Report

“Assessment on the level of transport costs for gas storages in the Netherlands”

for

Autoriteit Consument en Markt („ACM“)

by

KYOS Energy Consulting BV (“KYOS”)

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Content

1 Background

The Netherlands Authority for Consumers and Markets (“ACM”) has requested KYOS to make an assessment on the level of transport costs for gas storages in the Netherlands. The reason for the assessment is that the Dutch association for gas storages (“VGN”) has expressed its concerns over the level of transport costs that storages face in the Netherlands. According to VGN, transport costs for gas storages are considerably higher in the Netherlands compared to Germany; this results in lower (or even negative) margins which may lead Dutch gas storages to close down. ACM has requested KYOS as an external and independent consultant to evaluate the claim of VGN.

KYOS Energy Consulting BV (“KYOS”) is an expert in valuation of flexibility in energy markets, and is market leader in delivering gas storage valuation software in Europe. Over the last years KYOS performed various research studies in relation to gas storage.

2 Research questions

Transport costs are the costs which the users of gas storage have to incur in order to transport the gas to the storage from the network and vice versa. The transport costs are fees which are paid to the transmission system operator (TSO). VGN claims that transport costs in the Netherlands are high, and considerably higher compared to Germany. They claim that this leads to lower (or even negative) margins, and potentially a withdrawal of storage facilities from the Dutch TTF gas market. One of the main reasons brought forward by VGN is that in Germany, day-ahead transport capacity is offered at more favorable terms, and availability of daily transport capacities is much better guaranteed than in the Netherlands. Another reason brought forward by VGN is that in the Netherlands, the application of seasonal factors makes transport in the winter costlier.

The claim of VGN leads to the following two main research questions:

1. How can the transport costs for storages in the Dutch and German gas markets be compared, considering the differences in storage parameters, tariff structures and market practices? Are transport costs for storage facilities higher in the Netherlands than in Germany?
2. What is the impact of high transport costs on the business case of Dutch storage facilities? What is a likely course of action when a storage operator is confronted with a prolonged period of depressed margins?

To address the first question, this report presents an in-depth quantitative analysis of the storage transport costs in 2017 in the Netherlands and Germany. The costs are calculated for a representative sample of individual storages, of which 14 are connected to the Dutch gas network and 25 to the German gas network[1]. In order to have a fair comparison between markets and storages, the main analysis uses optimal storage flows in the storage year 2016 (1 April 2016 to 1 April 2017), calculated with actual market prices and using the KyStore gas storage optimization software. The use of optimal flows, instead of actual historical flows, ensures that the results are not affected by maintenance schedules, differences in booking practices or suboptimal usage of the storage.

To address the second question, the report assesses the market value of Dutch storages. The deduction of transport and other costs leads to an estimate of the margin and allows us to assess the business case of Dutch storages. This provides insight into whether storages may withdraw from the Dutch market, either by connecting to the German grid (if possible) or closing the facility.

In chapter 3 the transport booking structures and costs are compared between Germany and the Netherlands. We assess the costs of annual bookings, daily bookings and the actual booking practices. Chapter 4 describes the business case of Dutch gas storages and assesses their

[1] Note that we refer to the first group as ‘Dutch storages’ even though they may physically be located in Germany; we refer to the second group as ‘German storages’ even though they may be physically located in Austria. Some storages appear in both groups if they have a connection to the Dutch and the German network.

profitability. This sheds light on the conditions under which storage closures or departures from the Dutch gas market may be expected.

3 Transport cost comparison

There are several ways to compare storage transport costs between countries, not only because there are different tariff structures, but especially because there are different booking strategies and practices. In this chapter, in the beginning of 3.1 we calculate the average level of the tariffs, simply adding up entry and exit tariff which apply to annual bookings, and taking the average across a sample of 14 Dutch and 25 German storages.

The subsequent more detailed analysis derives the transport costs from the optimal storage flows of each storage individually:

- Assuming annual bookings in both countries (3.1)
- Assuming daily bookings in both countries (3.2)
- Assuming annual bookings in the Netherlands and daily bookings in Germany, the current actual business practice (3.3)

Section 3.4 summarizes the results.

3.1 Costs for annual bookings

The main component in the costs of transport on the gas network is the level of the entry and exit fees. Table 1 shows the summary statistics, calculated over all 14 storages in the Netherlands and all 25 in Germany, and adding up the tariffs for entry and exit. The average combined tariff for the Netherlands for an annual booking equals 1.76, and for Germany 3.15 €/kWh/h/a. For Germany, this includes the 50% discount, for the Netherlands the 25% discount for storage operators.

	NL	DE
Average	1.76	3.16
Median	1.68	3.29
Minimum	1.35	1.65
Maximum	2.22	4.57

Table 1: Summary statistics of the sum of entry and exit tariffs in 2017 for annual bookings. The statistics are calculated over 14 storages in the Netherlands and 25 in Germany. The tariffs are in €/kWh/h/a. Source: TSO websites and KYOS analysis.

