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# POWER STORAGE IN SMART NATURAL GAS GRIDS: FICTION OR FACT?

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## ABSTRACT:

The high volatility and unpredictability of renewable power generation leads to increasing uncoupling between power production and consumption. Development of storage technologies and construction of storage capacities are therefore of important interest for future power handling.
Extension of power transmission lines goes along with high costs and long-lasting permission processes. The existing natural gas infrastructure in Germany has, due to huge gas consumption, enormous energy storage capacity available.
Surplus-power of renewable energy sources can be used to power hydrogen (H2) electrolyses and feed “green” hydrogen directly into the natural gas grid. The existing transportation pipelines from the north-sea coast to south are properly qualified for transmission of the natural gas / hydrogen composition. High-efficient gas steam combined cycle power plants as well as multiple distributed and decentralized combined heat & power (CHP) plants can quickly and flexibly compensate temporarily renewable power reduction on demand.
The paper will describe carrying capacity possibilities and limits of the natural gas infrastructure for hydrogen and exemplarily depict costs/benefit considerations.



Key words: electric power storage, electrolysis, natural gas storage, load management, methanation, smart grids, wind hydrogen

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## 1. ENERGY STORAGE IN THE NATURAL GAS INDUSTRY

Natural gas transmission and distribution would be inconceivable without storage facilities are these are needed for energy supply structuring, in other words for compensating differences between supply and demand.

The stages on the way to efficient energy storage included gasometers, spherical tanks and finally geological storage facilities such as cavern or aquifer storage facilities which offered increasingly large capacities with falling specific costs. Nowadays the total storage capacity available in Germany amounts to about 20 % of annual natural gas demand. Ideally, storage facilities should be located near to the users giving rise to demand fluctuations. In the case of natural gas, they are normally located in sales areas, near to consumers.

## 2. ELECTRIC POWER STORAGE: THE CURRENT SITUATION AND FUTURE POTENTIAL

The power industry does not have such well-developed storage facilities as the gas industry. There are established technologies, such as water reservoirs, which can be used for storing energy in the form of potential energy, or the well-known compressed air storage facility in Huntorf, but the total capacity installed is only of the order of 0.04 TWh, which is sufficient for meeting power demand for only 0.6 hours. In comparison to the capacity of the gas industry, this figure is extremely low. In addition, the short "discharge" time of power storage facilities has far-reaching technical consequences, forcing power companies to maintain generating reserves in order to respond to demand fluctuations. The growing number of decentralized power generation facilities, especially based on renewable energy sources such as wind energy or solar power, do not help to relieve the situation. This type of power generation is characterized by stochastic fluctuations in availability. In the case of wind farms, efforts are being made to adapt the design of plants (e.g. by using greater hub height) or to select more suitable locations (e.g. offshore) with a view to boosting annual operating hours and approaching base-load generation capabilities. The aim is to reach 4,000 operating hours per year. However, the scope for such optimization faces natural limits in the form of the availability of wind. The same applies to photovoltaic systems, which are affected by cloud cover. In the renewable energy sector, only power generated using biomass, biomethane or SNG can be used for meeting base-load demand.

In addition to the wish to smooth out the severe fluctuations in wind power generation, there is a second reason for searching more intensively for power storage possibilities. As a result of additional wind farms, local oversupply situations are becoming increasingly common. If power generation is in excess of demand, this may lead to the return of power to the next highest supply level, the transmission system operator; if the maximum capacity of the grid has been reached, it may be necessary to shut down wind power facilities (the procedures are set out in Section 11 (1), Renewable Energy Act.

Theoretically, an ideal storage facility would allow a fluctuating generation profile to be converted into a homogeneous profile and excess supply to be shifted to times with a supply shortfall. For wind or photovoltaic energy, such a storage facility would need to be located at the point of generation or network supply. In the case of an offshore wind farm, the storage facility would also need to be able to compensate for supply fluctuations within a range of tens to hundreds of megawatts.

Looking at the storage technologies currently available for exergy (see Fig. 1), it is clear at first glance that these requirements cannot be met by batteries, supercapacitors or flywheel energy storage, but certainly can be met by external long-term storage technologies such as hydrogen storage. In this process, electrolysis is used to produce a substance that stores energy in electrochemical form. The hydrogen may also be processed to produce other substances such as methane.

