

## Original Paper

# Critical Analysis of Pumped Storage Power Plants in Germany

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Received: January 21, 2020  
doi:10.22158/jbtp.v8n1p45

Accepted: February 2, 2020

Online Published: March 14, 2020

URL: <http://dx.doi.org/10.22158/jbtp.v8n1p45>

### Abstract

**Purpose:** *Anyone who wants to generate substantial amounts of electricity using regenerative systems must store excess energy so that it can be used again for times when it is needed but not generated by the sun and wind. Pumped storage power plants are currently the only way to present this on a larger scale realistically.*

**Design/methodology/approach:** *The aim was to find out what the current status quo for pumped storage power plants in Germany is. Only current German literature was evaluated. All relevant German political parties were interviewed and all generally refused to take a position. In a longer expert interview with one of the leading professors and experts in this special field, the deeply unsatisfactory situation and development was clearly confirmed.*

**Findings:** *The findings achieved can only be described as devastating, since the responsible politicians/parties fundamentally avoid the discussion and the environmental associations and ultimately also the electricity suppliers do not build up the necessary political pressure, while the locally affected population legally defends itself by all means to prevent necessary and directly related changes in your own life.*

**Research/practical implications:** *In the previous form, it does not go on, since no progress has been made. There must be concerted action by all governing parties, all environmental associations and the media to make it clear that many changes are pending in this area in the future. All future and necessary investments and changes must be legally clear and fundamentally secured in advance. Future research must always stand on three legs here: politically/legally, economically/ecologically and most intensively, sociologically about the population and their approval of the changes, which are sometimes serious.*

**Originality/value:** *There are hardly any relevant publications about it so far, and it seems that all politically responsible people are trying, at least so far, to keep the topic silent.*

### Keywords

*pumped storage power plants, storage of excess green energy generate*

## 1. Introduction

At the 2018 Paris Climate Conference, the countries of the world community decided that, in order to at least slow down anthropogenic climate change, a massive reduction in potential greenhouse gases, significantly CO<sub>2</sub>, is necessary. This affects above all the energy sector, where the generation and transport of energy is concerned. Proposed or defined solution: A permanent reduction in the use of fossil raw materials, turning to renewable energy sources, mainly sun and wind. Problem: These are only discontinuous (supply), which is diametrically related to the need (demand). Solution: Storage of excess energy so that it can be used as a re-serve in the event of a shortage. Pump storage power plants are currently the most suitable storage options.

## 2. Pumped Storage Power Plants in General and in Germany

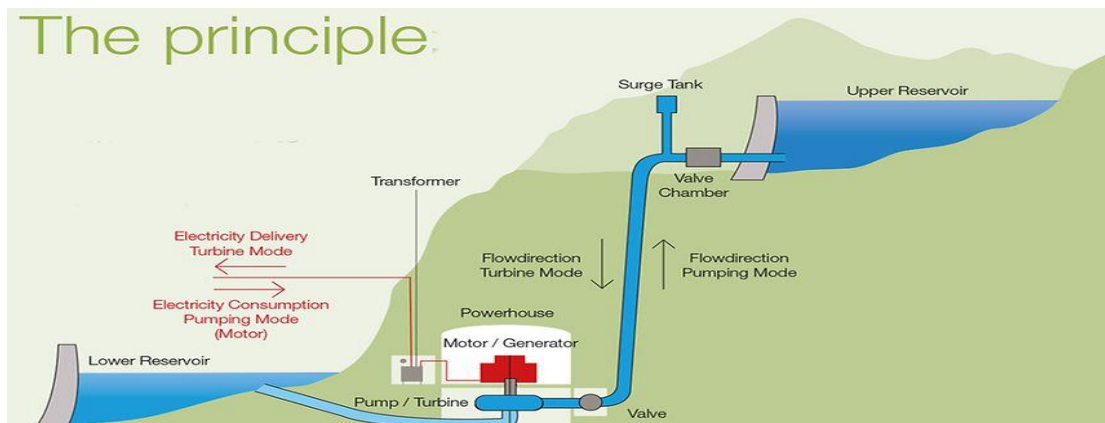
This scientific paper focuses exclusively on the German market when considering pumped storage power plants as a renewable energy source, which is why only German literature sources were used. Due to the fundamentally very specific situation in the area of renewable energy sources in general and in the case of pumped storage power plants due to the necessary topography in particular, generalizations or a type of transformation to other countries are only possible to a limited extent, although not generally impossible, because most constellations remain the same ,

