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New challenges for the water and energy binomial: special reference to the case of reversible hydroelectric plants and their current momentum in Spain

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Abstract: The relationship between water and energy is bidirectional and highly interdependent. Water is essential for energy production, while energy is critical for the whole water cycle, including urban water supply, sanitation, purification, and irrigation. The global energy crisis and water scarcity have posed severe challenges to the traditional hydropower sector. As a clean and stable renewable energy, hydropower accounts for 17%–18% of Spain's energy mix, but its development is restricted by decreasing water availability and climate change. Against this background, Spain's Law 7/2021 on *Climate Change and Energy Transition* strongly promotes reversible hydroelectric plants, which can serve as large- scale energy storage and improve the efficiency of water use. This paper analyzes the definition, types, and operating mechanism of reversible hydroelectric plants, as well as the relevant legal framework in Spain, involving water concessions, third- party rights, environmental protection, and administrative authorization. It points out that the key to further developing such plants lies in improving the supporting legal system to ensure legal certainty for investors and balance the goals of energy transition, water resources management, and environmental protection.

Key words: water- energy binomial; reversible hydroelectric plants; pumped storage; energy transition; water law; Spain

1 Introduction

The relationship between water and energy is bidirectional and characterized by an increasingly clear and evident interdependence. Water is necessary for energy production, and energy is fundamental for almost any process related to water. Energy consumption is essential throughout the entire water cycle. From the urban water cycle (supply, sanitation, and purification) to water management for irrigation, energy is indispensable to harness and utilize water. It is estimated that 8% of global energy is consumed in water treatment. On the other hand, water is essential for energy production. 15% of the water consumed worldwide is used for energy generation. This interdependence is therefore more than evident at the global level.

Energy is a decisive factor for access to water and sanitation services. In the area of urban water, the cost of energy is one of the components that most influence the final price of water production and distribution. Therefore, in an environment where energy prices are rising steadily, the production costs of urban water are increasing. Under a regime of regulated prices, the extra cost for the urban water cycle has led to numerous problems regarding price reviews in water contracts, which cannot always be implemented. This has negative consequences both for compliance with the European cost-recovery principle and for ensuring the necessary investments in the infrastructure on which the urban water sector depends.

On the other hand, water is not only essential for hydropower generation. The production of other energy sources such as nuclear power also relies on water to cool their systems. In the summer of 2022, rising river water temperatures severely hampered the cooling operations of nuclear power plants across France, which in turn further undermined national energy security.

The interrelationship — and even mutual dependence — between water and energy has become increasingly evident and pressing in recent years. The ongoing energy security crisis, particularly in Europe, stems from the 2022 energy crunch. This crisis was triggered by multiple factors including export curbs imposed by China, the conflict in Ukraine, and skyrocketing coal and natural gas prices. As Europe's energy system remains heavily reliant on non-renewable sources — which accounted for 57.8% of the overall energy mix in 2022 — electricity prices surged dramatically. Despite a record 14% expansion in renewable energy capacity in 2023, rising energy demand pushed fossil fuel consumption up by 1.5%.

2 Water as a direct source of energy generation: hydroelectric power in the context of a "water crisis"

Referring to the case of Spain, in 1940, 92% of the energy came from hydroelectric sources. Currently, with a larger population and, above all, with much higher energy demands than at that time, hydroelectric power production represents between 17 and 18% of the total energy produced in the national energy mix[i].

Hydropower is the cleanest, most efficient and most reliably supplied renewable energy. Provided there is sufficient water, it is not subject to external factors unlike solar and wind power.

The problem, however, is that we are living in a time of crisis for global water security. Although the amount of water on the planet remains the same, its current form and uneven distribution constitute factors of uncertainty that do not favor water security. But the most significant problem is related to the continuous and progressive increase in population. According to the UN, by 2050 a quarter of the world's population will live in countries with a chronic lack of clean water. Global demand for freshwater will grow by more than 40%, mainly due to population growth, which is projected to reach 8.5 billion in 2030, 9.7 billion in 2050, and 10.4 billion in 2100. This population increase necessarily entails ever-increasing food needs, which are the primary driver of global water consumption. According to FAO data, agriculture accounts for 70% of global freshwater consumption. In Spain, food represents approximately 80% of a consumer's personal water footprint (6,700 liters per person per day). Therefore, a greater volume of water will be needed for food production, consequently impacting other uses such as energy production.

