



**Pumped Storage
Hydropower**
International Forum



**Policy and Market
Frameworks
Working Group**

Europe

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Lead authors

Sofia Siachou (PPC, Greece), Santiago Rivas Navarro (Alpiq, Switzerland)

Contributors

Ministry of Environment and Energy/Greece, Independent Power Transmission Operator/Greece, Tron Engbrethsen & Olav Hølland (Statkraft AS), Terna S.A/Greece, EDF/France, Swiss Federal Office of Energy, Peter Bauhofer - TIWAG/Austria, Gundula Konrad – Verbund/Austria

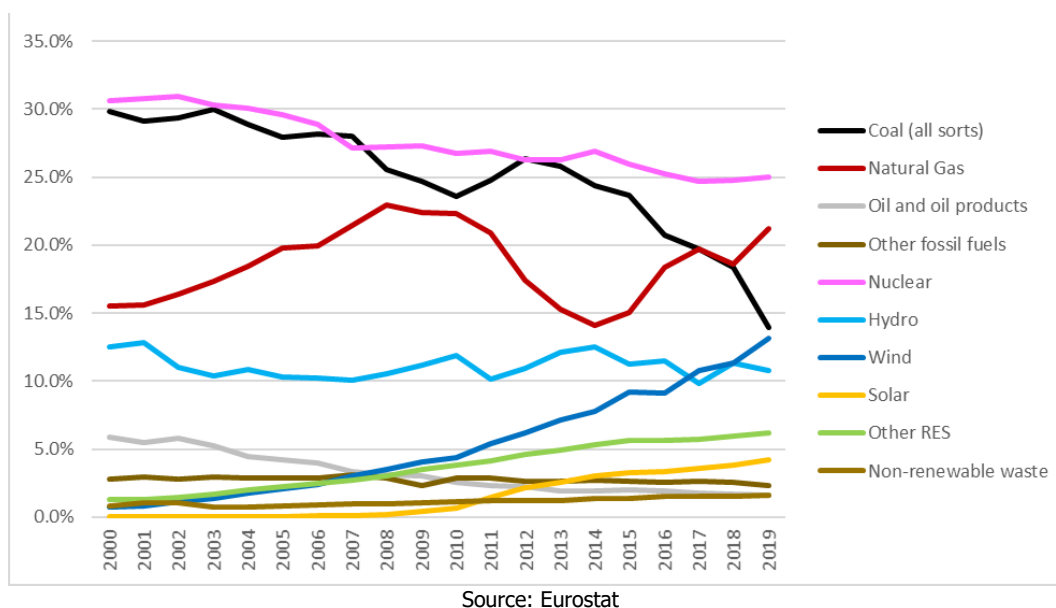
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Overview of the European electricity market

The European electricity mix has experienced significant and disruptive changes since 2000: oil, coal and nuclear, which used to be the dominant sources of generation, have been steadily replaced by natural gas and renewable energy sources (RES) (source Eurostat). While nuclear generation still keeps a sizeable share, the most polluting technologies (i.e., coal) will be progressively phased out in most European countries (e.g., 2022 in France, 2025 in Italy, 2038 in Germany, 2028 in Greece) with significant coal installed capacity only in some Eastern European countries (i.e., Poland, Czechia).

Figure 1 Share of power Generation per fuel (EU-28)



The share of renewable production has grown from 14% in 2010, mostly hydro, to 34% in 2019, with wind having the largest increase. The EU's objective for renewable production in 2030 is 65% of power generation, and close to 100% in 2050. Moreover, RES is expected to be the major domestic source of power as early as 2025. For renewables integration, and to bring about a successful energy transition, electricity storage will be crucial, and particularly pumped storage hydropower.

The main challenges of the energy transition are achieving complete decarbonisation and increasing energy efficiency. For this, transportation, heating and industrial sectors will likely become more "electrified". Electricity will have to be mostly produced from renewable sources, particularly solar and wind, which have the biggest potential, but both are non-dispatchable and their profitability suffers from their own cannibalization effect. High renewable energy penetration power systems require large flexibility to cope with steep ramp-ups, sudden production changes, lack or surplus of renewable resource (e.g., wind or sunlight).