The share of renewable energy sources rose from 3.6% in 1990 to approx. 35% in Germany in 2018 (AG Ener-giebilanzen). This shows that the energy transition is now on an irreversible path even in a high-tech country like Germany. Storage technologies (such as pumped storage power plants) can support this task, since they store the excess energy and can make it available again at any time when needed (Hartmann, 2014, p. 3). They use the potential energy of water at various levels to generate and store energy and, by retaining water at a higher level, acquire their storage capacity (Sterner & Stadler, 2017, p. 26). Around 75,000 MW are currently installed or under construction in pumped storage power plants worldwide (Giesecke, 2014, p. 125).

The ability of energy storage enables the use of regenerative energy sources such as wind and sun, which will become increasingly important in the future due to their increasing production (Sterner, 2017, p. 36). It is important that you need two reservoirs at different heights, as well as corresponding pipes and the power generation unit, as can also be seen in the following graphic, for the standardized structure.

It is almost a kind of closed cycle: if the energy is excess (e.g., too much wind and sun with too little consumption at the same time) the water is pumped from the deeper into the higher pool. If there is too much demand, the water is released from the upper to the lower basin and the required electrical energy is obtained via a turbine, resulting in so-called withdrawal (Sterner, 2017, p. 28). It is clear that the electrical energy supplied to a pumped storage system must be greater than that recovered later, because transformation losses always occur (Sterner, 2017, p. 522). Particular attention must be paid to the fact that it is long term. Germany takes at least 10 years between conception, planning and final implementation (not counting the time for previous complaints by citizens' groups and associations), and the lifespan is at least 60-100 years (Sterner, 2017, p. 699). According to the Federal Network Agency, 47 active pumped storage power plants are now integrated into the German power grid, of which 26 are located in the surrounding area. Together they achieve a net nominal output of 9.81 GW with an approximate capacity of 40 GW (Federal Network Agency). And that already shows part of the problem: overall only a small capacity and more than half of the systems are abroad. The fact that only

one new plant is planned within the next 3 years, albeit with a net nominal output of 16 MW, shows the very little progress. Of the 28 projects, 16 were put on hold, 6 completely banned and only 6 are left, the total output of which corresponds to approximately 2.4 GW (Heimerl, n.d., p. 79). This is all the more unfortunate since the pumped storage currently represents over 86% of all storage capacity, while the other storage technologies, such as battery storage, compressed air storage and power-to-gas, are not significant in terms of quantity (Stolle, 2018, p. 55). Because of these difficulties or extremely slow implementation, other solutions must be found in the short and medium term. The Federal Environment Agency suspects an immense potential of approx. 240 GWh with a renovation of the existing dams. Investigations in a dissertation by Czisch (p. 111) showed a potential in Germany of at least 20 locations with a capacity of 14 GW. Nevertheless, the potential is classified as low, since the intervention in the natural environment, especially in scenic mountain regions, against the massive resistance of the population, hardly seems feasible. Prof. Volker Quaschnig, who is one of the leading experts for regenerative energies in Germany and teaches at the University of Applied Sciences (HTW) in Berlin, also sees it that way.



**Figure 1. Pumped Storage Plants Pump Water to Higher Elevation Reservoirs at Times When There Is a Surplus of Electricity, to then Release This Water into Lower Elevation Reservoirs to Generate Electricity When Needed**

Source: Lechner, A. in: Andritz Homepage, accessed 2019.12.31.