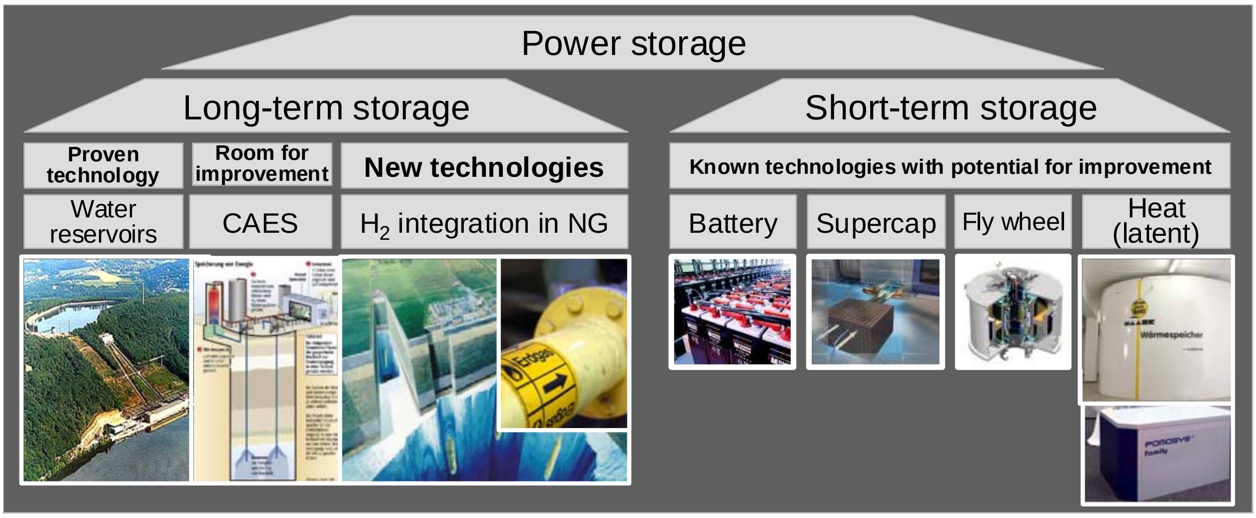
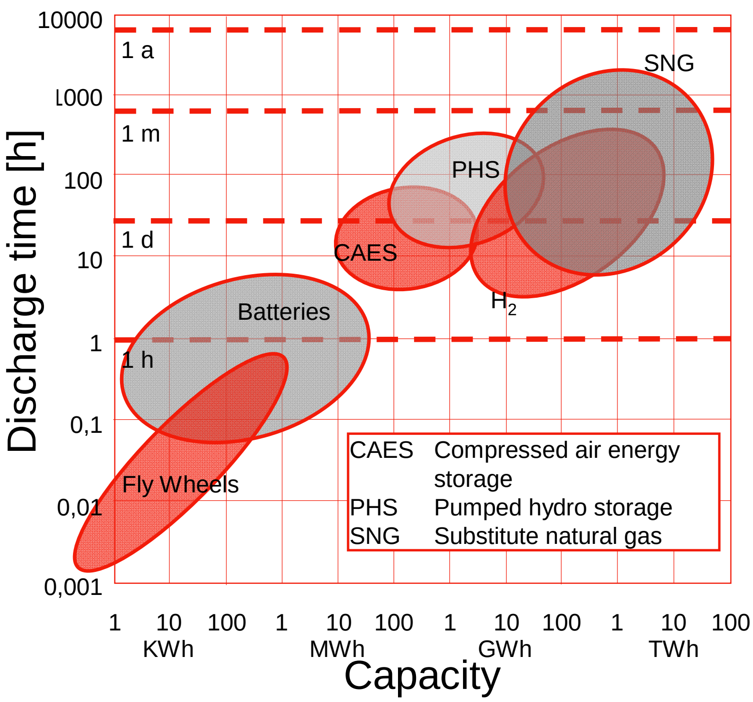



Figure 1 : Power storage technologies

In this context, the available infrastructure of the natural gas system offers one of the greatest possible storage capacities. In addition, the substance carried by the system (methane or a methane/hydrogen mixture) has a high energy density (see Fig. 2).



