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GAS STORAGE IN SALT CAVERNS "AARDGASBUFFER ZUIDWENDING" THE NETHERLANDS

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ABSTRACT

The Dutch national transport company Gasunie and the Dutch energy company NUON are in the process of implementing a large project involving the storage of gas in salt caverns, the first of its kind in the Netherlands. The Dutch-based international company Akzo Nobel has agreed to cooperate in the crucial part of realising the caverns.
Basic engineering work has been completed and the project has received approval to start construction early in 2006 with gas coming on-stream by the end of 2009.
Four salt caverns will be leached in a salt dome near the village of Zuidwending, situated in an area where Akzo Nobel has a concession to mine salt. This company has produced brine from this area since the 1960s, processing it in its factory in Delfzijl.
Coincidentally, this salt dome lies on top of the giant Groningen gas field.
The four caverns will each have a geometrical volume of 500 000 m3, and will be operated between 90 and 180 bar, resulting in a working gas volume of 45 million m3 per cavern.
Because a high total send-out capacity of 1.6 million m3/h as well as a high send-in capacity of 1.2 million m3/h is envisaged, two tubings will be installed per cavern.

The storage facility will be built and technically operated jointly by Gasunie and NUON. In line with the requirements of the Dutch energy regulator, marketing of storage capacity will be performed completely separately, using two "gas storage companies", one owned by Gasunie and one owned by NUON.
We expect the project to contribute to an increased security of supply and liquidity of the north-West European gas market.
Many aspects, such as regulatory issues, impact on the storage market, and the relationship between the partners presented a true challenge to the developers.
This paper will describe the project in some more detail.

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1. INTRODUCTION

1.1. Project history

During the last two decades, Gasunie has focussed on gas storage in caverns several times. The incentive to study caverns was the attractiveness as a high capacity measure during wintertime. Between 1986 and 1989, Akzo Nobel and Gasunie were in the process of executing a project in which 12 caverns were anticipated in the "Adolf van Nassau" concession near Zuidwending, a small village some 30 kilometres east of the city of Groningen. In this period, the project progressed to drilling a pilot well in order to establish the geological data, and to obtain core samples for leaching experiments and ascertaining the geo-mechanical stability of the caverns. The project was halted in 1989 because other alternatives - notably underground gas storage in the depleted Dutch gas field of Norg - proved to be more attractive in fulfilling the requirements at that time.
In the mid-nineties, during joint studies by NAM and Gasunie into the possibilities of covering the decreasing capacity of the Groningen gas field, caverns were once again in the picture. However, renovation of gas production clusters, addition of compressor units and additional storage facilities in the depleted gas fields of Grijpskerk and Alkmaar proved to be the preferred measures.
In 2000, the liberalisation process in the Netherlands triggered the Dutch regional energy distribution company NUON to study the feasibility of caverns in the Zuidwending area. At the same time, Gasunie was in the process of unbundling into a trading and a transport company. As a consequence, the transport company was facing changing responsibilities with respect to grid stability and security of supply, and became interested again in studying the feasibility of caverns. Because of reasons such as economies of scale and the different functions in the liberalised markets for NUON and Gasunie, the parties decided to join efforts. In the following years, all potential issues were covered in order to take a decision on the realisation of this project. Major items were the permits and zoning area procedure, as well as the execution of the basic engineering packages for the underground and surface facilities.

1.2. Gas infrastructure in the Netherlands

The main driver for building the Dutch gas infrastructure as it exists today has been the discovery of the huge Groningen gas field in the northern part of the Netherlands.
Gas penetration is now the highest in Europe, contributing more than 40% of total Dutch energy consumption, almost twice the EU average. The residential and industrial markets are more or less saturated.
Because the free flow capacity of the Groningen gas field is gradually decreasing, gas storage facilities have been developed during the last decade in order to be able to meet peak demand. The underground gas storage facilities in the depleted gas fields of Norg, Grijpskerk and Alkmaar have a total send-out capacity of up to 6 million m^3/h and several billion m^3 working gas volume.
In addition, production capacity from the Groningen gas field itself is prolonged under the Groningen Long Term Project, where each of the 29 production locations of the gas production company NAM will be upgraded with booster compressors.
Transmission of gas is the responsibility of the Dutch transmission system operator Gas Transport Services, a 100 % subsidiary of NV Nederlandse Gasunie. Gasunie owns and operates a high-pressure transmission network with a length of 11 600 km. Gas distribution is a joint effort of about 25 regional distribution companies, owning a distribution network with a total length of almost 120 000 km.