In order to support and promote the expansion of RES, Governments have adopted a series of measures: capacity auctions, simplifying and speeding up the licencing framework, ensuring optimal integration of RES in electricity networks, geographic planning in order to increase the number of RES projects. Of utmost importance for RES success is the need for increased system flexibility and the development of electricity storage technologies¹.

¹ Until recently, RES had not considered storage options like PSH. Now several, including Portugal and Germany, have begun to link at least partially RES with storage in their RES support mechanism (mainly auctions), to enable RES integration.

All countries are planning a significant increase of the installed capacity in such technologies, pumped-hydro storage particularly (see table 1 on national storage targets), but current market conditions prevent the construction of new PSH plants. Several national measures are under discussion, such as capacity remuneration mechanisms, but specific PSH remuneration mechanisms should be created.

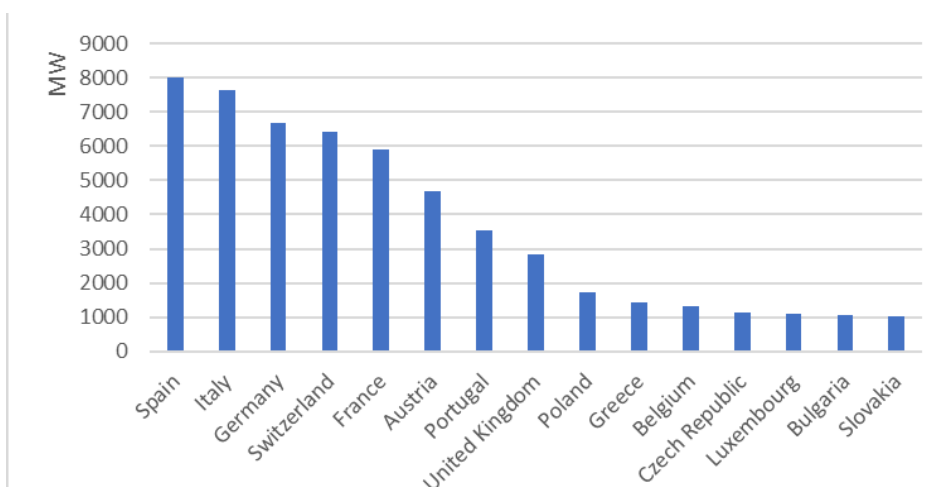
Table 1 National storage targets in Europe

Government	Storage target/ identified need
France	French "Programmation Pluriannuelle de l'Énergie" forecasts additional +1.5 GW of PSH before 2035. ⁱ
Germany	German "Netzentwicklungsplan 2021" forecasts, in 2035, additional +0.4 GW of PSH, +3.4 GW of grid batteries and +13.5 GW of PV-associated batteries. ⁱⁱ
Greece	In Greece's NECP, it envisages 750 MW of PSH, with two big PSH projects and 500 MW of battery storage of medium to small capacity storage. ⁱⁱⁱ
Italy	Italian NECP plans +6 GW of new storage capacity, with at least 50% from PSH plants. ^{iv}
Portugal	The Portuguese Roadmap to 2050 includes ~7.5GW of storage. 4 GW of batteries and 3.4 GW PSH, of which 2.5 GW already exists, and 0.9 GW are under construction and set to be commissioned in 2023. ^v
Spain	Spanish National Energy and Climate Plan considers 6 GW of additional storage capacity by 2030, 3.5 GW of which from PSH. ^{vi}
Switzerland	Swiss last updated version of Energy Perspectives 2050+ considers +1.8 GW PSH in zero-carbon scenario by 2050. ^{vii}

Current status of pumped storage & development potential

In Europe, PSH plants were predominantly built between 1970 and 1990. From 1990 the growth slowed down and then sped up from 2010. The countries with the largest capacities as of 2020 (including pure and pump-back or mixed PSH plants) are Spain, Italy, Germany, Switzerland and France. In the period 2010-2020, new PSH installed capacity in Europe was almost +8 GW, with the biggest growth in Switzerland (+1400 MW, Limmern, FMHL+-), Austria (+1400 MW Koralpe, Feldsee, Limberg II, Reisseck II, Obervermuntwerk 2), Portugal (+1400 MW, Salomonde II, Baixo Sabor, Venda Nova III, Foz Tua), Spain (+800 MW La Muela II) and France (+240MW, La Coche).