### 3. Decentralized Energy Supply as a Result of the Planned Energy Transition

Since Germany decided after the reactor accident in Fukushima in 2011 to completely abandon nuclear energy and the last coal-fired power plant is to be switched off by 2038, a switch to renewable energies under massive time pressure is now mandatory. Alternatives to this no longer exist (Stern, n.d., p. 71). One of the most important foundations is the Renewable Energy Sources Act (EEG), which grants a feed-in guarantee for renewable generation plants and additionally guarantees the plant operator fixed remuneration with a minimum amount, completely independent of the market prices achieved (German Bundestag). Since the Paris climate agreement in Germany is the absolute benchmark that must be implemented and the goals must be achieved (“regardless of losses”), action must be taken in any case, either way. Since a significant part of CO<sub>2</sub> emissions comes from energy generation, action must also be taken here, i.e., the suppliers of electricity are under pressure (Federal Ministry, climate protection plan 2050, p. 35). The so-called base load capacity and the dark calm are currently problematic. Both

are currently not yet solved challenges. Ultimately, you will probably have to generate completely renewable energy in the future than before. If it is generated regenerative, it will only occur discontinuously and must therefore be stored temporarily so that there is always enough available. RWTH Aachen (University in Aachen) has created two studies with a 60% and 80% share of regenerative energy. The use of pumped storage power plants was a mandatory prerequisite to ensure a permanent energy supply (Moser, 2014, p. 63). In any case, the storage must be decentralized, since the loss in electricity transport is massive, so that one has to try to adequately distribute the pumped storage throughout Germany, depending on the electricity demand. The only currently appearing alternative seems to be the power-to-gas technology, which can be distributed via pipelines and is therefore not as location-dependent as pumped storage, especially since nature is not affected. However, the currently very low efficiency of 30-38% (Sterner, 2017, p. 464), as well as the need for pipelines, must be taken into account.

#### 4. Economic Analysis of Pumped Storage Power Plants

In a market economy, it is crucial whether an investment is financially worthwhile. This is becoming increasingly difficult to answer for pumped storage systems, since the discontinuous accumulation of regenerative energy leads to ever larger price jumps on the power exchanges. In particular, negative prices for excess energy are a massive problem. From this perspective, pumped storage systems are an ingenious alternative, since you yourself determine when they should produce electricity (when the price is particularly high because there is not enough electricity) and when it is excessive is negative (Bundesverband, 2018, p. 2). When considering the economic situation, it is essential to take into account the Phelix day base (an index for the average price over the entire day) and the Phelix day peak (the average price for the period from 8 a.m. to 8 p.m.). In 2017, the highest value was € 101.92/MWh and the lowest was € -52.11/MWh. Decisive for the profit-ability of the system are the possibilities to buy cheaply when it is offered and only to sell if the price promises at least a reasonable profit. The efficiency of the system of approx. 80% must also be taken into account here (Bundesnetzagentur, 2019, p. 233).

A few figures for an overview: The investment costs amount to approx. € 1,500/kW, but for existing power plants they can also be significantly lower, especially if these pumped storage power plants are older. According to Gieseke (p. 65), a realistic average value can be around € 1,050/kW. Based on relatively difficult calculation costs, you end up with around € 0.089/kWh. Calculations based on the Phelix day peak of € 0.04461/kWh thus result in a final value of € -0.04439/kWh. Answer: It is not economically worthwhile. Unless “playing” with the existing variables such as the development costs, the lifespan of the system, taxes/duties and the achievable sales price.

On the other hand, it is extremely disadvantageous for potential investors to invest in a project that you do not know if it can ever be realized, because the massive danger of citizens’ initiatives and supposed interest groups are delaying the start by years, if not at all, by new lawsuits impossible. It cannot be conclusively judged whether this anger of citizens or associations is typically “German”, but in any case it has a massive impact on a possible feasibility. The last legal problem is that the system is seen both as an “end user” when it is stored and as a “power generator” when it is withdrawn (Bundesverband der Energie). Ultimately, a clear legal basis is necessary, which must be based primarily on federal or even European laws. So far, all of them are lacking in scope, clarity and awareness. Why is unknown, but obviously politicians lack the courage to take a clear position in this

area and firmly anchor pumped storage power plants in politics and society as an absolute necessity.

