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# Integrated subsurface gas storage of $CO_2$ and $CH_4$ offers capacity and state-of-the-art technology for energy storage in China

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**Abstract**

Integration and development of the energy supply in China and worldwide is a challenge for the years to come. The innovative idea presented here is based on an extension of the "power-to-gas-to-power" technology by establishing a closed carbon cycle. It is an implementation of a low-carbon energy system based on carbon dioxide capture and storage (CCS) to store and reuse wind and solar energy. The Chenjiacun storage project in China compares well with the German case study for the towns Potsdam and Brandenburg/Havel in the Federal State of Brandenburg based on the Ketzin pilot site for CCS.


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*Keywords:* gas storage; carbon dioxide; methane; hydrogen; renewable energy; carbon cycle

## 1. Introduction

The energy concepts of governments' worldwide aim at a reduction of greenhouse gas emissions in the near future [1]. Within that context available renewable energy plays a far greater role in satisfying energy requirements than before [2]. Nevertheless, integration and further development of the energy supply system is and will remain a major challenge for the years to come. An energy system which is based on renewable energy sources needs to

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account for short-term as well as long-term shortages of electricity. Due to the volatile nature of wind- and solar-based electricity, large fluctuations in the supply of power can occur. Therefore, the system needs to be stabilised by a quickly responding reserve in order to maintain the supply during the day. On the time frame of weeks, little wind and sunlight can occur especially during autumn and winter. Here, storage and generation capacity must be available as well to bridge potential electricity gaps. For the latter, we suggest an integrated system of subsurface storage of carbon dioxide ($CO_2$) and methane ($CH_4$) to buffer renewable energy in chemical form between its generation and final consumption. The innovative idea presented here is based on the extension of the "power-to-gas-to-power" technology by establishing a closed carbon cycle [3]. Hydrogen generated by electrolysis from excess renewable energy is transformed into methane for combustion. Carbon dioxide produced as well as methane are temporarily stored in subsurface reservoirs [4]. Consequently, renewable energy generation units can be operated even if energy demand is below consumption, while stored energy can be fed into the electricity grid as energy demand exceeds production [5]. Any kind of carbon Capture, Utilization and Storage (CCUS) technology is needed to reduce emissions from the whole lifecycle of especially energy-intensive industries [6].

Within the study presented here, the concept of the extended "power-to-gas-to-power" technology is first outlined. Second, we recapitulate the German show case for renewable energy storage with integrated subsurface gas storage; and third, give a comparison to the situation of the Chenjiacun site in the Ordos Basin of China.

## 2. Concept of the extended "power-to-gas-to-gas-to-power" technology

The idea behind integrated subsurface gas storage works as follows [3-5]. When the current electricity demand is lower than the production level from renewable sources like wind and solar, the surplus is used to produce hydrogen ($H_2$) by means of electrolysis of water. The hydrogen is then used as a reactant for methanation of $CO_2$ originating from one of two subsurface storage reservoirs installed for that purpose. The generated methane, is put into the second reservoir ready for extraction and conversion back to electricity when required. To close the carbon cycle and keep $CO_2$ available, a power plant has to be located in close proximity to both geological storage sites to enable the produced $CO_2$ to be directly separated and fed back into the $CO_2$ reservoir again with negligible transport costs (Fig. 1).

Energy storage on the basis of methane offers four major advantages: i) it represents the current state-of-the-art and can be applied in the short term; ii) retransformation of methane into electricity can fall back on established power plant technology; iii) methane can be easily fed into the existing gas network, and iv) decades of experience exist with subsurface storage of natural gas [3-5].

## 3. German case study for the storage of excess renewable energy

The show case outlines advantages and disadvantages of the extended "power-to-gas-to-power" technology concept on the basis of a practical example for the cities of Potsdam and Brandenburg/Havel [3] in the Federal State of Brandenburg (Germany). This includes estimates of the process efficiency and costs of electricity [4]. Brandenburg was selected as a study area, because it is a net exporter of electricity and covers an essential proportion of approximately 15% of its energy requirements from renewable sources. Further, an essential factor is a $CO_2$ storage reservoir on the order of magnitude as needed for the introduced technology of approximately 100,000 t $CO_2$. The Ketzin pilot site was not only successful from the scientific and engineering point of view but also with regard to the public perception gained [7,8].

An essential factor of the energy storage concept is a combined cycle gas turbine (CCGT) power plant in the immediate vicinity of the storage location. The smallest economically viable power plant is 120 $MW_{el}$. However, this exceeds the demand of the city of Potsdam, but was found to be suitable for additionally supplying the city of Brandenburg/Havel. The two cities represent a non-industrial supply area with a total population of about 227,000 and a total electricity demand of 900 GWh per year of which 30% are supposed to be provided from renewable sources. Our calculations are based on the assumption that the power plant contributes 2,800 full-load hours to supply the area under investigation and that it is able to support covering the increased daytime demand of both cities [9].