1.3. Market liberalisation & unbundling in the Netherlands

Since July 2004, market liberalisation for gas as well as electricity is effective for all groups of customers, including residential customers. The main gas supply company of the Netherlands, Gasunie Trade & Supply, imports gas for both local and export markets in order to prolong the life of its own sources. Distribution companies and other shippers nowadays import gas for their own portfolios, whereas in the pre-liberalisation era the distribution companies purchased their gas requirements from the formerly integrated Gasunie.
Following the full liberalisation of the Dutch energy markets, the formerly integrated Gasunie has been spilt into two independent entities as from July 1, 2005. These entities are N.V. Nederlandse Gasunie, including the TSO Gas Transport Services (100 % Dutch state-owned) and Gasunie Trade & Supply (Shell, Exxon, Dutch State). Although Gasunie Trade & Supply is still by far the largest supplier of gas

to the Dutch market, other suppliers are active in the Dutch market too. Energy distribution companies are free to purchase gas from companies other than Gasunie Trade & Supply.The larger distribution companies such as Essent and NUON have even built storage facilities using salt caverns (Epe - Germany), in order to accommodate – part of - their need for flexibility.The wholesale market, supplying the larger consumers as for instance the chemical industry and power plants, has been developed significantly too in the past years. For these consumers additional storage possibilities may be worthwhile.

2. OBJECTIVES

Whereas Akzo Nobel will extend the profitable use of its salt concession and mining know-how, Gasunie expects to be able to provide a full range of balancing and/or storage services to market parties. Nuon, because of its large portfolio of retail customers, requiring substantial gas supplies, seeks to:

- reduce costs associated with peak load demands
- reduce costs for re-balancing between actual and forecasted demand programs
- seize trading opportunities
- sell flexible gas services to 3rd parties.

3. PROJECT DESCRIPTION

3.1 Location of the gas storage project

The Dutch-based international company Akzo Nobel owns the "Adolf van Nassau" salt-mining concession in the Zuidwending area. Since the 1960s it has produced brine, which is processed in its plants in Delfzijl, some 35 kilometres east of Zuidwending, see figure 1. The detailed figure shows that the storage project is situated between three small villages, Zuidwending, Ommelanderwijk and the Pekela's.

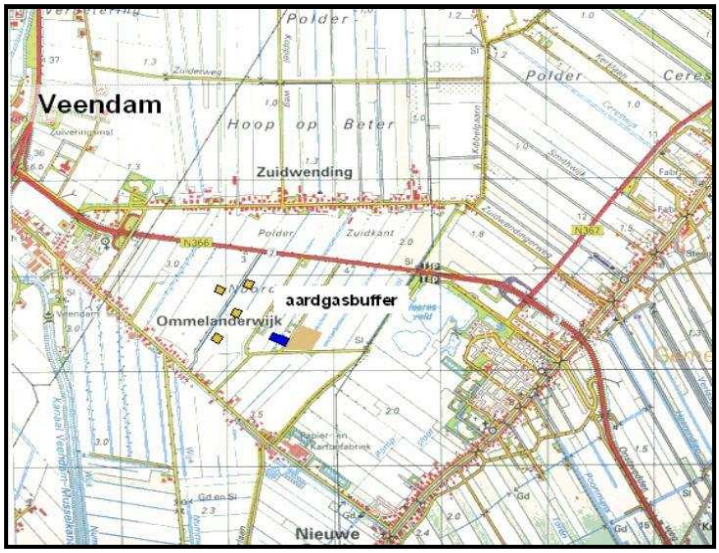

Fig.1a & 1b - Location of the gas storage project

The excellent brine quality up till now indicates a very pure salt dome, minimising the geological risk of constructing and operating gas storage caverns. In addition, the proximity of gas lines and the Groningen gas field make the site highly favourable for natural gas storage.

