

Biogas demonstration unit in the area of influence (São Miguel do Iguaçu, Brazil)
Alexandre Marchetti/ Itaipu Binacional

Lessons learned

A number of lessons have been learned from the development of this innovative process. Regulations exist in relation to the quality of the biomethane that is produced. In the beginning, sewage sludge, organic waste from restaurants and mowed grass residues from of the Itaipu's facility were used as the feed material for the digesters. Today, only organic waste from restaurants and vegetable oil are being used as feed material, given the treatment costs and low efficiency levels of the other feed sources.

Results

Itaipu's experience with this innovative process to produce biogas and biomethane has resulted in a number of benefits. The experience with the creation of the International Center has demonstrated the potential for this process to be replicated at an industrial level in other places. Continuous research and development activities generate valuable data for future applications and Itaipu is contributing to the dissemination of this knowledge.

Some specific results related to this activity include:

- Currently, there are 6 demonstration units, which summed up produce almost 5,000 m³ of biogas daily or 1,7 millon m³ yearly;

- The unit inside Itaipu alone has the potential to produce 15,000 m³ of biogas per month, and 7,500 m³ of biomethane, avoiding monthly emissions of approximately 700 kg of GHGs;

- Currently, 87 vehicles of Itaipu's fleet are operated with this fuel. As a by-product, 75,000 liters of biofertilizer are produced and used for gardens and lawns in the Itaipu grounds;

- The courses offered by CIBiogás, which cover technologies and processes to obtain biogas as an energy source, either thermal or electric, have trained over 1,500 people from 28 countries.

Inside the spiral case - Victor Azcona/Itaipu Binacional

5.

HYBRID ELECTRIC (SOLAR AND WIND) GENERATION SYSTEM

Solar panels in the Paraguayan Chaco/ Itaipu Archive

Objective and Description

Itaipu supported the installation of a Hybrid Electric Generation System (HEGS), for secure energy supply in isolated places, in the military base of Joel Estigarribia and in Pablo Lagerenza, both located in the isolated area of Chaco, in Paraguay. The system is based on solar photovoltaic and wind technologies, which have been providing reliable electricity to this facility. The installation exemplifies Itaipu's commitment to promoting the use of renewable energy particularly in isolated rural areas, where there is no access to the grid. The project was carried out by the Itaipu Renewable Energy Advisor Office, Paraguayan side, and the Itaipu Technology Park Foundation (PTI).

The HEGS has allowed electricity access to the facility on a 24-hour basis, drastically reducing the use of diesel generators which could only provide electricity for a few hours each day and could not cover electricity needs for refrigeration of food and medicines, and for communication. The HEGS has a remote energy monitoring system and, through the implementation of an efficiency improvement program and the use of electric vehicles, has reduced considerably the base's dependency on fossil fuels.

The system consists of solar panels associated with two wind turbines and a battery bank for specific use, with the support of a diesel generator for use in cases of high demand peaks and long cloudy periods.

The HEGS is also a research and demonstration place being used to study the potential for installing similar systems in other isolated communities of Paraguay in the future.

Related SDG 7 targets

This activity relates to Target 7.2 on increase substantially the share of renewable energy.

Challenges

One of the main challenges faced by Itaipu for the installation of the HEGS was related to the isolated location of the military base. The lack of proper roads in the area was a major difficulty for the transport of the equipment. In addition, the area lacked sufficient proper water for the completion of the civil construction works.

Lessons learned

The experience of Itaipu with the HEGS is considered very positive, resulting in important lessons learned. The combination of solar and wind technologies is considered the most appropriate for this energy system, given the climatic conditions of the region, and represents the least costly option.

The Remote Monitoring System is very practical and allows online monitoring and the development of charts summarizing the operation and performance of the plant on an annual and monthly basis. This information can be accessed through a dedicated website.

Results

The electricity generated by the HEGS has resulted in the satisfaction of important needs at the location. The communication system now allows a satellite internet connection that facilitates the coordination and logistics of the work.