Figure 2 PSH capacity per country in Europe



Source: DOE Global Energy Storage Database by National Technology & Engineering Sciences of Sandia, LLC (NTESS)

PSH's main role is to provide flexibility to the electricity system, consuming power in low-demand/low-price periods (usually off-peak hours) and producing in high-demand/high-price periods (usually peak hours). PSH plants participate in the Day-Ahead and Intraday electricity markets (under Trading Rulebook provisions) and in the Balancing Markets.

The European electricity sector has been liberalized. Some activities (natural monopolies) are regulated (i.e., transmission, distribution) but generation and sales are deregulated, allowing competitors to invest in generation projects and participate in the market in accordance with European legislation. Some countries (Italy, France, UK) have created capacity markets, in which storage plants can participate, but currently there is not a bespoke economic regulation applied for storage.

PSH plants are remunerated through their participation in the different markets: energy (Day-Ahead and Intraday), balancing and capacity. The main revenue streams are the price arbitrage between low and high price hours (generally speaking, peak-off, peak spread), and the provision of flexibility in the balancing markets (primary, secondary and tertiary reserves).

However, current (and foreseeable) power market conditions show that the revenues attained from the price differential (arbitrage) along with the declining revenues from the provision of the ancillary services are not enough to cover the fixed investment and administrative costs of these units.

As part of the EU's Fit for 55 Green Energy Transition, the Revision of the Energy Taxation Directive included amendments for storage². The revision to the Energy Taxation Directive (ETD) seeks to prevent double taxation or distortion of the trade of electricity. For electricity storage facilities, such as long duration PSH, they have suggested that they be considered redistributors when they supply electricity in order to avoid the risk of double taxation.

Some projects are currently under construction (Gouvães 880 MW in Portugal; final works in Nant de Drance 900 MW, Switzerland). EDF is heading up a major project in the La Truyère Valley, extending the La Truyère and upstream part of the Lot concessions to address storage requirements. The concession to extend La Truyère was submitted by the French State in April 2017 to the European Commission. An authorisation in principle is awaited prior to the formal notification process. In Greece, 880 MW of PSH projects (Amfilochia and Amari) are in the pipeline already designed (they await the needed construction permissions). However, due to the

² "COUNCIL DIRECTIVE restructuring the Union framework for the taxation of energy products and electricity (recast)", *European Commission*, 14 July 2021 https://ec.europa.eu/info/sites/default/files/revision_of_the_energy_tax_directive_0.pdf

absence of a relevant regulatory compensation and clear licensing/ permitting framework the construction has not yet begun.

Back in 2010, the number of announced projects was much bigger, with an expected capacity growth of 27,000 MW until 2020. Many of them have been put on hold because of a perceived lack of profitability: Lago Bianco 1,000 MW and Grimsel III 600 MW in Switzerland, Atdorf 1,400 MW in Germany, Aguayo II 1,000 MW in Spain. However, Aguayo II is being analysed by its new owner, Repsol. Lago Bianco and Grimsel III are still included in Switzerland's "Strategy 2050" document. Hence, the remaining technical potential is still huge.

Furthermore, all Governments, in their 2030-2050 energy strategy plans (e.g., NECP, other national energy strategy plans), intend to largely develop electricity storage capacity, and especially PSH, although at the moment no concrete measures are announced.