3.2 The Zuidwending salt dome

The salt dome is an upward lobe of the Zechstein Salt Formation, tightly sealing the huge Groningen gas field, which lies beneath almost the whole province of Groningen, in the northeastern part of the Netherlands. The salt dome itself consists of two distinct lobes, starting at a depth of 3000

m up to 200 m below ground level. Only Akzo Nobel has exploited the northeastern lobe up till now, using nine brine production caverns. The cross sectional area of the salt dome is approximately 15 km². The shape of the salt dome has been derived from seismic data, see figure 2.

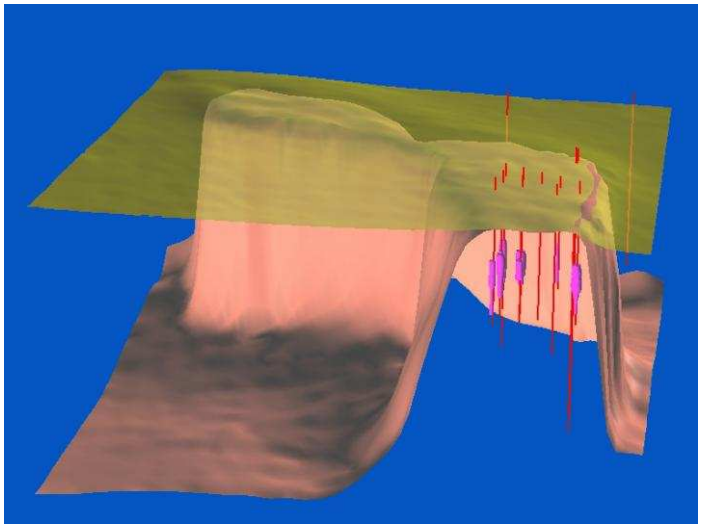

Fig. 2 - Zuidwending salt dome

The northeastern lobe is situated between three small villages, Zuidwending, Ommelanderwijk and Oude Pekela.

3.3 Design data

The main characteristics of the planned Zuidwending Storage facility are given in table 1.

Design data Zuidwending gas storage		
Number of caverns	4	-
Geometrical volume / cavern	500000	m3
Depth of casing shoe	1000	m
Depth of cavern sump	1350	m
Send-out capacity	1.6 mln	m3(n)/h
Send-in capacity	1.2 mln	m3(n)/h
Working gas volume	180 mln	m3

Table 1 - Design data Zuidwending gas storage

The geometrical volume of 500 000 m³ is a common size for gas storage caverns, and appears to be sufficient for the anticipated purposes. The depth of the last cemented casing shoe is 1000 m, permitting a maximum storage pressure of 180 bar. This depth also guarantees a very low convergence of the caverns. Extensive calculations based on the existing brine production caverns and accurate subsidence measurements have shown that the subsidence resulting from the cavern convergence will be insignificant.

Gasunie and NUON will each be entitled to half of the available geometrical volume. From the total send-out capacity, Gasunie will held 1.0 million m³(n)/h, whereas NUON will be entitled to 0.6 million m³(n)/h.
With respect to injection capacity, Gasunie has entitlement to 1.0 million m³(n)/h and NUON to 0.2 million m³(n)/h.

3.4 New leaching facility

The existing brine pumping station of Akzo Nobel cannot be used to leach the gas caverns, as this pumping station is not designed for the pressures necessary to leach at the desired depth with a leaching capacity of 300 m3/h. Therefore, a new leaching facility will be built, capable of leaching four caverns simultaneously, hence having a maximum capacity of 1200 m3/h. Because the brine will not be saturated due to the high flow per cavern, saturation will be performed by pumping the unsaturated brine into the existing caverns of Akzo Nobel. An artists' impression of this new pumping station is presented in figure 3.

