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DISCUSSION
PAPER N°
IDB-DP-00900

October 2021

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**Pumped Storage
Hydropower**
International Forum



**Policy and Market
Frameworks
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Acknowledgement

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Overview of the region's electricity market

Latin America and the Caribbean (LAC) includes 33 countries. The electricity sectors are diverse, ranging from fully integrated and state-owned entities (such as Paraguay), to deregulated markets with complete private participation in generation, transmission, and distribution (such as Chile), and mixed models (such as Brazil). LAC has a very large potential for conventional and non-conventional renewable resources. Nonetheless, until recently, only hydropower has been exploited at a large scale. The region historically has been a global leader in hydroelectricity generation. With almost 200 GW currently in operation, the region has the largest share of hydroelectricity generation in the world, and the percentage has remained above 45% during the last 5 decades. However, it has been continually declining since 1993 as countries transition to a more diversified portfolio mix, with natural gas playing an important role in recent decades, and variable renewables gaining importance recently¹.

It is expected that electricity demand in the region will double from the current 1550 TWh to 2800–3500 TWh by the year 2040, which represents an annual growth rate of 2.7%–3.6%, depending on the growth scenario. The Southern Cone² accounts for 57% of the total power demand and is expected to continue to be the largest consumer in coming decades, particularly influenced by the weight of Brazil. Central America³ and the Andean Zone⁴ follow as the second and third consumers in the region, with higher growth rates than the Southern Cone's large countries. Although no subregion will dominate the cumulative increase in electricity supply, demand in the Andean Zone is expected to rise at a slightly faster pace, with an average annual growth rate of 4.7% from 2014 to 2040, followed by Central America with 3.9%, compared with an average of 3.2% for the whole LAC region⁵.

In the next decades, it is expected that the growth in supply will be dominated by the development of cleaner options, particularly variable renewable sources, as in most countries these technologies are already competitive and are being installed to reduce fossil fuel consumption. Therefore, a change in the generation matrix is expected, with hydropower and natural gas still dominating, but with a growing participation of solar and wind power. A conservative scenario projects 19% of solar and wind generation by 2030, with hydropower still providing 46% of electricity⁶. More aggressive scenarios for the region envisage a larger participation of renewable sources, in order to achieve net zero emissions by 2050. The evolution of the power sector in the region will be based on a combination of large-scale and centralized power plants, distributed generation, and even isolated microgrids. Storage technologies will be crucial to enable the management of the intrinsic variability of some renewable generation (wind and solar), particularly in scenarios where there is a need to reduce fossil fuels used for base generation. Pumped Storage Hydropower (PSH) technologies⁷ are an attractive alternative, given the region's hydropower potential, existing installed capacity, and technical knowledge.

Current status of pumped storage & development potential

In 1939 the first PSH facility was inaugurated in Brazil, and three additional plants were built and entered commercial operation before 1955. Since then, no other PSH facilities were built in LAC, except for Argentina that developed Los Reyunos (224 MW), between 1978 and 1983, and the Río Grande PSH plant between 1970 and 1986. The latter is a reversible plant with the highest capacity in South America. In the same period there was a great development of hydroelectric plants with large reservoir storage capacity in the region and the incorporation of PSH was not considered necessary. Consequently, there is only 1 GW installed of PSH power plants in Argentina (750 MW and 224 MW) and Brazil (20 MW), currently in operation.

However, the region is seen as one of the most attractive emerging markets for energy storage development. The expected growth in variable renewable energy generation, rapidly growing population and associated energy demand, and the need for higher flexibility

¹ Yépez-García, R. A., Hallack, M., Ji, Y., & López Soto, D. (2018). The Energy Path of Latin America and the Caribbean. IDB Monograph 683

² Brazil, Argentina, Chile, Paraguay and Uruguay

³ Belice, Guatemala, Honduras, Costa Rica, Nicaragua, Panamá and El Salvador

⁴ Venezuela, Colombia, Perú, Ecuador and Bolivia

⁵ Yépez-García, R. A., Hallack, M., Ji, Y., & López Soto, D. (2018). The Energy Path of Latin America and the Caribbean. IDB Monograph 683

⁶ Paredes, J. R. (2017). La Red del Futuro: Desarrollo de una red eléctrica limpia y sostenible para América Latina. Banco Interamericano de Desarrollo.