#### *4.1 Opportunities and Hurdles from a Political Perspective*

It is interesting that the Federal Environment Agency in 2010 wrote in its paper “Energy Target 2050” that pumped storage power plants are currently the best option for short-term storage (Klaus, 2010, p. 33). In 2012, the Federal Ministry of Economics signed a contract with Austria and Switzerland for corresponding cooperation in this area. Legal protection with various paragraphs in the Energy Industry Act has also laid a good foundation. This good foundation was then massively questioned again in 2015 with a politically changed perspective and the “Electricity Market 2.0” agenda. In this regard, the state wants to shift all activities to the electricity market, i.e., the market economy (Federal Ministry of Economics, p. 22). This behavior is a real outsourcing of costs, risks and all responsibilities.

##### *4.1.1 Promotion and Subsidization of Pumped Storage*

It seems obvious that the entire transformation of the energy industry from fossil to renewable energy sources cannot be successfully implemented without government support and therefore subsidies in the relatively short period that is sought. The Federal Ministry of Economics is planning to spend € 1 billion on battery storage by 2022 (Federal Ministry of Economics, p. 1). In 2018, only 0.1% of all money for renewable energy systems went to hydropower plants. Why this is so cannot be explained here. This is particularly incomprehensible because it diametrically contradicts the Federal Government's goal of switching to renewable energy sources.

##### *4.1.2 The Reaction of the German Parties Represented in the State Parliament of NRW*

As part of a research project at the University of Applied Sciences North Hesse (DIPLOMA FH Nordhessen) in summer 2019, we have tried to get statements by responsible politicians in general and by the governing parties in particular, in the state parliament of the most populous German state of North Rhine-Westphalia (NRW), to seek an opinion. None of the politicians or parties, despite the author's most intensive attempts over several weeks, received even a single answer. A situation that must be deeply irritating, because it leaves the feeling that either knowledge in the subject area is largely lacking among those responsible and/or that politicians and parties are simply not really interested. Both options must be rated as absolutely depressing, because politicians are obviously trying to take responsibility in an absolutely future-oriented field of energy supply, and we are talking here about Germany, the economically strongest country within the EU. From the perspective of the necessary future orientation, this fact cannot be accepted under any circumstances.

#### *4.2 Public Perception of Pumped Storage Power Plants through Interventions, Citizens' Initiatives and Media Reporting*

The fact that an extraordinarily promising facility, where practically all parameters fit, was planned for years in the southern Black Forest and then re-employed after the local population was tested again, confirms the so-called Nimby effect (Not In My Back Yard). The term originating from the USA refers in particular to the mentality of people who use the advantages of modern technology but do not want to accept disadvantages in their own environment (so-called free-rider problem). Nimbys try to pass on these disadvantages to other members of society, which they can do if they can make themselves heard. It follows that there is hardly any acceptance of pumped storage power plants, or that new construction is currently more than difficult. This situation is all the more regrettable, since the construction of new pumped-storage power plants, together with the fundamental renovation of existing dams and hydropower plants, is the prerequisite for the changeover to renewable energy sources.

## 5. Conclusion

Pumped storage power plants are currently the only really feasible way to store excess renewable electricity locally and to convert it back into electricity if necessary. New construction projects are postponed again and again and finally completely discontinued or prohibited. Acceptance of the local population in the affected areas varies from very low to nonexistent. An economic profitability cannot currently be shown for a separate unit without integration into the big picture. This only works in conjunction with the production of renewable energy. The state has so far not offered any relevant funding or subsidies, which means that such power plants alone are not worthwhile. Possible solutions: 1) A legal basis must be created, e.g., no complaints can be made against the construction of such pumped storage power plants in the interest of the common good. These laws must be standardized across the EU and finally adopted. 2) The state must make it clear to the population that any type of energy generation always involves a certain burden on nature, humans and animals and cannot be represented in any other way, with the creation of reservoirs being one of the lowest ecological burdens at all. 3) Without appropriate state support measures of various kinds, including massive subsidies for the respective operators and affected municipalities, implementation will not succeed. Research and action paths: 1) All relevant political parties and environmental organizations must understand pumped storage power plants as currently the only relevant option for electricity storage and must work intensively and publicly for this. 2) This results in a concrete action plan for Germany and possibly for the entire EU. 3) This must be based on appropriate funding schemes with substantial subsidies and especially on a newly created legal basis, which, on the other hand, makes complaints practically and fundamentally impossible.

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