Increased energy demand and a growing population in a context of climate change that also entails a decrease in water availability in the medium or long term due to increased temperatures and altered rainfall patterns.

In Spain, the turning point in recognizing the importance of the water-energy nexus was *Law 7/2021 on Climate Change and Energy Transition (LCCTE)*. This law, as part of European energy policy, aims to reduce and ultimately eliminate energy production from carbon sources, primarily fossil fuels. Therefore, this legislation underscores the urgent and essential need to definitively promote renewable energies by more effectively integrating them into the energy mix. The objectives of decarbonization, reduced external energy dependence, and security of supply can be achieved by boosting the contribution of renewable energies.

We are therefore faced with a dilemma. We need to scale up renewable energy, including hydropower, yet less water will be available for uses other than urban water supply and food production. For Spain and many other regions, a viable solution lies in reversible hydropower plants, which are promoted under Article 7 of the *Climate Change Act*. This legal provision also addresses power generation within the urban water cycle, aiming to tap into its often underrecognized and underutilized potential.

3 Hydropower from reversible hydroelectric power plants

Article 7.1 of the *2021 Climate Change and Energy Transition Act* establishes that "In order to meet the renewable energy objectives set out in this *Act*, new concessions granted, in accordance with the provisions of water legislation on the public water domain for the generation of electricity, shall prioritize support for the integration of renewable technologies into the electricity system. To this end, pumped-storage hydroelectric plants shall be promoted in particular, provided that they comply with the environmental objectives of the water bodies and the ecological flow regimes set out in the river basin management plans and are compatible with the rights granted to third parties, with the efficient management of the resource and its environmental protection."

As can be seen, this is a strategic commitment, firstly established by a law, which has subsequently been developed through reforms to water legislation and the approval of plans and projects that have sought to materialize this firm commitment to pumped-storage hydroelectric plants. This foundational law certainly aims to safeguard two rights or legal assets requiring protection: the environmental protection of water (including ecological flows) and the pre-existing rights of third parties, which cannot be violated or altered by this new, enhanced renewable energy regime derived from pumped-storage hydroelectric plants.

For its part, Section 3 of this provision refers to a renewable energy source that remains underutilized to date, namely electricity generated from the urban water cycle. The provision explicitly states: To drive technological innovation in renewable energy and help attain the goals set forth in this Law, the use of water flows from urban water supply and sanitation systems for power generation shall be promoted to meet the internal demand of the urban water cycle. Such practice shall be carried out only where technically and economically feasible and where the basic functions of the aforesaid systems can be fully guaranteed.

Spain has 1,350 hydropower stations. Of these, 1,200 are small hydropower plants with an installed capacity of less than 10 MW, accounting for merely 12% of total hydropower generation. Accordingly, the remaining 150 plants produce 88% of the annual hydropower output. Hydropower refers to electricity generated by converting water power into electrical energy via the rotation of turbines at hydropower facilities. There are three main types of hydropower stations, which will be briefly outlined below.

a) Run-of-river power plants are those in which a portion of the river's flow is captured to drive the turbines and then returned to the river, taking advantage of its natural velocity. There is no storage capacity; the installed capacity is small and has little environmental impact.

b) Reservoir power plants. In this case, we start with the existence of a reservoir, which can be natural (a lake, for example) or, more commonly, created by the construction of a dam. The water is transported to the turbines through pipes and then returned to the river's normal course. These are large-scale power plants. It is possible to control electricity production as long as the reservoir contains water. They have a high environmental impact due to the need for extensive infrastructure and the disruption of the river's natural flow.

c) Pumped storage or reversible power plants. This type of power plant is the major national focus and can help overcome the contradiction between the need for greater renewable energy from water and the decreasing availability of this resource.