⁷ IDB (2020) From Structures to Services: The Path to Better Infrastructure in Latin America and the Caribbean. Cavallo, A. Powell, & T. Serebrisky (Eds.) Inter-American Development Bank.

of power systems, are among the major factors driving interest in energy storage technologies throughout LAC, PSH among them. Energy storage technology can provide services at the large scale, for example: bulk energy services, integration services, ancillary services, transmission and distribution services, and customer energy management services.

This is particularly relevant for PSH, as the technology is already mature and reliable. PSH could be developed either through green-field projects or through adaptation of existing hydroelectric power plants to PSH. Although conventional hydropower potential does not automatically define PSH potential as well, it does provide an indication to further assess such potential, thus it is of value to mention that the untapped potential for hydropower is estimated between 250 to 500 GW in the region⁸. Moreover, there are around 130 GW of existing hydropower plants that will need to be modernised in the coming decades, and some of them could have the potential to be adapted to develop PSH⁹.

Regarding the different regions of LAC, both South America and Central America are among the regions with the greatest energy storage potential in the world, with 7000 to 8000 GWh per million people each¹⁰. However, this development potential is multifactorial, and the region shows advantages and disadvantages. Relative advantages include the favourable geography with great slopes and space for the location of reservoir, and the growing development of variable renewable energy projects. However, the electricity market environment and its current regulation could be limiting the region's possibilities to promote pumped storage hydroelectric power plants.

PSH projects are not listed in public investment portfolios, or in planning portfolios. There are only very specific initiatives, usually promoted by the private sector. In Chile, for example, there is the Espejo de Tarapacá pumped storage hydroelectric project, which already has environmental permits; and in Peru, a mining company has developed the project profile of a 100 MW pumped storage hydroelectric plant with an estimated CAPEX of USD\$ 145 million. In the rest of the countries, except for Argentina where a PSH plant has been operating for years, project development is not reported.

It can be noted that in several LAC countries, changes in energy sector regulations can take a long time to be implemented. Therefore, a first step for PSH development could be to identify a solution that could allow an attractive environment for investors but avoiding any major changes in regulations. In the case of countries where the transmission system has been deregulated, but there is a central operator of the grid, a possible way to introduce PSH could be to label it as a transmission asset, to be dispatched by the grid operator in the benefit of an optimized, safe, and reliable operation of the grid. In that scenario, the private investors would be paid in the same way as the transmission line owner, through a fix monthly fee, associated with target metrics of availability and performance. Regional coordination and knowledge exchange could be useful to develop regulations that enable storage and hydro-pumped storage technologies.

Challenges, barriers and emerging opportunities for pumped storage development

There are several reasons behind the lack of development of PSH in LAC. Firstly, there are many hydroelectric power plants with large reservoirs that provide robust energy storage capacity. The region has developed many major hydroelectric power plants in the past decades, with reservoirs that allow short- medium- and long-term energy storage, and there is a still significant hydroelectric potential remaining that may allow the construction of new hydroelectric plants at competitive prices, providing additional storage for the systems¹¹. Moreover, retrofitting projects might also extend the life of the existing large scale power plants associated with these reservoirs, hence, enabling the power systems to still have storage capacity available.

⁸ Alarcón, A.D., "El sector hidroeléctrico en Latinoamérica: Desarrollo, potencial y perspectivas (The hydroelectric sector in Latin America: Potential development and future perspectives)". Interamerican Development Bank, Washington, DC, USA; 2018

⁹ Martins Nogueira, M. F., and Alarcón, A., "Impacto de las paradas en la generación hidroeléctrica de Brasil", Interamerican Development Bank, Washington DC, USA; 2019.

¹⁰ Stocks, M., Stocks, R., Lu, B., Cheng, C., Nadolny, A., & Blakers, A. (2019). A global atlas of pumped hydro energy storage. Australian National University. Las Accessed 13-03-21: <http://re100.eng.anu.edu.au/global/>

¹¹ All new development must consider environmental and social best practices, and therefore, large reservoirs are less frequent in new greenfield projects.

Secondly, there is a lack of adequate regulation for energy storage in the region. There are few cases of energy systems with significant differences between peak and non-peak pricing. Also, most regulatory frameworks lack capacity payments that could give economic feasibility to PSH development. Additionally, markets for auxiliary or complementary services, which are necessary for this type of project to be competitive, are non-existent.