Medicines are now being stored in refrigerators, improving the lives of the personnel and nearby isolated communities that sometimes are supported by this military base. The refrigeration is also used to store food and meats for considerable periods of time. Running water in the facility is now available resulting from electricity access at all times.

From the environmental point of view, fossil fuel consumption has been reduced to a minimum and, on average, about 23.8 tons of CO_2 emissions in Joel Estigarribia, and 22.9 tons of CO_2 emissions in Pablo Lagerenza are avoided on a monthly basis. The reliable and efficient operation of the HEGS has already provided sufficient savings and it is expected that the project will achieve its return on investment in less than 8 years.

The view from the Reservoir to the Production Building and the Paraná River
Victor Azcona/Itaipu Binacional

6.

ITAIPU'S ENERGY EFFICIENCY PROGRAM FOR ITS GENERATION OF ELECTRICITY

The Charge Dispatch Control Room at Itaipu Binacional - Victor Azcona/Itaipu Binacional

Objective and Description

In 2012, Itaipu adopted a model designed to improve the efficiency of its hydropower plant. The major objective is to achieve higher levels of efficiency by maintaining excellence in the integrated management of water and energy for the generation of electricity. It requires integrated and coherent work among the teams of hydrology, operation, and maintenance. The model has been named "Dance with the waters". It attempts to make the most of all the water that reaches the Reservoir for the generation of electricity (ITAIPU, 2018 a).

In addition to the availability of water in the Reservoir, three other factors are determinant for the plant to generate electricity: the number of generating units in operation, operating transmission lines and electricity demand in Paraguay and Brazil. The optimization in the management of these four areas is what allows for energy efficiency improvements (ITAIPU, 2016 b).

Everything begins in the Hydrology area, which maintains an uninterrupted monitoring of the behavior of the Reservoir, its tributaries, and rainfall in the Paraná Basin. The data provided by Hydrology is decisive for the decision-making of other areas related to electricity generation, which, within certain principles and limits, have the mission of providing the best use of water resources. The goal of the energy efficiency model is to provide excellent monitoring of the parameters of the Hydrology area.

The data acquired can be used to assess if the incoming water is sufficient or if the use of the Reservoir stock will be necessary. The scenario is also defined with the knowledge of the predicted and future conditions of the electrical systems of Brazil and Paraguay that can impact the Itaipu hydropower plant.

The data are captured automatically by 40 stations, which represent the Hydrometeorological Telemetry System (STH), and sent to a central station. The plant also uses data from meteorological systems, such as satellite imagery, radar images and the location of electric discharges, through agreements with the Paraná Meteorological System (Simepar) and the National Civil Aeronautics Directorate (DINAC) of Paraguay (ITAIPU, 2016 b).

The forecast goes to the planning area of the operation, which in turn receives, from ANDE[2] (in Paraguay), ELETROBRAS[3] and the National System Operator (in Brazil), the forecast of energy demand in both countries. The operation seeks, therefore, to adopt the maximum use of water to the times of greater consumption, ensuring high efficiency.

At the same time, maintenance actions and works that may involve machinery shutdown are also scheduled appropriately. To maximize efficiency, the maintenance is scheduled to occur on more adequate dates and within

certain limits, and can be advanced or postponed taking into consideration the best use of water (ITAIPU, 2016 b).

Typically, Itaipu operates with the availability of 18 generating units, while 2 units undergo maintenance. Among the 20 units, ten are in the 50 Hertz sector and ten are in the 60 Hertz sector. The flexibility adopted by the plant also implies using more water in one or another sector, depending on the scenario.

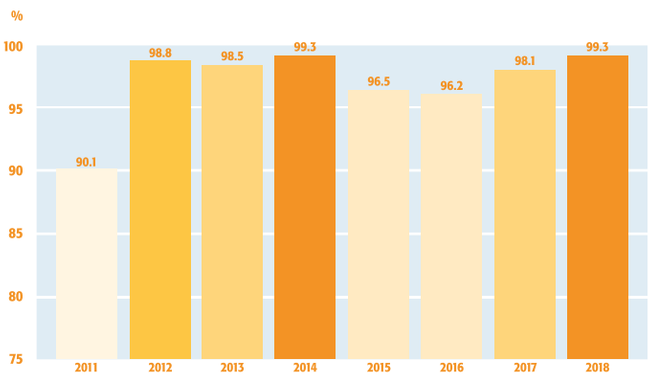
The optimal management of these areas and conditions by the teams of hydrology, operation and maintenance is what has allowed the generation of electricity by Itaipu to become more efficient since 2012 (ITAIPU, 2016 b).

