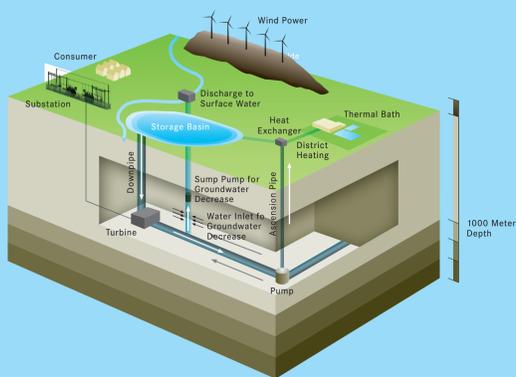


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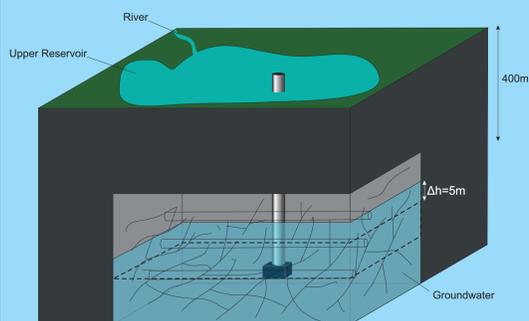
It may be that by 2050, 100% of electrical power will be produced by renewables in Germany. Following different scenarios, about 2/3 of this power will be generated from temporarily variable sources such as wind energy and photovoltaics. Therefore high-capacity energy storages will be needed for a constant supply with electrical energy using renewable resources. Modeling of future generation and consumption of electrical power shows that storage capacities in the order of 50 TWh and an installed power of 50 GW would be needed to secure power supply. Some alternative locations for installing Pumped-Storage Power Plants in Germany are presented here.

## Type I

Drifts and shafts of deep coal mines will serve as lower reservoirs for sub-surface pumped-storage power plants. Upper Reservoirs can either be lakes at surface or adits in shallower depth. System efficiency can be increased by using thermal energy from the air released from the drifts during filling and also by using ECBM techniques.



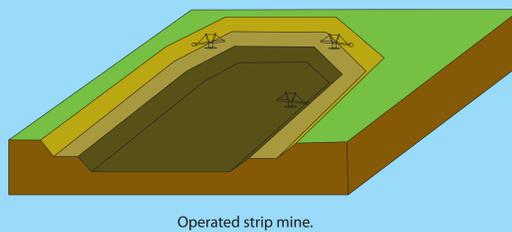
Closed-system SS-PSPP in combination with groundwater decrease. By pumping groundwater to the surface an opposite water flow is induced relative to the flow of the process water in the pipe from turbine to ascension pipe. This causes a higher transport of thermal energy from groundwater to process water.



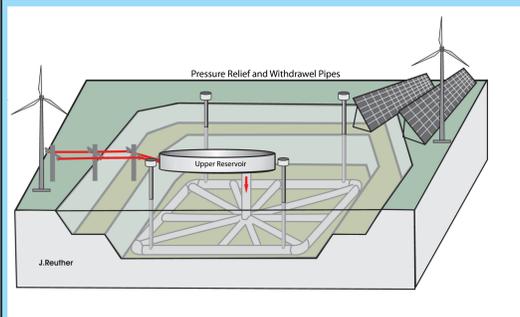
Open-system SS-PSPP in combination with groundwater decrease. In the Ruhr-District the bedrock is highly fractured due to mining activities and a lot of adits are still open, at least in a hydrological meaning. In an area of several tens or hundred of square kilometres groundwater table has to be decreased to more than 1km until the end of mining activities. After the end of mining groundwater is intended to be decreased on a level of 400m below surface. Variation of the groundwater level in a range of 5m causes a high capacity lower reservoir.

## Type II

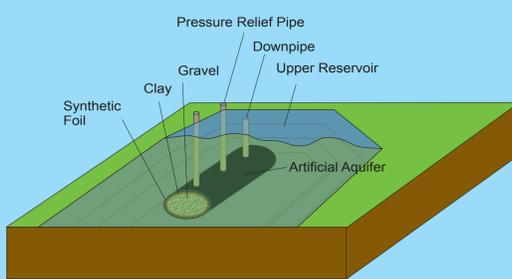
Abandoned strip mines will be used for this type of SS-PSPP. The upper reservoir will be a lake which forms because of the volume deficit after backfilling the mine. The lower reservoir can either be constructed by pipes and caverns or by artificial aquifers. Water drop height will be in the range of 200-400m



Operated strip mine.



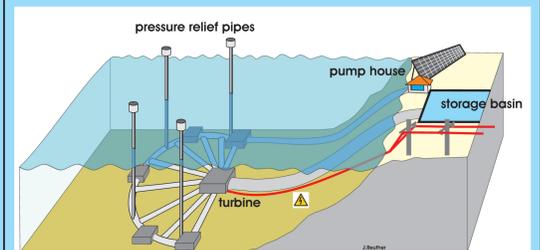
Backfilled strip mine with lower reservoir realized by pipes or caverns.



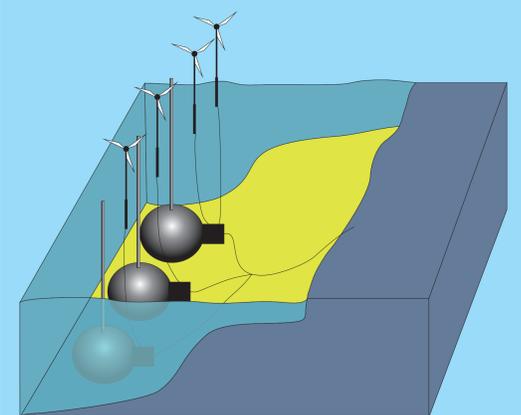
Backfilled Strip mine with artificial aquifer (lower reservoir) and lake (upper reservoir). The Aquifer is built up by a casing of clay to prevent loss of water and a core of gravel with high permeability and porosity.

## Type III

In many regions of the sea large differences in altitude may be used for installation of PSPP. On steep slopes downpipes may be installed analogue to the installation of conventional PSPP. Offshore SS-PSPP may be installed in combination with swimming Wind power plants.



Aquatic pumped-storage power-plant for construction in coastal regions with steep slopes.



Modular constructed lower reservoirs with integrated turbines and pressure relief pipes. Water enters the turbines under ambient pressure and is afterwards pumped to the water surface. This construction doesn't need steep slopes and is connected to the coast only via electric power cables. This principle is also discussed by Prof. Schmidt-Böcking from Goethe University, Frankfurt/Main.

## Outlook

Realization of Sub-Surface Pumped-Storage Power-Plants can contribute to the increase of energy storage capacity which is necessary for an energy supply based on renewables. Before that important basics have to be researched and many Problems to be solved.

First of all, adequate localisations have to be found in Germany, Europe and selected areas in the world. The stability of both, bedrock and lower reservoir has to be researched at every possible location. Long-time effects like erosion, solution, corrosion and many more have to be modeled adequately to prevent damage from humans, construction and environment. Economic aspects have to be calculated to guarantee efficiency during the whole lifetime of the construction.

This interdisciplinary project combines four institutes from two Universities and is funded by the Mercator Research Center Ruhr, an initiative of the Stiftung Mercator and the Universitätsallianz Ruhr.