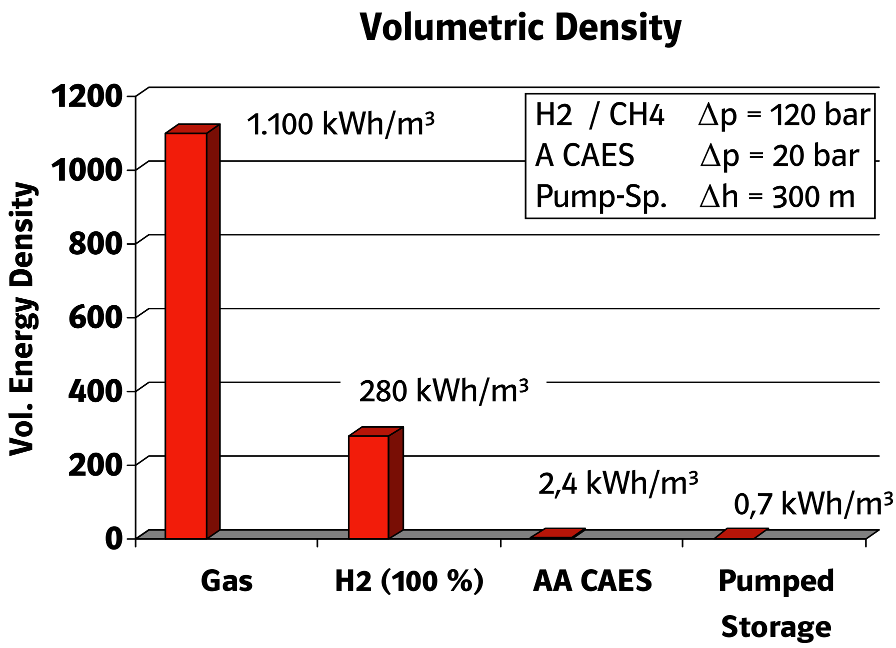



Figure 2 : Comparison of capacities of different storage media according to (1) and (2)

## 3. DVGW. RESEARCH PROJECT ON THE USE OF THE NATURAL GAS NETWORK FOR ENERGY STORAGE

Deutsches Brennstoffinstitut DBI GUT, the Engler-Bunte Institute EBI, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES and the gas companies Verbundnetz Gas and E.ON Ruhrgas were therefore instructed by DVGW as part of its innovation campaign to investigate the potential for storage in the natural gas system (3). The project is to analyse the feasibility and economic viability of converting excess electric power into hydrogen using the latest electrolysis processes. These include for example PEM (polymer electrolyte membrane) electrolysis, which is especially attractive because it delivers products with a high degree of purity at a high pressure. This is a considerable advantage because it means that the hydrogen can be injected into the natural gas system without compression and therefore at low cost. The hydrogen methanation approach, i.e. the conversion of hydrogen into methane, $CH_4$, with the addition of $CO_2$, is also to be investigated. Ideally, the carbon dioxide required should be taken from biomethane plants, as the methane produced could then be considered to be a renewable resource. The process would then be free of $CO_2$ emissions.

Both the power storage approaches described above are highly promising. For example, in the early years of gas pipeline companies, hydrogen was a component of the coke-oven gas which was then handled. Methane is the main constituent of natural gas and can be carried by existing pipeline systems without any problems at all.

The research team is also to consider comparisons with other storage technologies such as compressed air energy storage, and to make implementation recommendations. A key element of the study is that it is to take realistic network situations into consideration. In other words, a storage facility is to be modelled including local power generation capacities and network infrastructure (for electricity and gas.

Let us begin with hydrogen injection. How much hydrogen can be injected into a natural gas system and from what point does methanation become necessary? It will only be possible to give a precise answer to this question when the research work has been completed. Many studies state that current standards allow the injection of 5 % hydrogen into a natural gas system. This would mean that about

20 % of the wind energy target of about 15 TWh/year stated in the IECP (the German government's integrated energy and climate programme) could be stored in the natural gas system. The share of hydrogen would then be of the order of 4 %. Initial analyses using the E.ON Ruhrgas "GasCalc" calculation module indicate that even the injection of 15 % hydrogen would not result in gas composition outside the limits laid down in DVGW Code of Practice G 260 ("Gas Composition") in the case of the gas present in the system in Northern Germany (i.e. gas from the Netherlands and the North Sea), where wind hydrogen injection is most likely to take place. It appears that even higher shares of hydrogen would not really be critical. However compliance with the limits set in G 260 is not sufficient to warrant acceptable gas composition. It is also necessary to take into account possible effects on system components along the supply chain, including the effects of hydrogen on steel pipelines, compressors, underground storage facilities, distribution systems (steel and plastic) and the equipment of gas users (burners, heating systems, compact CHP plants). It would also be necessary to verify the use of this mixture as a motor fuel. Finally, we need to clarify the consequences of expected fluctuations in gas composition if electrolysis and injection plants are operated intermittently as a result of changing wind conditions. Will this have a significant impact on the service life of electrolysis units? All these questions will need to be answered by the research work carried out over the next 15 months.