The chart shows the Plant's Operational Capacity Factor (FCO from 2011 to 2018). This index measures how much water has passed through the plant and has effectively been transformed into energy. It is possible to observe that, in 2011, before the implementation of the new model, this ratio between production and available energy was lower than in the following years (ITAIPU, 2018 a; ITAIPU, 2018 c).

[2]National Administration of Electricity, responsible for the transmission and distribution of energy in Paraguay
[3]Electric power holding company, largest generation and transmission company in Brazil

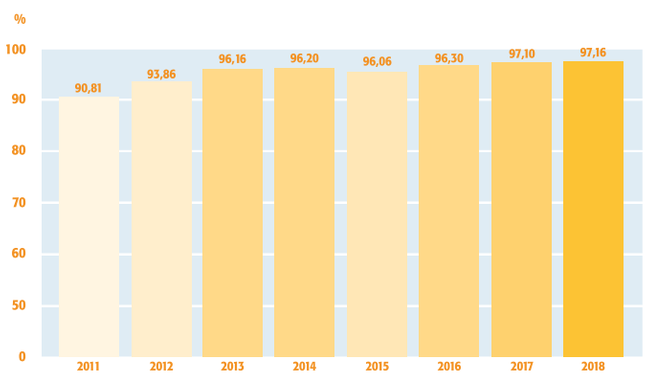
The International Board of Civil Consultants conducts technical inspections and analyzes auscultation data to assess the power plant's operation and dam safety conditions.
Alexandre Marchetti/ Itaipu Binacional

OPERACIONAL CAPACITY FACTOR



Source: ITAIPU, 2018 d.

AVAILABILITY OF GENERATING UNITS - ANNUAL



Source: ITAIPU, 2018 e.

In relation to the year 2018, the Plant's generation was 96,586 GWh, which represents its fourth best production year. With this production, it is possible to note that the best five production years happened since 2012, when the new model was implemented. In ascending order, the best production years were: 2017, 2018, 2012, 2013, 2016 (Clickfoz, 2019). The average factor of availability for 2018 was 97.16 for the plant's generating units during that year. This factor measures the percentage of time during which the generating units have remained in operation or have been available for the production of energy.

Another strategy of Itaipu that should result in efficiency improvements is the technological upgrade of the plant, with an investment budget of 660 million dollars over the next 14 years of work, considering two generating units per year. This action will be a benchmark in risk management control and production of digital and modern technologies that will replace equipment of the plant that, in some cases, still utilizes analog technology of the 1970s (ITAIPU, 2018 a).

Related SDG 7 targets

This activity relates to Target 7.3 on improving energy efficiency.

Challenges

Along with Itaipu's 35 years of experience in generation, there is continuous improvement of the models that project the behavior and the amount of water in the watershed. This activity represents a major challenge to Itaipu. The hydrometeorological bulletin is a key factor in the production planning.

The forecast goes to the operation planning area, which also receives from ANDE (in Paraguay), ELETROBRAS and the National System Operator (in Brazil) the forecast of energy demand in both countries. The Operation seeks, therefore, to adapt the maximum efficient use of water to the times of greater consumption.

Other variables influencing the production management come from the binational teams that supervise the operation of the machines and the entire plant in the Supervision and Central Control room. The generating units have a series of sensors that can trigger alarms, signaling some type of malfunction, such as an abnormal temperature rise. Binational teams have to assess the most efficient ways to solve the anomalies on the spot, while the machine is working, by scheduling the intervention for a moment of low consumption, or in emergency case, shutting down the machine.