Developers may not be willing to invest or may require a large return on investment to develop a project with high risk arising from unclear regulation, with an unclear revenue stream, and that they are not well familiarized with. So, a regulatory solution that makes PSH an attractive investment option for most developers should be identified. However, the requirement of major changes in the power sector regulations may be a great barrier for developing any storage projects, including PSH. So, it is recommended to identify first the lowest impact way of introducing storage into the current grid regulations, to accelerate its development.

Another barrier is related to limited local experience and knowledge of energy storage. Although PSH is the only proven, and by far the most widely adopted, technology for large scale energy storage in the world, the knowledge regarding opportunities in the region is lower than that of other technologies, hindering its massive potential. PSH projects are not listed in public planning portfolios and the information related to access to affordable financing is not widely available. Other energy-based projects, especially renewables, are currently competing with the funds that could be used to develop PSH projects as well.

Finally, there are potential barriers related to social and political opposition which are of similar nature to those that are related to greenfield hydroelectric plants. There is a challenge regarding the lack of involvement of the affected stakeholders in the appropriate stages of the planning process. There is a need to develop socially responsible projects to mitigate these types of barriers. If this is not considered, political acceptability can become a major factor that may slow down the development of the technology. Moreover, other storage technologies that are perceived to have less social and environmental impacts might be favoured in planning processes.

Regarding opportunities, pumped storage hydroelectric plants could be promoted if the following issues are considered. Firstly, there are geographic advantages, such as coastal and mountain cliffs in many of the countries, which provide elevation differences necessary for hydroelectric generation. Besides, the proximity to the sea in the many of the countries makes it possible to have water resources for intake and discharge and may even provide desalination services. In third place, an enhanced regulatory framework that enables more accurate price signals would probably encourage the development of the technology. Finally, the construction of a PSH project planned for Chile is expected to show both investors and society the benefits of this type of technology.

Recommendations

For Governments:

1. Improve knowledge about PSH technologies in the countries, across different actors of the sector (utilities, regulator, planners). This would help close the information gap and include PSH as an alternative in the energy planning process.
2. In the planning process, consider the expected future energy mix and grid expansion, especially the increase of variable renewable investments, and the inclusion of PSH as a potential technology that could be stimulated as complementary investment, in the form of joint facilities.
3. Identify and assess site-specific potential to build a PSH project pipeline that could be included in the planning process.
4. Evaluate if existing hydropower facilities could be converted to PSH, in modernization projects.

For Regulators:

1. Develop a minimum set of regulatory rules and conditions that would enable the different type of services that PSH can provide and assess for the applicability in the country.
2. Conduct official assessments on different available regulatory regimes and revenue models for energy storage and PSH plants: cost-of-service, direct-participation, and behind-the-meter (potentially applicable for some very large electricity consumers).
3. Consider if flexibility services could be eventually sold in “competitive” wholesale markets (energy, ancillary services, etc.), if markets rules could eventually allow storage services to compete in a non-discriminatory manner with other services.
4. Review the availability and level of development of markets and transparent prices for ancillary services, considering market signals and schemes for storage.
5. Review the existence of current incentives and standards which could be specifically modified for PSH and other energy storage technologies, considering its impact in generation (renewable generation) and transmission (grid stabilization).
6. Analyse if there are constraints to develop comprehensible business models, including multiple services (ancillary services, power, energy).
7. Review the regulation of energy networks, as storage services may avoid the use of “regulated” networks. Consequently, review if current network rules would allow them to compete in a technologically neutral manner (e.g., utility-scale storage vs. transmission upgrades).
8. Consider whether it would be possible and reasonable for the transmission system operator (TSO) to be a potential owner and/or operator of a PSH investment (given the aggregate information it holds, and economies of scale, to maximize intermittent renewable generation).
9. Consider the impact of potential vertical integration, due to new PSH investments, on previous contracts with generators and TSOs.
10. Identify the mechanism that shall require the least changes in the existing sector regulation to speed the process of implementing PHS.
11. Consider which regulatory solution could make investment in PSH projects more attractive for private investors and with better financing conditions (reducing the risks for investors).

For System Operators:

1. Include storage and PSH in planning exercises to support renewable energy development.
2. Update System Operation codes and regulations to include the possibility to include PSH.

For Utilities:

1. Consider and include PSH as a system/network solution when conducting planning assessments, when possible, and if it is allowed by regulation.

2. For hydropower utilities, evaluate the possibility to upgrade existing hydropower assets to PSH when possible (and following a cost benefit analysis).

For Developers:

1. Apply the sector best practices in the development of PSH projects (at least, the Hydropower Sustainability Assessment tools, and the IHA - ESG tool)