Pumped-storage hydroelectric plants, also known as reversible plants, have an upper reservoir upstream and a lower reservoir downstream. These reservoirs act as a kind of battery for the system. During periods of peak electricity demand, water from the upper reservoir is released to generate electricity, while during periods of lower demand, water from the lower reservoir is pumped back up to the upper reservoir for storage until it is needed again. This pumping operation consumes electricity. This model provides a high degree of system reliability.

These types of hydroelectric power plants have two reservoirs located at different levels. When the daily demand for electricity is at its peak, these plants operate like a conventional hydroelectric plant: water falls from the upper reservoir, turning the turbines, and is then stored in the lower reservoir. During off-peak hours, the water is pumped back to the upper reservoir to repeat the cycle. This type of plant uses water resources more efficiently.

In turn, reversible hydroelectric power plants have two modes: A) pure pumped storage (pumping is always required) and B) mixed pumped storage (pumping is not necessary as there are natural inflows to both reservoirs). There are also other types of reversible power plants, although they are less common or more technically challenging to install. I am referring to marine hydroelectric plants instead of river-based ones. This type of plant has great potential in countries with extensive coastlines, such as Spain and Chile. However, these plants face problems such as corrosion caused by seawater, as well as other environmental issues. Finally, as mentioned earlier, there is the possibility of power plants integrated into water networks, such as drinking water distribution systems, irrigation and navigation canals, pressurized pipelines, or wastewater treatment plants.

The Integrated National Energy and Climate Plan (PNIEC) 2021–2030 aims to double the installed pumped-storage capacity by 2030. Beyond technical matters, this target must be achieved through a thorough review and adaptation of the current legal framework for hydropower. Several new scenarios are proposed that must be integrated into existing water and energy legislation, or some reforms should be put forward if necessary.

The legal problems that arise in order to achieve this objective of promoting reversible power plants are of two types and have to do with whether we are dealing with "normal" hydroelectric power plants that are converted or transformed into reversible hydroelectric power plants or whether we are dealing with the case of hydroelectric power plants that are built anew.

Before briefly outlining the legal issues raised by each type of hydropower plant, I will first explain in basic terms the regulatory framework applicable in Spain to this form of energy production. In this regard, we may state that there are three principal laws corresponding directly to the three regulatory sectors involved: water, energy, and the environment. These are: the *Water Law* (and its Regulations on Public Water Domain), the *Electricity Sector Law*, the *Environmental Impact Assessment Law*. Three administrative and environmental control instruments are also required: two administrative energy permits (operation of power generation facilities and grid connection), one title for the use of public water domain (normally a concession), an environmental impact statement for these installations.

The implementation of new reversible hydroelectric power plants can place us in several situations:

a) Applications for the implementation of reversible uses for which the construction of new hydraulic works or infrastructure such as reservoirs, dams or canals would be required. Starting from 0.

b) Implementation of new reversible uses based on existing state-owned infrastructure (upon application from private entities or through public tenders organized by the public administration).

c) Applications for the deployment of new reversible hydropower facilities on existing reservoirs or infrastructures that are under concession (private reservoirs), submitted by parties other than the current operating concession holders of the said facilities.

d) Applications for the deployment of new reversible hydropower facilities on two reservoirs or ponds located outside the public water domain.

When converting conventional hydropower plants, various scenarios and application types may arise. Before elaborating on these two scenarios, it should be clarified that conversions herein mean existing hydropower concession holders seek to modify or extend their concessions to operate the facilities as reversible hydropower plants. Two main types of conversion applications can be distinguished:

a) Applications from existing hydroelectric concessionaires seeking to increase production beyond that obtained with current facilities, through the improvement or expansion of the existing facility.

b) Applications submitted by concession holders to increase production by adding new facilities that are independent of the existing ones on the same reservoir awarded to them for operation.