Operation on medium voltage equipment
Alexandre Marchetti/Itaipu Binacional

Operator regulates flow of the pure water cooling system
Alexandre Marchetti/ Itaipu Binacional

Lessons learned

There have been many lessons learned throughout the years of operation. The synergy between the generating units, the transmission lines and the demand for energy are critical to keep on having a large production, even when the affluence of the Reservoir is below-average.

The year of 2018, for instance, was very atypical in terms of rain. There was a lot of rain in the beginning, but between April and September it was quite dry, which had an impact on the Reservoir's level and on production. In the historical average, since 1990, the year 2018 was only the 17th in affluence. Even so, the operational capacity factor in that year was 99.3 %, and Itaipu had the fourth best production mark in its history.

Such situations reinforce the fact that it is important to work together in order to ensure that equipment and systems, associated with energy production, are available according to the hydrological sign.

Another fact that became better due to the experience throughout the years was the improvement of the Annual Machine Shutdown Program. With this, the time that a machine used to be stopped for maintenance will reduce in 40 % yearly (cumulative reduction since 2013), which represents a gain of 117 days of available units to generate power (Clickfoz, 2019).

Results

In summary, the energy efficiency model adopted by Itaipu in 2012 (Dance with the Waters) has been very successful, allowing an optimum utilization of natural resources through the excellent management by the hydrology, operation and maintenance teams.

The implementation of this model has resulted in high levels of electricity generation in the last several years, and a World Record in 2016 with 103 million MWh of electricity generation. The positive results since 2012 translate into millions of tons of CO_2 emissions avoided by using hydropower.

The results also demonstrate higher water use efficiency, showing that the hydropower plant has been adapting to changing rainfall patterns from climate change.

Energy Efficiency Van

Itaipu's Renewable Energy Advisor Office invested in an educational tool in order to raise awareness in schools about the meaning of energy efficiency: it is the Energy Efficiency Van.

It is a project that consists of a mobile laboratory with various equipment, such as small devices that teach children and young people how electrical energy is produced; a meter that compares the consumption of an incandescent lamp with a low consumption lamp; a miniature house that simulates a home's consumption with the use of showers and electrical appliances, besides giant screens in which audiovisual materials or simple cartoons are exhibited picturing the savings in the use of energy.

The Energy Efficiency Van is used for training, promotion and dissemination of concepts on the safe and efficient use of energy and the importance of change in the habit of consumption of citizens, being able to establish a new way of thinking and acting in favor of the environment and the economic and social sustainability of Paraguay. Throughout the year, the Energy Efficiency Van was used in Congresses, Seminars, Workshops, Fairs and Exhibitions nationwide.

A similar van is part of the pedagogical circuit "science and sustainability in the squares" in Brazil, in which the itinerant van travels the municipalities of the area of influence, presenting, in an interactive way, how important issues, such as water, energy and sustainability relate to people's daily life. It also proposes commitments to sustainable actions.

Energy Efficiency Van - Ever Portillo/ Itaipu Binacional

Axis of the generating unit 18 - Víctor Azcona/ Itaipu Binacional

7.

ELECTRIC VEHICLE PROGRAM

Electric vehicle fleet - Alexandre Marchetti/Itaipu Binacional

Objective and Description

Itaipu Binacional has an electric vehicle program for the promotion and development of sustainable and innovative technologies related to electric mobility. The program promotes the exchange of information among the different sectors of society and the development of electric vehicle technologies at national level in Brazil and Paraguay.

Itaipu is also supporting teaching and research entities to foster research and innovation in technologies for the development of mobility solutions, promoting investment in energy infrastructure and seeking energy efficiency. The program includes the use of electric vehicles within the Itaipu hydroelectric power plant facility and in some cities, including Curitiba and Brasilia, in Brazil and Ciudad del Este and Asunción, in Paraguay.