This comparison provides a first insight into the level of transport costs, but more factors need to be considered. For example, especially for fast cycle storages, the withdrawal rate is often higher than the injection rate, so more entry capacity than exit capacity is needed. Secondly, a fast-cycle storage may need the transport capacity on fewer days than a seasonal storage, but for relatively larger volumes, so the capacity costs may be high relative to the working volume of the storage.

In order to incorporate these elements, we have calculated for each storage facility the total costs of an annual booking of entry and exit, in line with the maximum injection and withdrawal capacity of each storage. For example, Zuidwending (Energystock) has a maximum injection rate of 258

GWh/day and a maximum withdrawal rate of 431 GWh/day. With an exit tariff[2] of 0.476 and entry tariff of 0.870 €/kWh/h/a, the costs are (258 x 0.476 + 431 x 0.870) * 10^6 / 24 = 20.75 mln € per year.

Figure 1 shows the level of these costs per MWh of working volume. It can be seen that, in general, fast-cycle storages have higher costs per MWh of working volume than seasonal storages. The Dutch storages are numbered from 1 to 14, in order of cycle time. We use the same numbering in other figures:

1. Zuidwending (Energystock)
2. Epe (Eneco)
3. Epe (Nuon / Vattenfall)
4. Nüttermoor (EWE)
5. Etzel (Crystal)
6. Epe (Innogy)
7. Jemgum (Astora)
8. Etzel (EKB)
9. Etzel Freya (OMV)
10. Alkmaar (Taqa)
11. Jemgum (EWE)
12. Bergermeer (Taqa)
13. Grijpskerk (NAM)
14. Norg (NAM)[3]

The transport costs in the Netherlands are on average lower (2.41 €/MWh) than in Germany (2.98 €/MWh). The difference is actually larger, because the Dutch storages are faster on average with a cycle time of 109 days versus 122 days for Germany. If we draw a line[4] through the German storage assets, and estimate the transport costs of a 109-day storage, the German annual booking costs are 3.28 €/MWh. So, we conclude that the average German transport costs per MWh of working volume, in case of an annual capacity booking, are 36% (3.28/2.41 – 1) above those in the Netherlands.

[2] The TSO exit tariffs are paid to transport gas out of the network of the TSO, e.g. injected into the storage. Likewise, entry tariffs are paid to transport gas into the TSO network, e.g. withdrawn from the storage.

[3] Norg is the largest Dutch storage facility. It is not used in the same way as other storages, because it has a direct pipeline to the Groningen production field. Therefore, most of the injections bypass the GTS network and no exit capacity has to be booked. For this reason, we have considered to exclude Norg. However, because Norg is an important Dutch storage, and for withdrawals it has to book capacity at GTS, we have decided to include it as a normal storage in the analysis. Where needed, the analysis corrects for differences in cycling time, so we believe this does not lead to a bias in the results.

[4] An ordinary least-squares regression analysis gives a relationship of Y = 5.72 – 0.0224 *X, where Y is the German transport cost for an annual booking and X is the cycling time in days. So, the estimated cost of a 109-day German storage is 5.72 – 109 * 0.0224 = 3.28 €/MWh. The same type of regression for Dutch storages leads to the cost of 2.41 for a 109-day storage.