Fig. 3 - Artists' impression pumping station for cavern leaching

3.5 Cavern design and well layout

The main dimensions of the caverns are visualised in figure 4.

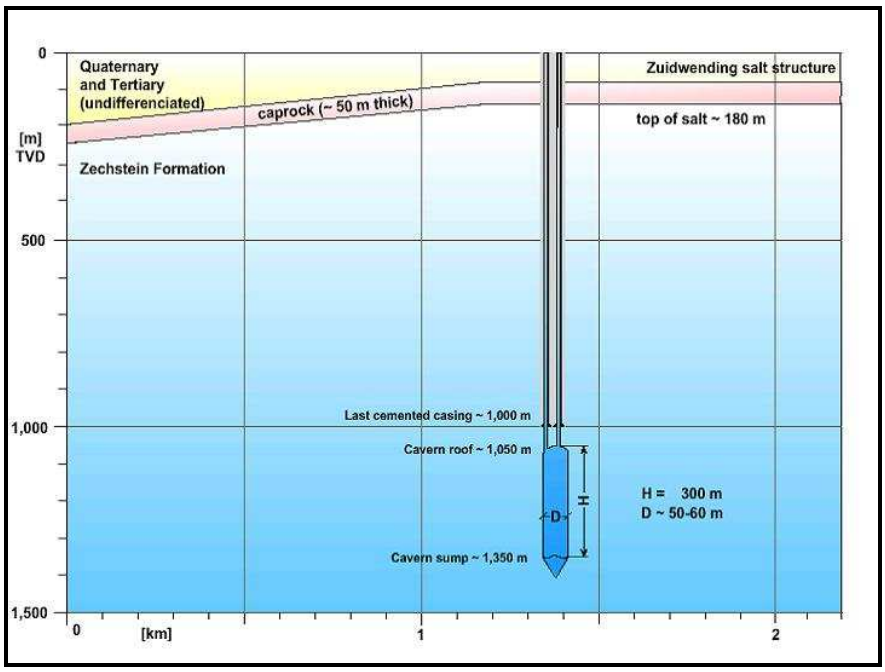

Fig. 4 - Main dimensions of the planned caverns

Due to the anticipated high withdrawal and injection rates of up to 400 000 m³ (n)/h per cavern, each caverns will be equipped with two wells. Although a rate 400 000 m³ (n)/h would be technically

possible with only one tubing, the pressure drop would be significant, decreasing the send-out and send-in capacities at lower pressure levels. Moreover, energy consumption during injection would be high, especially when frequent injection is anticipated.

3.6 Gas storage facility

The usual process steps in a gas storage facility are given in figure 5.
Natural gas needs to be compressed before it can be stored in a cavern. Since compression results in a temperature increase, the gas has to be cooled down before injection to prevent thermal stresses in cavern and equipment. A total of six compressors will be installed, each with a capacity of 200 000 $m^3(n)/h$. With this compressor pool, high flexibility and high availability will be achieved.

