THE FUNCTION OF SALT CAVERN STORAGES IN THE FRAMEWORK OF NATIONAL AND EUROPEAN ENERGY SUPPLY – BY EXAMPLE OF THE ETZEL CAVERN STORAGE

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Abstract

Since many decades industrialized countries in the European Community have been deeply dependent on imports of energy resources. Owing to the unique geological conditions in Germany energy fuels are being stored for almost 50 years in huge volumes in confined underground formations to ensure energy supply with crude oil and natural gas. In the beginning crude oil stockpiling was the main issue in order to bridge possible interruptions in supply from politically unstable regions.

Since the 1980s natural gas has grown to an important source on the primary energy market. New underground storages, mainly salt caverns, were installed in Germany and the working gas was used to balance seasonal consumption and to cover peak demand. The liberalization of the European gas market some ten years ago triggered the demand for large and flexible cavern storage capacities for gas trading.

With the realization of the "energy turnaround" policy in 2011, the German energy industry, scientists and the society in Germany is facing new challenges. The concept 'power to gas' enables the combination of the electrical power grid with the gas infrastructure and opens the option of storing renewable energies in the large quantities in underground storages.

The example of the Etzel Cavern Storage Facility with 10 m m³of crude oil storage and more than 4 bn Sm³ working gas capacity by the end of 2014 demonstrates how the energy hub in the Northwest of Germany will play an important role in current and future energy supply.

1. Primary Energy Supply of Germany

For many decades Germany is not able any more to cover its demand for energy resources from own production: For crude oil and natural gas as well as for coal the nation has a high import rate. Lignite and renewable energies are the only 100% domestic supply sources.

In general, imports make up to 71 % of Germany´s primary energy demand. This situation is basically caused by the shortage of own resources in combination with

- the high energy demand of the industry and business location
- the high standard of living (infrastructure, mobility, consumption)
- climatic situation (heat generation).

Due to these frame conditions the economic necessity arises to provide and stockpile energy resources for national supply.

Although a stagnation or in some phases even a slight decrease in energy consumption can be recognized, yearly variations show a general trend towards greater proportion of natural gas and renewables at the expense of nuclear power. In respect to the German energy mix it becomes evident that crude oil and natural gas still prevail with some 56 % followed by coal and lignite with some 24 %.

Renewable energies hold a portion of almost 12 %, thereof 2 % generated from wind and solar power (2013 values [1]). Only 10 % of the German gas market is supplied by domestic production. More than one third of the primary energy consumption is imported from Russia, another 31 % come from Norway and 19 % from The Netherlands.

The apparent secure transport connections and long-term supply contracts with foreign producers do not change the situation of increasing import dependence on energy raw materials. In order to maintain a stable, continuous and secure energy provision for an industrialized nation diversified sources of supply and sufficient storage capacity are essential.

2. Stockpiling of energy fuels, types of underground storages

Compared to above ground storage options only underground storages are capable to hold crude oil, natural gas and other energy products

- in great volumes
- in safe containment (against sabotage, accidents, extreme weather etc.)
- for long and short-term storage

combined with the advantages of being

- flexible (injection & withdrawal on short notice) and
- environmental friendly (transferred in closed system, little surface area).

Due to technical and economic reasons two types of underground storages have prevailed worldwide:

- Depleted reservoirs and confined aquifers for gas storage (pore storages)
  Advantage: great capacities, low specific costs
  Disadvantage: high proportion of cushion gas, comparatively slow with injection and withdrawal, low flexibility

- Salt caverns
  Advantage: large storage volumes, flexible, high injection and withdrawal rates, multi-purpose utilization
  Disadvantage: high construction, operation and decommissioning costs, bound to geological deposit, utilization or disposal of produced brine, cavern convergence / surface subsidence

3. Function of cavern storages

With a closer look the cavern storages serve the following functions:
Historically, the first function of cavern was to store liquid fuels in great volumes in a secure subsurface environment as protection against warlike threat and sabotage.
In the 1960s and 70s the main purpose of cavern storages was stockpiling of crude oil and products to cope for interruptions in supply.