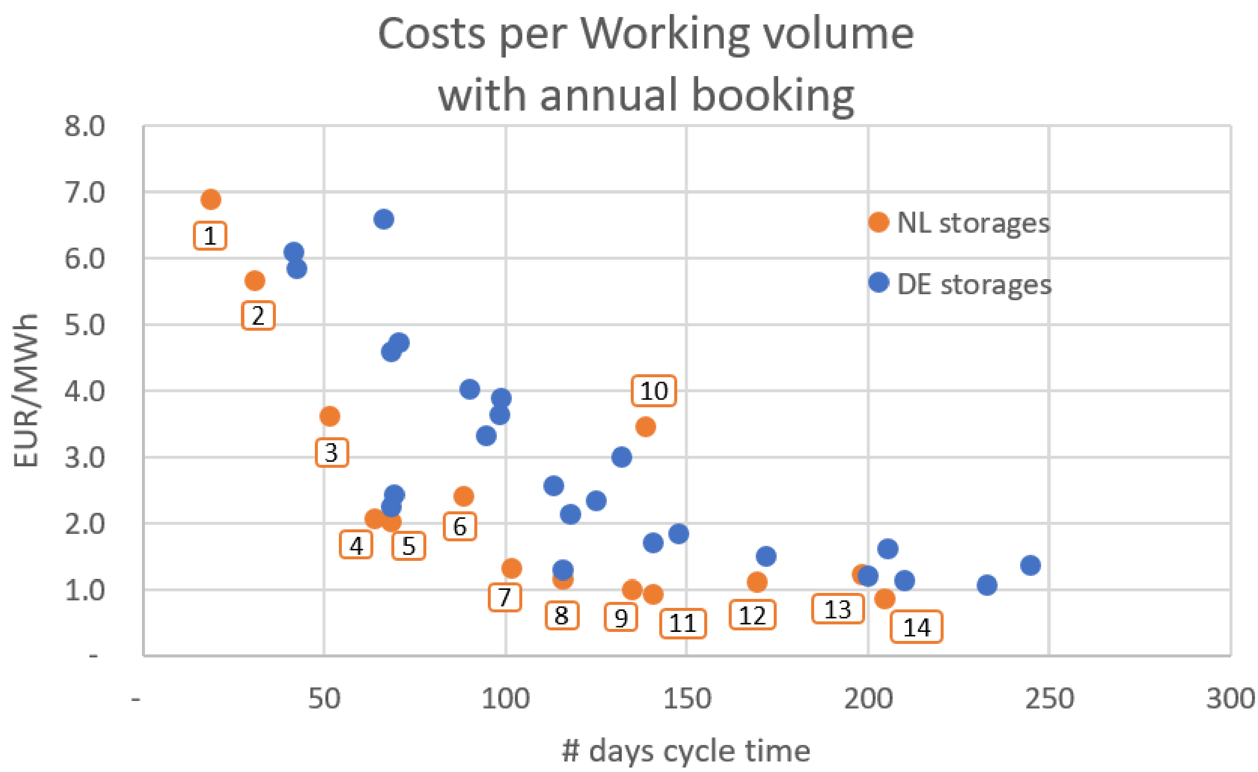

Figure 1: Transport costs in 2017 if entry and exit capacities would have been booked for the whole year. The costs are divided by the working volume. The Dutch storages are numbered from 1 to 14, based on their cycling time. Source: KYOS analysis.

3.2 Costs for daily bookings

3.2.1 Advantages of a daily booking

A crucial element of the Dutch storage operators' criticism on the level of storage costs, is the fact that they (have to) book per year in the Netherlands. This contrasts with Germany, where virtually all capacities are booked per day. So, a comparison based on an annual booking in both countries does not reflect the actual booking practice.

In practice, there are many days on which a shipper does not have to book capacity at all. And if capacity is needed, it is normally either entry or exit, not both. Our analysis (explained further on) shows that the average optimal utilisation rate for Dutch storages is just around 27% for injections and 14% for withdrawals. Daily bookings therefore create large cost savings, even though the TSOs apply multiplication factors to short-term bookings which are generally higher than 1. As explained in appendix B, this multiplier is 1.4 in Germany, while in the Netherlands it is 0.91 (May - September), 3.65 (December February) or 1.82 (March, April, October, November). The seasonality in the Dutch GTS multipliers makes daily bookings especially attractive in the summer.

Because of the large differences in seasonal multipliers in the Netherlands, there is no straightforward way to compare the costs of daily bookings between both countries. A fair comparison requires insight into the daily storage flows, which may e.g. be larger in summer than in winter. It would have been possible to use the actual historical flows as a benchmark, but there are a few reasons not to do so:

- Because users of Dutch storages have booked per year, their capacity costs are sunk costs and have no impact on their operations. In contrast, in Germany the bookings are (mostly) per day, adding to the variable operational costs. Consequently, utilisation rates in Germany are lower than in the Netherlands.
- Storages may not be used to their full economic potential. There may be technical reasons (outages), not all storage capacity may be sold to third parties, or the third parties (the shippers) may not operate optimally. It is better to make the analysis independent from these influences.

For completeness, the analysis has also been performed with the actual storage flows. The results are available on demand. The most important insight is that, in practice, German storages cycle less frequently indeed. The analysis also shows that storages are less actively used than optimal. This means that there are fewer injections and withdrawals than what would be optimal according to the Kyos analysis: in Germany 34% less, and in the Netherlands 28% less.

3.2.2 The optimal flows for storages

Instead of using actual historical flows, we have performed an in-depth analysis to determine the optimal flows in the market during storage year 2016, i.e. from 1 April 2016 to 1 April 2017. This so-called backtest determines the optimal action of the storage per day using the least-squares Monte Carlo methodology[5]. In this backtest, on each day the model 'knows' the current inventory level, the market prices (spot and forward), and the market price volatilities. Based on this information it finds out whether it is optimal to inject or withdraw, and this leads to a new inventory level the next day. The market prices (TTF, NCG, GPL) are from the exchanges ICE, EEX and Pegas. In this backtest analysis, we have added the daily booking costs to the storage variable costs. Figure 2 shows the result of one such backtest, taking as an example the Etzel storage of EKB, a joint venture of BP, DONG Energy and Gazprom Germany. The graph displays the development of the inventory level (blue bars) and the TTF spot price (black line).