## 4. POTENTIAL FOR HYDROGEN STORAGE IN THE NATURAL GAS SYSTEM

However, if we assume that the concentration limit which is finally established is about 15 % hydrogen in natural gas, the storage potential would be of the order of 60 TWh/year, corresponding to a generating capacity of about 30 GW with 2,000 operating hours per year.

There are not many alternative solutions to the problem of excess power generation from renewable sources. Currently, the approaches being explored in addition to the search for suitable storage facilities are load management and network expansion.

In the case of load management, the objective is to balance wind power surpluses by using smart grids. Networks could be stabilized by variable operation of major customers' systems; for example, power demand could be increased by lowering temperatures in refrigerated storage systems. Reactive power losses could also be avoided if precise phase synchronization were ensured between the various facilities feeding power to the grid.

The objective of network expansion is to allow the system to carry local power surpluses away from the generation area more effectively. However, we are far from having reached a "copper plate" covering the whole of Europe and the long approval periods for new power transmission systems mean that network expansion will be unable to keep pace with growth in wind power generation in many areas. The question of financing for network expansion also needs to be considered.

Fig. 3 indicates the interaction between and the limitations of these elements, power storage, load management and network expansion, on the basis of the annual power volume to be considered and the asymmetric generation profile of wind farms.

In future, it is highly probable that large-capacity electric power storage will be realized by using excess wind power to produce hydrogen ("wind hydrogen") which can be stored directly in the natural gas network. There are therefore prospects that two energy supply chains, electric power and gas, will converge. The wide range of applications of natural gas will be open to "wind hydrogen".

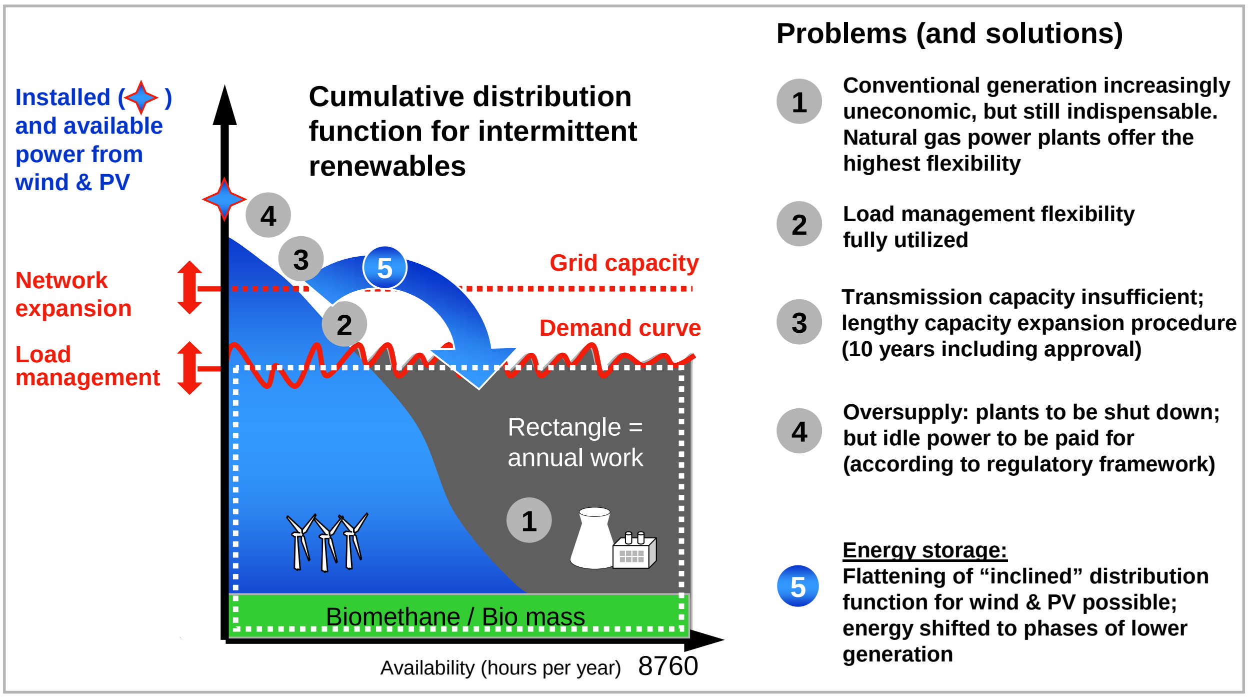



Figure 3: Limitations of load management and power grid extension and the effect of energy storage for an extended utilization of renewable energy

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