The electric vehicle program includes a number of related activities that are part of Itaipu's sustainable development strategies. They include, among others:

- Study and development of sustainable electric mobility solutions;
- Infrastructure solutions for the supply of electric vehicles;
- Assessment of the possible impacts of electric vehicles in the electricity network;
- Studies of new business models for the mobility sector;
- Energy storage systems with batteries, applying the smart grid concept;
- Implementation of green routes: electric vehicle charging stations with photovoltaic energy that allow regular electric vehicles to travel between the biggest cities in Paraguay;
- Preparation of suppliers, focusing on the nationalization of components; etc.

Related SDG 7 targets

This activity is directly related to the Target 7.a of the UN 2030 Agenda for Sustainable Development, since it enhances international cooperation by collaborating with different national and international companies to promote the use of electric vehicles.

Challenges

Although there is great interest in electric vehicles worldwide, Paraguay and Brazil need to overcome many challenges for their development and commercialization in these countries.

The knowledge dissemination and technology transfer is a fundamental issue to expand the penetration of electric vehicles in both countries. Further studies in policies and cost reduction are necessary to create economic viability with the objective of eventual industrial production of electric vehicles in the local markets. The creation of partnerships with different stakeholders should facilitate this objective.

Lessons learned

The electrification of the transport sector will prove multiple benefits to society. The implementation of mass transportation, such as Metrobus (electric or hybrid), electric proximity train and purely electric or hybrid buses should be intensified.

It is essential to strengthen international cooperation to enhance the exchange of knowledge, as well as to promote government programs, in order to enable the promotion and diffusion of clean energy technologies.

Results

As a result of this activity, Itaipu Binacional is recognized as a reference in the electric vehicle sector, nationally and internationally. It owns and operates 106 electric vehicles, 86 in Brazil and 20 in Paraguay. It also has an electric truck for small loads (capacity 5 t) for urban use, purely electric minibuses, hybrid electric / ethanol bus, Marruá off-road vehicle; electric vehicle charging systems, energy storage system with sodium batteries, full knowledge of the national production technology of the sodium battery. In addition, Itaipu has the first manned electric aircraft in Latin America, and is implementing, with the Itaipu Technology Park, the first Green Route of electric vehicles charging stations with support of photovoltaic energy, in Paraguay.

Part of the electric vehicle fleet at Itaipu
Alexandre Marchetti/Itaipu Binacional