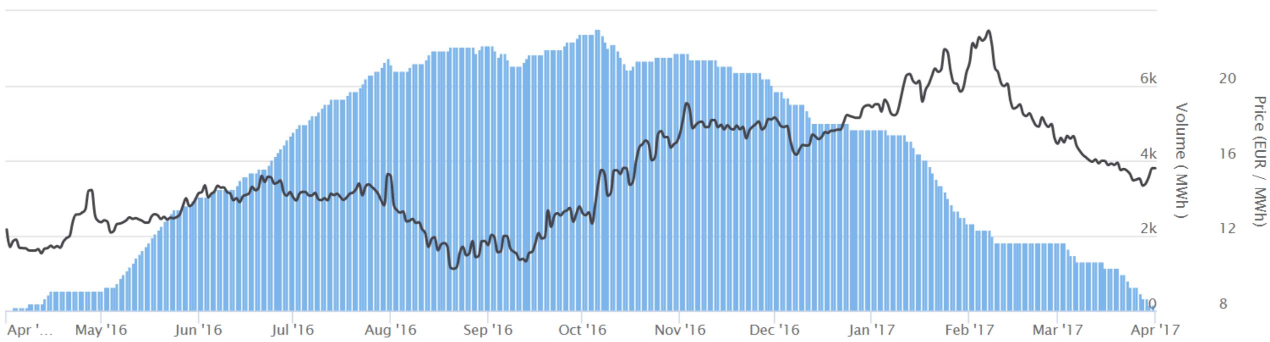

Figure 2: EKB Etzel storage optimal flows (blue bars), and TTF market prices (black line). Source: KYOS Analytical Platform.

[5] See https://www.kyos.com/gas-storage-pricing-hedging/ and https://www.kyos.com/energy-asset-optimization/gas-storage-optimization for descriptions of this methodology and the KyStore optimization software.

The backtest generates the optimal flows for the storages, as well as the corresponding daily booking costs. The costs are divided by the total cycled volume to obtain the transport costs per cycle[6]. On average, they equal 0.34 in the Netherlands and 0.48 €/MWh in Germany (41% higher). The results per storage are displayed in figure 3[7].

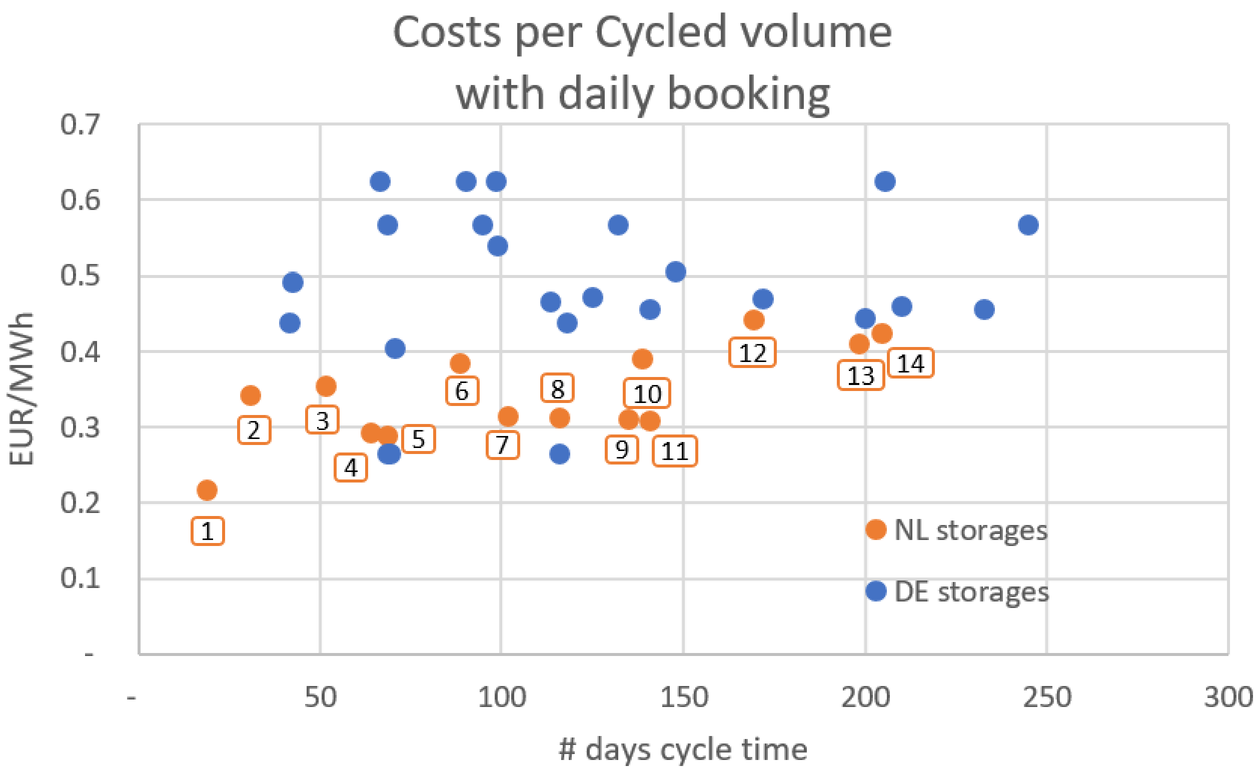

Figure 3: Transport costs in 2017 if entry and exit capacities would have been booked per day. The costs are calculated in a backtest to determine the optimal flows in storage year 2016, and divided by the total cycled volume. Source: KYOS analysis.