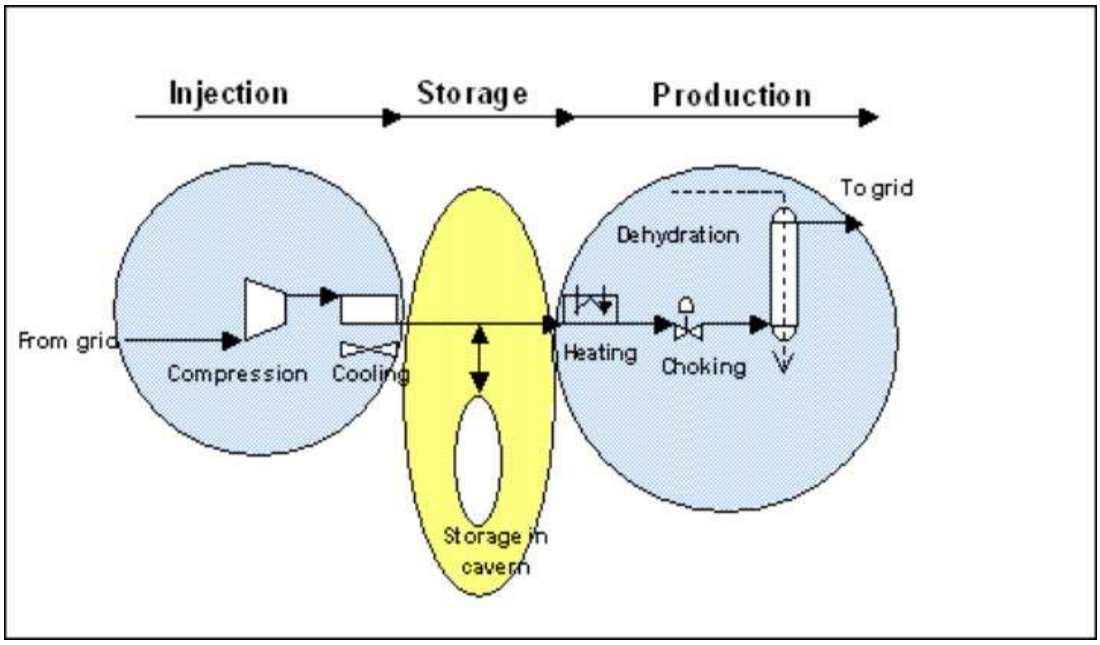

Fig. 5 - Main process steps in gas storage facility

During withdrawal of gas from the cavern (send-out), the gas needs to be reduced to the pressure, temperature and dew point conditions of the grid. For the Zuidwending project, an adsorption system (silica gel, mol sieves) has been compared to an absorption system (glycol). The anticipated operation of frequent changes from send-out to send-in and vice versa clearly favoured the latter system, as the frequent heating and cooling down of the adsorption beds would lead to significant energy losses. Three 50 % parallel process trains of heating and choking have been chosen, followed by two 50 % parallel process trains of glycol absorption, in order to achieve sufficiently high send-out availability. The piping arrangement has been designed to operate one, two or even three caverns independently from the other cavern(s), hence two different cavern pressure levels can be accommodated.

3.7 Permits & zoning plan

The implementation of a gas storage project requires a variety of permits. In the case of Zuidwending, the main legislation covering the various procedures for obtaining permits consisted of the Spatial Planning Act, the Environmental Management Act and the Mining Act.
Adaptation of the existing spatial zoning plan proved to be the most time-consuming procedure, taking more than two years, due to public hearings, appeals, consultation with municipal and provincial authorities etc. The application for the environmental permit required an environmental impact assessment (EIA), including a quantitative risk assessment of potential dangers, such as a pipeline rupture, a cavern blow-out and a gas explosion in the gas plant. The combined effect of all these potential dangers appeared to be low and manageable and obviously well within the legal limits required by the national authorities.
The Mining Act required a Salt Exploitation Plan, dedicated to the leaching of the gas caverns, a Gas Storage Plan and an application for a Gas Storage Permit. The Mining Act was renewed in 2002 and new principles regarding storage were included, several areas had not yet been completed however.

This very first gas storage project under the new Mining Act was, therefore, an additional challenge to both the authorities as well as the project team.

3.8 Environment

The environmental impact has been assessed for all relevant fields such as:

- soil and ground effects
- groundwater
- sound
- waste
- air emissions
- landscape

The results of this assessment have been reported and the main conclusions are published on the website dedicated to the project, www.aardgasbufferzuidwending.nl, and will therefore not be treated here.
As mentioned earlier, the possible subsidence has been investigated extensively, as this was obviously a major concern to the authorities as well as the neighbours. Fortunately, the brine production history of Akzo Nobel and the minor subsidence measured accurately could be used to adjust the subsidence modelling. Extensive calculations revealed that the subsidence due to gas storage will be minimal.