Challenges, barriers and emerging opportunities for pumped storage development

Barriers/challenges:

- a) Lack of regulatory framework which would ensure the necessary revenues visibility/certainty. PSH plants are capital intensive investments with long pay-back and construction timeframes, and appropriate incentives should be guaranteed for investors. The participation of the national transmission system operator (TSO) in the ownership, development, management and operation of PSH plants has been proposed as a possible solution, although this positioning is generally rejected by power generation companies and is made difficult by EU Directive 2019/944 which outlines limitations for TSOs and Distribution Network Operators (DNOs) to own or operate storage. Currently, PSH assets are considered generation assets in European legislation.
- b) During pumping operation, PSH helps the system to balance an excess of electricity supply, and this will need to happen more frequently to avoid renewable energy curtailment. This "service" is not specifically remunerated (apart from the low prices that usually occur in such moments).
- c) Competition from other storage technologies:
 - Batteries, which have started to capture a big share of high revenues markets (e.g. Primary/Frequency Control Reserves). They can be built module after module, in a relatively short time.
 - Power-to-Gas (PtG) including green hydrogen production. PSH is in general not suitable for seasonal storage. PtG will allow storage of hydrogen or synthetic methane in current gas storage infrastructure.

Opportunities/Benefits

- a) PSH will allow for RES integration, solving grid technical problems, not only at national level, but cross-border integration will allow for optimal continental grid utilization (e.g., offshore wind in Northern Sea can avoid curtailment through PSH in the Alpine region). It should be correctly remunerated for this wider grid service.
- b) European programs to harmonize power markets (particularly balancing markets and grid services, e.g., TERRE, MARI, PICASSO) will allow cross-border participation of PSH in these markets.
- c) PSH will benefit from wider hourly price spread between hours with low RES production (and hence high price) and high RES production (and hence low or even negative price).

- d) PSH is the most reliable and mature storage technology. It has low technological risk, large storage capacity, low operational and maintenance cost, high Global cycle efficiency (>80%), twofold operation (consumption or generation) so as to adapt to both balancing situations (supply surplus or deficit).
- e) Low environmental footprint of PSH, especially when using existing structures/reservoirs and underground powerhouses, with no/minimum impact on rivers.
- f) PSH construction will benefit local communities in rural areas (labour, investments). Also, most of the materials/equipment would be of European origin.
- g) After its last update, the EU Taxonomy Climate Delegated Act recognises all types of PSH as making a substantial contribution to climate change mitigation. Therefore, PSH projects are eligible for sustainable financing.

Organizations that could help to support PSH development

Power Transmission Operators (TSO), regulatory authorities, relevant Ministries, European Commission and financial institutions.

Some countries have set regulations that improve the profitability of PSH.

- a) Exemption of grid tariffs for pumping in Switzerland
- b) A significant reduction on transmission network charges (transmission network charges in France are reduced by up to 50% for energy-intensive industries using storage),
- c) Specific PSH support schemes (e.g., PNBEPH³ in Portugal)
- d) Participation in capacity markets (in France, Italy and UK)
- e) In Greece, in December 2020 the Ministry of Environment & Energy established a Committee for the development of a legislative and regulatory proposal for the participation of different storage technologies (including pumped storage) in the electricity market. The Committee has the obligation to submit its proposal within the first semester of 2021.

At the EU level, the European Commission also approves and updates a list of Projects of Common Interest (i.e., key cross-border infrastructure). The list mainly covers electrical grid network expansion and interconnections, but also includes a selection of PSH projects; 12 were included in the latest list published in 2019. Inclusion on the list provides the following benefits to proposed projects for development: accelerated planning and permit granting, improved regulatory conditions, lower administrative costs due to streamlined environmental assessment processes, increased public participation and also visibility to potential investors.

Nothing yet in place except France where the last PSH project developed was mainly financed by green bonds and without support.

³ Programa Nacional de Barragens com Elevado Potencial Hidroeléctrico, that is "High Hydroelectric Potential Dams National Program" or "National Program on High Hydroelectric Potential Dams"

Recommendations

1. Governments, European Commission:

Introduction of flexible capacity mechanisms/markets/products (e.g., flexibility options) in all European markets (organized as either energy-only markets or markets with capacity remuneration mechanisms), by the introduction of flexibility terms. Their design must consider the particularities of PSH (heavy capital investments, long paybacks) to secure payments for more than 15 years, which is the current payment period for new plants in existing capacity markets in Europe. They must allow the cross-border participation of flexible plants and particularly of PSH. This requires the harmonization of grid tariffs/costs to allow for fair competition and has recently been supported by the revision of the Energy Taxation Directive to avoid double taxation for energy storage and should now be applied by each EU state (e.g., removal of double charging in Austria or 7% Generation Tax in Spain). These flexible capacity products should be considered and developed by the European Commission and National Governments.