3.3 Costs with actual booking practice (Netherlands annual, German daily)

The analysis so far suggests that transport costs for storages in Germany are higher than in the Netherlands. With annual bookings in both countries, the difference is 36%, while with daily bookings the difference is 41%. However, the reality is that Dutch storages book per year, mainly because of their 10-year agreements with GTS[8], while German storages primarily book per day,

[6] We choose to divide by the cycled volume (optimized in the backtest), rather than the working volume, because it also captures the speed of the storage, and therefore leads to a fairer comparison of the costs. Storages which have a large working volume and are fast, will have the highest absolute costs, but also the largest cycled volume.
[7] Note that there is no real dependency of the daily booking costs on the cycling time, so no correction is needed to bring the German average cycling time to 109 days, as was done in the comparison of annual tariffs.
[8] The agreements between GTS and storage operators are private contracts to which Kyos has no direct insight. Our understanding of these contracts is based on general information which Kyos received from market players. According to that information, the 10-year agreements were standard practice of GTS to recover the initial investment costs of the grid connection. It is our understanding that these agreements

which is cheaper. For only one Dutch storage (Epe Innogy) the agreement with GTS is just past the end date; the other storages still have to wait for 1-7 years before transport capacity can be booked with GTS per day. Because of the differences in booking practices, the actual transport costs for Dutch storages are much higher than in Germany. Obviously, this also means that the income from storages is much higher for the Dutch TSO (GTS) than for the German TSOs.

Figure 4 displays these costs for each storage individually, expressed per MWh of working volume. For the average Dutch storage, the cost is 2.41 €/MWh, for the average German storage 0.50 €/MWh, a factor 4.9 difference. The figure also demonstrates that especially fast-cycle Dutch storages face high costs, with Zuidwending of Energystock at the top: almost 7 € per MWh of working volume.