3.9 Future extension possibilities

In the first phase of this gas storage project, four caverns will be leached. Because both Gasunie and Nuon anticipate future need for additional caverns an option for developing additional caverns has been agreed with Akzo Nobel.The spatial zoning plan as well as the environmental impact assessment have already been adapted to take account of this potential extension. Additional permits have to be obtained before an extension can be realised.

3.10 Investments

The total investment for this project amounts to roughly € 350 million, comprising the leaching facilities, cavern pads, cavern wells, casings and tubings, field pipelines, leaching process, first gas fill, gas facilities, a redundant power connection to the high voltage grid, as well as a connection to the gas grid.
Special attention has been given to integrating the facilities into the surroundings, where the wishes of local neighbours have been taken into account, as far as practically possible.

3.11 Time schedule

In figure 6 the main items constituting the overall time schedule are shown.

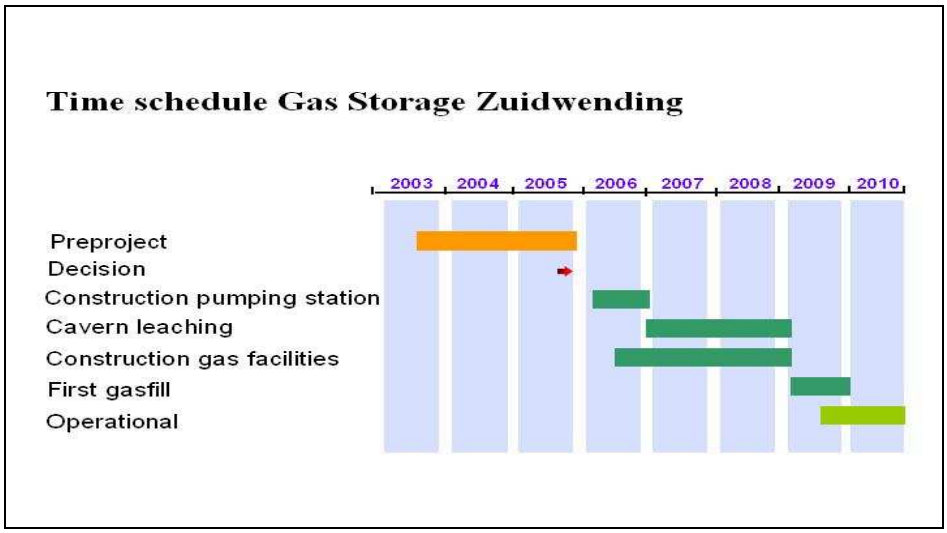

Fig. 6 -Time schedule

At the time of issue of this paper, i.e. at the end of January 2006, the activities for the construction of the leaching station were getting started: preparation of dedicated access roads, clearing of the construction area, activities to secure the power supply, pipe laying etc.
The plan is to start drilling the wells in July 2006, which will continue up to September 2007.
If no major problems are encountered, the leaching process for the first cavern will start at the end of 2006, work on the next caverns will gradually start in 2007. In principle, three caverns will be leached in parallel, and the fourth cavern will be leached if sufficient brine can be taken off by Akzo Nobel, or one of the three caverns is temporarily not being leached, for instance for cavern shape measurements. The first gas fill is envisaged to start end of 2008, resulting in having the first cavern operational in mid-2009. The other caverns should follow at intervals of several months.

3.12 Public relations

From the start of the pre-project, we realised that good public relations would be essential in order to get the required approvals in time. We started by informing the national authorities, followed by the provincial and municipal authorities, the local neighbours and the press, all by way of short presentations showing our intentions, and we encountered an attitude that was mostly constructive but included some criticisms. Every six months we organised an evening for the local neighbours, keeping them informed, but also giving them the chance to voice any worries, raise questions etc., all in a very informal way. Applause at the end of every presentation undoubtedly proved that this type of information exchange was highly appreciated ! We have tried to be as "open" and informative as possible in our communications, even using a dedicated web-site www.aardgasbufferzuidwending.nl, Q & A possibilities etc.