These are the situations we may encounter, and in the absence of prior regulation or legal provisions, the solutions we have arrived at are set out below. Above all, as required by the *Climate Change Act*, such new facilities must be made compatible with third parties' pre-existing rights. Summarized in outline form, the real-world cases currently arising across Spain are as follows:

1. Pre-existing rights situations

a) Water concession rights of holders holding valid hydropower concessions

The incumbent concession holder is the party proposing to expand or upgrade its water development via pumped-storage reversible facilities. Two subcases apply as follows:

i) The holder holds an exclusive private water-use concession for power generation at a non-reversible (run-of-river or dam-toe) hydropower plant. The preferred solution consists of amending the existing concession to convert the conventional plant into a reversible pumped-storage facility, in accordance with the procedure set out in Article 143 and subsequent provisions of the *Public Hydraulic Domain Regulation*. Neither the concession's purpose nor the authorized water flow changes; the new equipment merely constitutes technical modifications to the original facility.

ii) The concession holder holds a water-use concession linked to a "private" reservoir which the holder built to implement the concession (private hydraulic works). It is established that the "affected river stretch" – an essential defining feature of the concession – does not encompass the entire reservoir but only the intake point, and multiple intake points may exist on one single reservoir. Since the concession remains with the same holder, a concession amendment would be issued to cover the new facilities.

In both scenarios, where conversion entails costly investment in new infrastructure, the appropriate measure is to restore the concession's economic balance. The additional revenue generated from increased output may offset such expenditure; where this proves insufficient, an extension of the concession term may be granted.

iii) Cases where a third party (other than the existing concession holder) applies to build a reversible pumped-storage hydropower plant (CHR) on a concession-awarded reservoir with privately owned hydraulic works.

In this case, a new concession must be processed in accordance with Article 104 and subsequent provisions of the *Public Hydraulic Domain Regulation*. Obviously, the applicant's rights need to be coordinated with the pre-existing rights of the incumbent concession holder. Since the defined scope of the "affected river stretch" differs from that of the "intake point", no legal incompatibility arises between the two concessions that would justify rejecting the application for the new concession.

Ultimately, the State may enforce compatibility through ex officio modifications and compensation (Art. 96.3 Regulation of the Public Water Domain).

b) Affected rights of other concessionaires (excluding hydropower- use concessions).

Except in cases of double storage, water used for reversible pumped-storage hydropower plants (CHR) is non- consumptive use (a matter of ongoing technical debate), so associated conflicts remain limited. Available remedies: a) Secure a private agreement with affected parties to obtain approval for concession amendments or new concessions; b) Apply Article 90.2 provisions on compensation, costs borne by the beneficiary; c) Impose civil liability and cost recovery via higher water royalty or additional terms attached to the concession; d) Expropriations

2 Position regarding new CHR concessions (no pre- existing water rights).

In this scenario, the procedure provided under Spanish law is set forth in *Article 104 of the Public Hydraulic Domain Regulation*: project approval jurisdiction. Where the concession concerns a state-owned or revertible reservoir and its exploitation, access may be granted via public tender in accordance with Article 132 of the Regulation.

4 Conclusion

The potential to enhance the contribution of hydroelectric power to the energy mix in the context of a water crisis necessarily relies on the technology of pumped-storage hydroelectric plants. One of the main challenges to achieving this objective is the lack of a sufficiently developed legal framework to provide legal certainty for investors. Therefore, it is essential to create clear rules, agreed upon with the sector, so that this economic sector truly has the stability necessary for its development. Regulation in such sensitive economic sectors as energy in general, and renewable energy in particular, must be carried out in a very balanced manner and with the sector's consent. The State must carefully measure and calculate the instruments for promoting renewable energies to avoid sudden changes in the rules of the game that lead to a situation like the one experienced in Spain in 2014, where the remuneration system changed radically and generated flight in investments and condemnations, especially in international instances, which have not yet been satisfied and are causing no small problems for the Spanish State.

[i] The PNIEC (National Integrated Energy and Climate Plan) reduces the representation of hydroelectric power in the national energy mix from the current 17% to 15% by 2030.