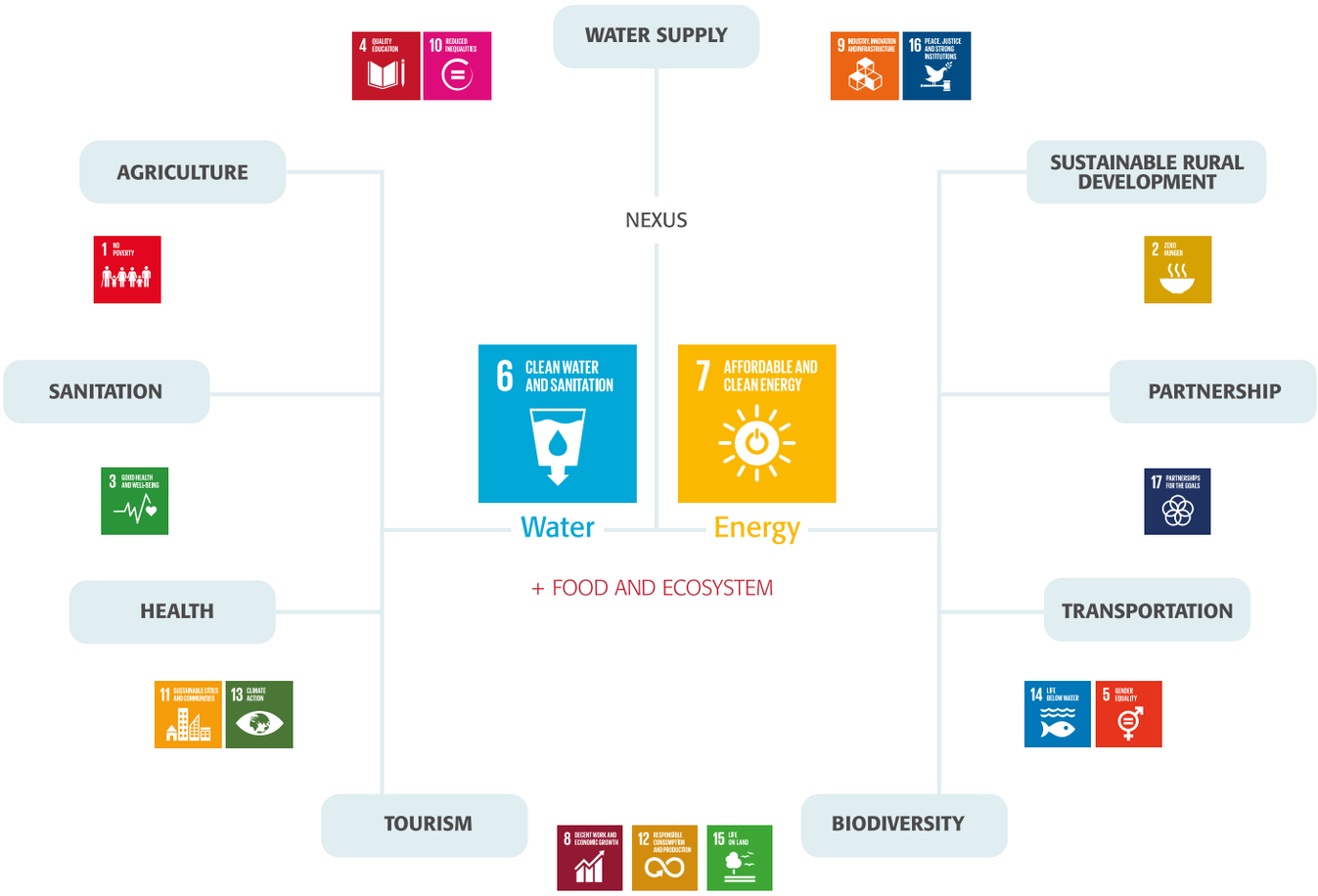
Dam´s foundation: the former Paraná River bed
Alexandre Marchetti/ Itaipu Binacional

INTERLINKAGES WITH OTHER SDGs

Sunset at Itaipu - Alexandre Marchetti/Itaipu Binacional

Our actions in the SDGs

Our approach - Integrated actions in the territory



The interlinkages between energy related activities (SDG7) and other SDGs are vast. One of the strongest interlinkages is related to water (SDG6), given the fact that water is the essential factor that allows the generation of renewable energy in the form hydropower at Itaipu.

The interlinkage of SDG7 is also very strong in relation to poverty eradication (SDG1), sustainable agriculture and food security (SDG2), climate change (SDG13), health (SDG3), education (SDG4), gender (SDG5) and economic growth (SDG8).

Another strong interlinkage is with respect to sustainable cities (SDG11) and partnerships (SDG17). There are also very interesting interlinkages between energy activities being led by Itaipu and the rest of the SDGs of the UN 2030 Agenda for Sustainable Development.

Side view of the dam
Maya Riquelme/Itaipu Binacional

CONCLUSIONS

The concrete dam and the Paraná River
Víctor Azcona /Itaipu Binacional

Itaipu Binacional has played a major role in creating long lasting prosperity in the region for over three decades, through the generation of reliable and clean electricity. Itaipu has also been a key element in the creation of awareness, among all stakeholders, of the need to protect the water and terrestrial ecosystems and in promoting sustainable development. The integrated approach to water management and territorial development while providing clean energy has translated into effective economic growth and improvement in social well-being.

The successful operation and management of the Itaipu Binacional hydropower plant has guaranteed access to affordable, reliable and sustainable renewable electricity to Paraguay and Brazil. In Paraguay, the benefits from Itaipu go beyond providing access to electricity to its population, given the economic benefits derived from electricity exports. In Brazil, the power plant is a main source of electricity, reaching populations far away from the region surrounding the plant.