4. BUSINESS MODEL

It is envisaged that Gasunie and NUON will form an entity for the construction, operation and maintenance of the installation. Each company will have a 50 % voting right in this entity. However, the ownership of the Zuidwending facilities belong to the Gasunie Zuidwending Company and the NUON Zuidwending Company, and is based on the investment costs contributed by the two companies. The structure is presented in figure 7.

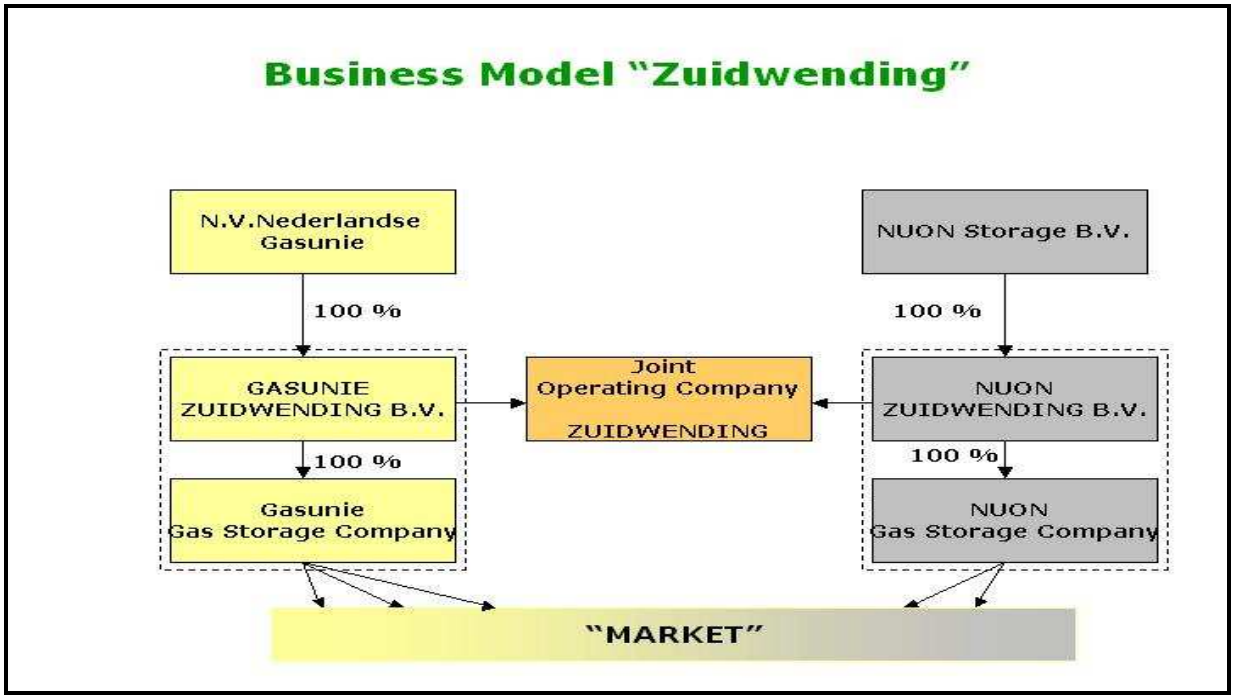

Fig. 7 - Business model Zuidwending

Operation and maintenance of the installation will be procured via Service Level Agreements as far as practically possible.
Gasunie and NUON will market the capacity via their Zuidwending Company, possibly by dedicated Gas Storage Companies. Anyway, Gasunie and NUON will separately and independently market the capacity they are entitled to.
The benefits of the cooperation are in the economy of scale of the installation and in the operation and maintenance of the facilities.

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