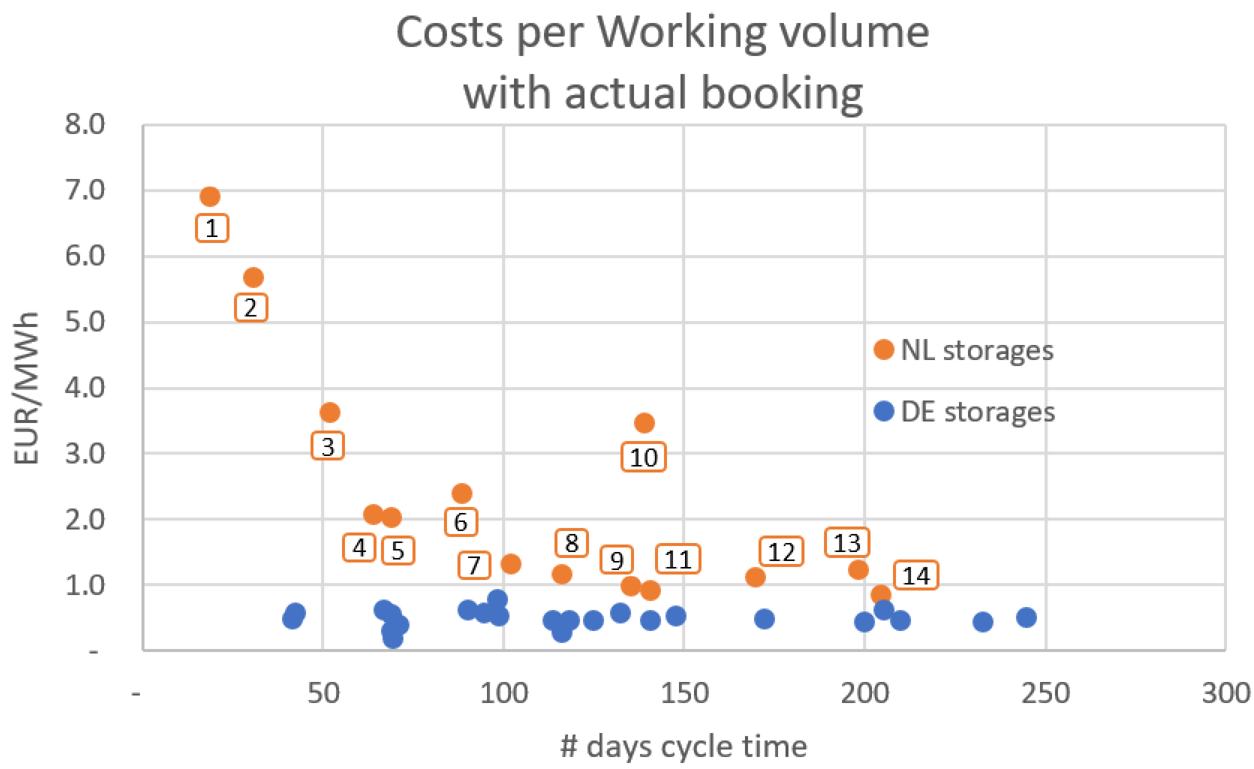

Figure 4: Transport costs in 2017 if entry and exit capacities would have been booked per year in the Netherlands and per day in Germany, in line with actual practices. The costs are calculated in a backtest to determine the optimal flows in storage year 2016, and divided by the working volume. Source: KYOS analysis.

In figure 4 it can be seen that, in the Dutch gas market, the booking costs per working volume decrease with the number of days to cycle. In figure 5 the costs are displayed per cycled volume, providing a more equal level for fast and slow storages. An annual booking strategy allows all storages to make more cycles: once booked, the capacity costs are sunk and extra cycles come

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require storage operators or the shippers to make annual bookings for their maximum injection and withdrawal capacities. This is also supported by the information about multiple years of booked transport capacities which is published on the transparency website of ENTSOG. Note that for the economics of a storage, it is irrelevant whether the shipper or the storage operator books the transport capacity, because this will be reflected in the price paid for storage. In this report, whenever it is stated that storage operators book per year, in practice this may be the shippers using the storage.

essentially for free, except for the storage's own variable operational and maintenance costs. With a second series of backtests, we confirm this behavioral change. In this second type of backtest, the daily booking costs are not included in the daily optimization. Compared to the first series of backtests, this increases the average number of cycles in the Netherlands from 1.35 to 1.65, in Germany from 1.02 to 1.21.

With the two types of backtests we can make a fair assessment of the transport costs per cycled volume based on current booking practices (and possibilities) in both countries. For the Netherlands, the relevant volumes are those from the backtests excluding daily booking costs (because bookings are per year); for Germany, the relevant volumes are those from the backtests including daily booking costs. The results are presented in figure 5. The average for Dutch storages is 1.35, for German storages 0.48 € per MWh of cycled volume. This is a factor 2.8 difference.