Itaipu Binacional represents a major source of renewable electricity generation not only in Brazil and Paraguay, but also in South America. Its generation of clean electricity is avoiding the daily use of the equivalent of 550,000 barrels of oil, or 50 million cubic meters of natural gas. This represents a major worldwide contribution towards the mitigation of climate change. The emissions of CO_2 avoided are estimated at 87 million tons if it replaces coal or 39 million tons of CO_2 emissions if it replaces natural gas.

The energy efficiency programs currently being implemented by Itaipu have allowed record generations in multiple years demonstrating that Itaipu is not only the largest hydropower plant worldwide in terms of generation of clean electricity, but also one of the most efficient. The life span of the power plant has also been extended to over 180 years as a result of integrated management strategies of energy.

Partnerships among companies, government agencies, institutions and academia are fundamental for the success of Itaipu's actions. The support among these actors, through the participative community management directly linked to socio-environmental actions, promotes sustainable development and prosperity for future generations.

A summary of specific accomplishments resulting from Itaipu's energy related activities is illustrated in the diagram below. The diagram demonstrates the integrated and interconnected approach of Itaipu with respect to the social, economic and environmental dimensions of sustainable development.

7 AFFORDABLE AND CLEAN ENERGY

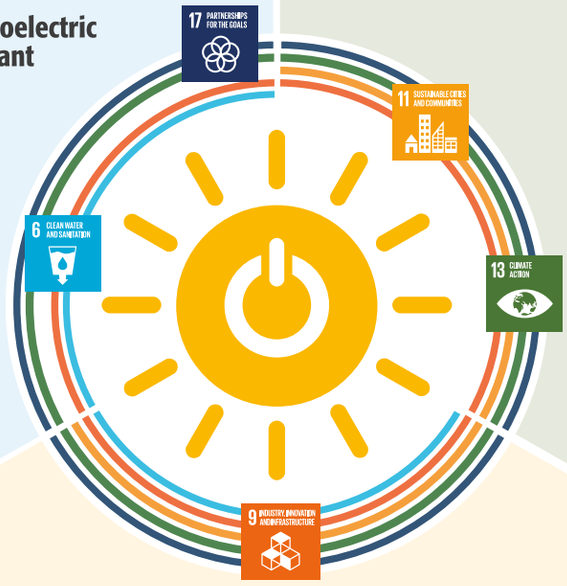
20
GENERATING UNITS
clean and renewable energy

Energy supply in 2018
15% BRAZIL
90% PARAGUAY

Fully electric minibus
Hybrid bus powered electricity and ethanol
Electric urban truck for light load
Electric utility car with 4x4 traction
First manned electric aircraft in Latin America

14,000 Mw
of installed capacity

The Hydroelectric Power Plant



103,098 GWh
World record in annual generation in 2016

EQUIVALENT TO
550,000 barrels of oil daily
50 million m³ of natural gas

AVOIDS THE EMISSION OF
87 million tCO_2e mineral coal
39 million tCO_2e natural gas

Sustainable Mobility

ITAIPU FLEET
106 electric vehicles - Avoids the emission of 23.8 tCO_2
87 biomethane vehicles

Energy storage system with sodium battery
Domain of domestic production technology of sodium battery

Other Renewable Energy Sources

International Center on Renewable Energy
Emphasis on biogas

SOLAR THERMAL PARK
Instalation of 56 solar heaters for 112 homes

6 units
of biogas generation
Produce annually
1,683,380 m³ biogas

-700 kg CO_2e
Monthly

Biogas Demonstration Unit
potential to produce 15.000 m³/month
SUPPLIES
87 corporate vehicles
PRODUCES
75,000 liters biofertilizer

Dissemination of knowledge
1,500 PERSONS TRAINED
28 COUNTRIES

Installation of photovoltaic systems
rural properties and remote communities of Paraguayan Chaco

Itaipu Hydroelectric Power Plant
Alexandre Marchetti/ Itaipu Binacional

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The Paraná River, the concrete dam and the transmission lines at Itaipu Binacional
Alexandre Marchetti/Itaipu Binacional

ITAIPU BINACIONAL

UNDESA–Itaipu Binacional
SUSTAINABLE WATER & ENERGY PARTNERSHIP

7

AFFORDABLE AND CLEAN ENERGY