2. Governments and regulatory authorities:

Introduction of specific PSH capacity products or appropriate purchasing mechanisms: storage capacity auctions, winter reserves. Governments and regulatory authorities should introduce these PSH specific capacity products and/or purchasing mechanisms.

3. Regulators, TSO, Governments:

An appropriate regulatory framework must provide enough revenue visibility for operators and to allow the profitability of new PSH investments. Policy changes are needed (e.g., to facilitate long-term agreements between transmission operators and energy storage developers; remunerate PSH for grid deferral savings); Regulators, TSO, and Governments should acknowledge the advantages of PSH to avoid onerous grid extensions.

4. Regulators, Governments, Operators, European Commission:

Reassessment and repositioning of tariff/market structures for ancillary services, and compensation for a wider range of ancillary/balancing services. All services should be remunerated. The recognition of benefits of PSH for the power system like security of supply, RES integration, etc. could be the basis to support, and correctly remunerate, PSH.

5. TSOs, Governments:

Assessment of the future grid development concepts, i.e., cross border collaboration of operators on grid services to support the development of PSH plants. The analysis of system adequacy, interconnection capacities, grid capacity requirements and need for storage should be performed at regional level – by TSO's and Governments.

6. Introduction of new commercial products:

PSH can be used as back-up, bundled with renewables: RES PPA integration, full renewable supply, real time renewable supply, virtual storage for households PV – power supply companies should innovate and propose new products to their final customers.

7. Governments, regulatory authorities:

Design thinner financial market products (15 min and less), introduction of additional reserve products dedicated to monitoring residual demand – these market products should be introduced by Governments and/or regulatory authorities.

8. Governments, regulatory authorities:

PSH systems should be able to operate as demand-response providers participating in the market under more favourable conditions (e.g., special provisions for less strict imbalance tolerances) – regulatory authorities and Governments could introduce these favourable conditions.

ⁱ Programmes pluriannuelles de l'énergie, 2021, Ministère de la Transition écologique -

<https://www.ecologie.gouv.fr/sites/default/files/20200422%20Programmation%20pluriannuelle%20de%20l%27e%CC%81nergie.pdf>

ⁱⁱ NETZ-ENT-WICK-LUNGS-PLAN 2035, 2021, submitted by Übertragungsnetzbetreiber (ÜNB), published by Bundesnetzagentur (BNetzA) - <https://www.netzentwicklungsplan.de/de/netzentwicklungsplaene/netzentwicklungsplan-2035-2021>

ⁱⁱⁱ National Energy and Climate Plan, 2019, HELLENIC REPUBLIC Ministry of the Environment and Energy, Greece. -

https://ec.europa.eu/energy/sites/ener/files/el_final_necp_main_en.pdf

^{iv} Integrated National Energy and Climate Plan, 2019, Ministry of Economic Development, Ministry of the Environment and Protection of Natural Resources and the Sea, Ministry of Infrastructure and Transport, Italy. -

https://ec.europa.eu/energy/sites/ener/files/documents/it_final_necp_main_en.pdf

^v Roadmap for Carbon Neutrality 2050 (RNC2050), Long-Term Strategy for Carbon Neutrality of the Portuguese Economy by 2050, 2019, Minister of the Environment and Energy Transition, Portugal - <https://www.portugal.gov.pt/download-ficheiros/ficheiro.aspx?v=%3D%3DBAAAAB%2BLCAAAAAABACzMDexBAC4h9DRBAAAAA%3D%3D>

^{vi} Integrated National Energy and Climate Plan 2021-2030, 2020, Spain-

https://ec.europa.eu/energy/sites/ener/files/documents/es_final_necp_main_en.pdf

^{vii} ENERGIEPERSPEKTIVEN 2050+, 2020, Swiss Federal Office of Energy. -

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