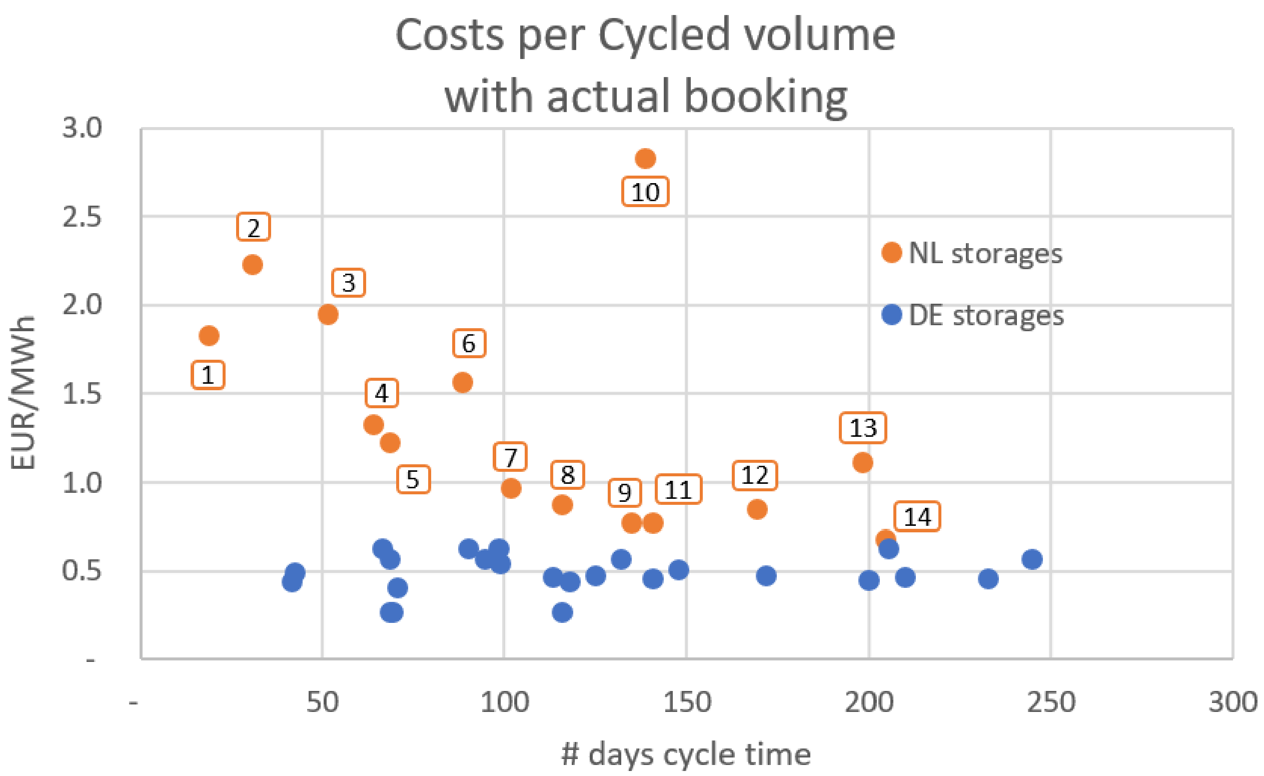

Figure 5: Transport costs in 2017 if entry and exit capacities would have been booked per year in the Netherlands and per day in Germany, in line with actual practices. The costs are calculated in a backtest to determine the optimal flows in storage year 2016, and divided by the total cycled volume. Note that the scale is different than in figure 4, because costs per cycled volume are generally lower than per working volume. Source: KYOS analysis.

3.4 Summary of the cost comparison

The results of the previous sections are summarized in tables 2 and 3. Assuming the same booking strategy in both countries, Germany has higher transport costs. The costs for daily and for annual bookings in Germany are higher both per working volume (table 2) and per cycled volume (table 3).

However, the picture changes drastically when the current actual business practice is assumed, where almost all Dutch storages book per year, while German storages book per day. Then it can be concluded that the costs per working volume are a factor 4.86 (per working volume) or 2.79 (per cycled volume) higher in the Netherlands than in Germany. The figures 4 and 5 furthermore show that mainly fast Dutch storages (Zuidwending, Epe) are affected by the cost disadvantage, and especially when the costs are expressed per working volume.

Costs per working volume	NL EUR/MWh	DE EUR/MWh	DE/NL	NL/DE
Annual bookings	2.41	3.28	136%	73%
Daily bookings	0.45	0.50	111%	90%
Actual bookings	2.41	0.50	21%	486%

Table 2: Transport costs in 2017, average across the 14 storages in the Netherlands and 25 storages in Germany. The costs are divided by the working volume. Source: KYOS analysis.

Costs per cycled volume	NL EUR/MWh	DE EUR/MWh	DE/NL	NL/DE
Annual bookings	1.35	2.40	177%	56%
Daily bookings	0.34	0.48	142%	70%
Actual bookings	1.35	0.48	36%	279%

Table 3: Transport costs in 2017, average across the 14 storages in the Netherlands and 25 storages in Germany. The costs are divided by the cycled volume. Source: KYOS analysis.

4 Business case for Dutch storage facilities

Dutch storage operators, or the gas shippers using their storage, face relatively large transport costs. The analysis in chapter 3 shows that Dutch storage operators and shippers make high transport payments to GTS, and these are higher than the transport payments for storages connected to one of the German grids, where bookings are made per day. The level of the costs is especially problematic, because market conditions are not good. The income of gas storage operations is mainly a function of winter-summer spreads and of spot price volatility in the gas market. Both are at historically low levels and there is currently no indication that they will rise in the foreseeable future.

Figure 6: Development of the TTF winter-summer spread, more precisely the 50-day moving average of the most nearby Jan-Mar forward price minus the Jul-Sep forward price. Source: KYOS analysis using ICE settlement prices.

Section 4.1 describes storage operator options to deal with the low profitability: connecting to a German grid, mothballing or closure. Section 4.2 analyzes in more detail the profitability of storage operations, comparing the expected income to the transport and other costs. The main explanation for the high costs in the Netherlands, is the practice of booking per year. In section 4.3 we discuss the risks of daily bookings. Section 4.4 discusses potential implications for the Dutch gas market if storages would either close or connect to the German grid.

4.1 Potential response of storage operators to high costs

It is without doubt that storage operators face challenging market conditions. There are several possible responses to deal with this situation.

The storage operators in Germany (Epe and Etzel areas), connected to the Dutch GTS network, may decide to connect to a German grid. Various operators located across the border in Germany already have such a connection, or can make it with a relatively limited investment. For example, Innogy is far ahead in the process of connecting its Dutch Epe storage to the Open Grid Europe (OGE) network, providing access to the NCG market area. The estimated investment is 1.2 mln €, as can be inferred from the legal case between OGE and Innogy[9]. This is a relatively small investment relative to the total costs of operating a storage facility. For other facilities close to the Dutch-German border the costs will be different, but will generally be low, or the connection may already be in place. The storages in Epe are for L-gas; once connected to and used within the German grid for H-gas, it is technically very difficult and/or relatively costly to connect back to the Dutch L-gas grid.