Stockpiling for crisis

- setup of national petroleum reserves
- on legal regulation
- organized by stockpiling agency

[1] AGEB Arbeitsgemeinschaft Energiebilanzen

Arbitrage

- by commercial trading companies
- in times of periodic price fluctuations
- under specific conditions (limited by location and time)

In Germany the first gas storage cavern became operative in 1971 with a working gas volume of 2 m Sm³. With increasing demand for gas storage several phases in development could be observed:

Phase 1: Safeguarding of contracts to supply

- by uncertainty in production and transport
- establishment of buffer-storages

Phase 2: Seasonal storage

- to balance seasonal differences in consumption
- coverage of peak demand

Phase 3: Intensification of trade

- as a result of the liberalization of the European gas market
- extension of the gas infrastructure in Europe
- establishment of „hubs"
- diversification of production centers

Phase 4: Underground storage of renewable energies

- transformation of electricity into mechanical energy (compressed air energy storage /CAES)
- transformation of electricity into chemical energy carriers (hydrogen or synthetic methane)
- storage of heat energy

4. Etzel Cavern Storage

The development and major characteristics of German cavern storages can be retraced by the example of the IVG´s Etzel Cavern Storage, situated near the city of Wilhelmshaven in the Northwest of Germany. Since more than 40 years the core business of IVG Caverns GmbH has been the construction, operation and lease of salt caverns for crude oil and natural gas. IVG is the only independent provider of subsurface energy storages in Germany. At Etzel a total of 73 Caverns (49 for gas, 24 for oil) are located which hold a total geom. volume of some 46 m m³. With the existing facilities a number of up to 25 caverns can be solution mined at the same time, and there is a potential for further development.

Fig. 1: Aerial View of Etzel Cavern Storage

The underground storage is connected to the European energy network by several major transport pipelines for oil and gas. By the customers the capacity is used for interim storage of import supply volumes and to cover peak demand. Besides natural gas the Etzel storage holds an important part of the strategic petroleum reserve of Germany and other states from the European community. There were good reasons to develop the location to an energy hub in northwestern Germany: The quality and the depth position of the Etzel salt dome, the favorable infrastructure, the proximity to the North Sea and the only deep water port of Germany where the largest crude vessels are being unloaded.

These unique conditions as well as longtime expertise in respect to perfected and safe cavern technology have convinced many big European energy suppliers to commit themselves to the Etzel site. Up to date, 73 caverns are in operation main characteristics:

1. Crude Oil Storage Caverns (24),
   favorable factors:
   - storage volume more than 10 m m³
   - pipeline connection to tank farm and tanker jetty (VLCC)
     further connected to refineries
   - high flexibility and flow rates for injection & withdrawal

2. Gas Storage Caverns (49),
   favorable factors:
   - storage volume (total WGV) more than 4.2 bn Sm³
   - pipeline connection to gas supply & distribution systems
     (BEP, NETRA, Emden-Etzel-Pipeline)
   - high flexibility and flow rates for injection & withdrawal

The capacity of the Etzel Storage corresponds to more than one quarter (27 %) of the German petroleum reserve and 17 % of the German underground storages for natural gas, hence it is of strategic importance for the security of supply of Germany.

5. Development of the storage capacity in Germany

With an underground storage capacity of 23.8 bn Sm³ (pore storages and caverns) Germany is able to stockpile 24 % of its yearly gas consumption. By diversification of supply for oil and gas, by a developed transport system and existing underground storages Germany is comparatively well positioned. The possible perspective to establish a \`Strategic Gas Reserve´ for Germany or other European partners could further improve the situation.

6. The function of underground storages with regard to renewable power production

The so called energy turnaround initiated in Germany in 2011 is mainly driven by the development of renewable electrical energy generation at the expense of nuclear and fossil fuels. Today, electricity occupies some 20 % of Germany´s energy demand. The withdrawal from nuclear power plants and the drastic reduction of CO_2-emissions is the political aim. The realization is planned to be achieved in the upcoming decades by the promotion of wind and solar energy production.

In this context the northern part of Germany, especially the state of Lower Saxony, will play a dominant role: Due to its geographical position a lot of wind power plants have already been installed and more will be built up on- and off-shore, and most of the existing underground storage capacity is also situated in this area because of the favourable geological conditions – huge salt formations in the subsurface.

According to political plans renewable power is becoming a primary energy source in Germany, its share in national power supply keeps rising. Due to geographic and climatic conditions wind power will play a leading role in this development. In order to balance the fluctuating and unpredictable electrical power production of wind parks large and flexible energy storages will be essential.

A very realistic option of storing excess renewable energy in large quantities is presented by the system `Power-to-Gas´ (PtG) using electrolysis to transform wind electricity into hydrogen or synthetic natural gas (SNG) and subsequently to store the chemical energy carrier in salt caverns.

Together with its partners, IVG is planning to build a pilot system for the long-term storage of wind-generated hydrogen at Etzel: A wind-hydrogen plant in combination with a large-scale storage (salt cavern) shall make use of synergies at the location. The stored hydrogen shall be made available according to requirement e.g. for admixture into the gas grid, usage for the industry, for mobility or for re-conversion to electricity. With such a pilot plant at Etzel the feasibility of a complete system of wind energy production/electrolyzer/ H_2-storage could be transferred from laboratory scale to industrial level. The wind energy bulk-storage process could be tested and optimized in respect to efficiency and cost effectiveness.

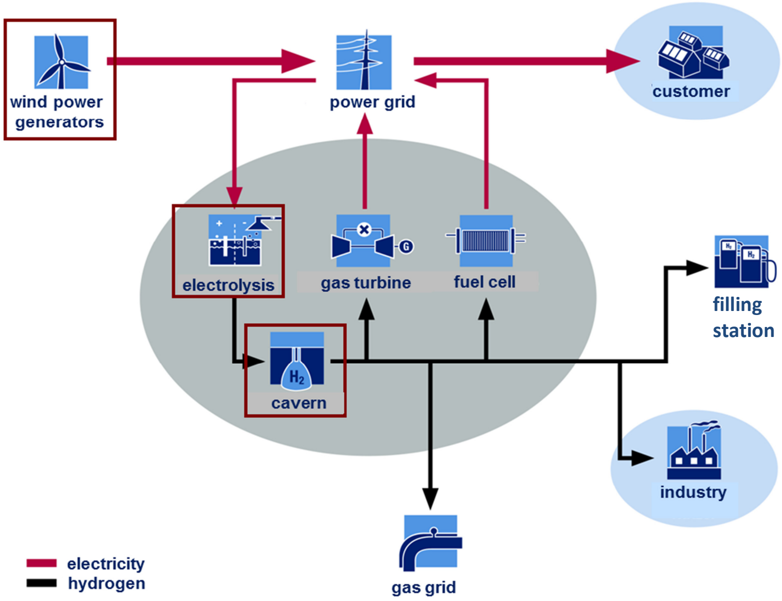

Fig. 2: Scheme of a pilot plant with different ways of H_2-utilization.

7. Conclusions

Increasing public opposition against any kind of mining activity and industrial large-scale projects as well as time-consuming authorization processes require the energy industry to be aware of the specific business situation. No matter what projects are planned or what operation has to be maintained in production, transportation or storage the branch is facing the following tasks and challenges to be cared for:

- Safety and environmental protection
- Enhancement of network
- Utilization of versatile supply
- Structuring of the energy sector
- Research & development
- Storage tailored to the market needs
- Cost control for energy supply

Other than years ago another important factor has to be considered for successful business and operation: Communication and public relations, that means

- consideration of the social environment,
- cooperation with politics, federations and authorities in order to establish planning reliability and
- generation of social confidence and acceptance by objective information and transparency.