Storage operators which cannot easily make a connection to the German grid may decide to mothball their facility for one or more years. This is not likely to happen for a number of reasons. First of all, even during the mothballing period, certain costs have to be made, whereas there are no revenues. Secondly, during the mothballing period, the storage must be (almost) full with gas in order to avoid water leakage into the storage (depleted gas fields) or to avoid contraction of the cavern (salt caverns). So, during the mothballing period the company will face extra high capital costs due to the full storage. To our knowledge, there are currently no storages in Europe being mothballed, and it does not seem to be a viable option for Dutch storage operators either.

The most drastic response to the tough market conditions is to close a facility. The development of a new storage facility requires large initial investments. It is therefore not easily decided to terminate operations, even if these operations are currently unprofitable. As long as the yearly operating cash-flow is positive, or expected to increase in the future, it may be better to continue than to terminate. However, significant maintenance expenses, which periodically are required, may trigger a decision to close. In the next section we analyse the profitability, and the decisive factors for a potential closure, in more detail.

4.2 Profitability of Dutch storages

We have no direct insight in the profits and losses of individual storage operators. Even if the companies would make their income statements public, the results will often be a mix of different activities and the results of an individual storage may be hard to infer. Furthermore, due to multi-year contracts with storage customers that were signed in the past, storage operators may be able to survive now, but have a bad business case when those contracts expire. What really matters, is the market value of their storage service in relation to their costs. This market value is primarily determined by the winter-summer forward spread and the price volatility in the gas market.

To estimate the market value, we use the Kyos storage valuation model KyStore, which was also used to determine the optimal flows in the backtests. The market parameters, winter-summer forward spread and price volatilities, together with the parameters of the storage facility, are inputs into the KyStore model, and lead to an estimate of the market value. The model is used by a few dozen market players in Western Europe and the market-based methodology is widely accepted as a reference for storage value. The model calculates both the intrinsic value, which is easy to capture and a function of the summer winter spread, and the full option or spot trading value. This latter value requires a more active trading strategy and can only be realized with some uncertainty. We

[9] See https://www.bundesnetzagentur.de/DE/Service-Funktionen/Beschlusskammern/1BK-Geschaeftszeichen-Datenbank/BK7-GZ/2016/2016_0001bis0999/2016-0100bis0199/BK7-16-0151/BK7-16-0151_Beschluss.html?nn=360898

therefore assume that storage operators can sell their capacity at an equally weighted average of intrinsic value and full option value[10].

Because all analysis has been for storage year 2016, we take the forward winter-summer spread at the start of this period as input for the intrinsic value, and the price volatilities in this period as input for the estimation of the full option value. With these inputs, the expected value of the Dutch storages is estimated and expressed per MWh of working volume. The calculated market value includes the 0.50 €/MWh variable costs which are directly related to the injections and withdrawals, mainly fuel costs for the compressors and other facilities. All other costs are mostly fixed over the year and not included in the market value: overhead costs, cushion gas capital costs and periodic maintenance costs. We quantify each of these separately, together with the transport costs. This quantification is mainly to assess the likelihood of storage closures. For this reason, the initial investment (capital) cost in the facility, except for the cushion gas, is not quantified: it is a sunk cost which cannot be recovered when the storage is closed. Apart from the initial investment, storages require a re-investment after about 10-20 years, in particular to replace compressors. According to one market source, this is around 10% of the initial capex. If the re-investment cost is sizable and eminent, it could be an important reason for early closure. When taking a decision to close, the transport costs in the next few years play hardly any role, but instead such a decision is based on expected margins over the next 10-20 years. For that reason, re-investment costs are not included in this analysis.

The first cost component, for overhead, is mostly fixed over the year and covers personnel, marketing and sales activities, housing, the normal ongoing small maintenance, etcetera. We estimate these annual overhead costs to be in a range between 0.10 and 0.20 € per MWh working volume, linearly increasing with the number of cycles that can be made per year. For example, for Zuidwending the costs are 0.20, for Norg, Grijpskerk and Bergermeer 0.10 and for Eneco Epe 0.16 € per MWh of working volume per year.

The second cost component is associated with the cushion gas, which can be sold when a facility is closed. Depending on the individual storage characteristics, the release of the cushion gas may take roughly between 1 to 7 years. Already for some time now, TTF gas futures prices for delivery several years ahead are at about the same level as for one year ahead. In other words: the forward curve is rather flat. This means that there is no obvious upside from keeping the gas in store to sell it in the market many years later. Instead, selling the cushion gas now frees up capital and reduces capital costs. We quantify this benefit under the assumption that capital costs (WACC) are 2% and TTF gas prices are 16 €/MWh. A salt cavern (fast-cycle) requires around 0.3 MWh of cushion gas per MWh of working volume, while it is at least 1 MWh for depleted gas fields[11]. This means that capital costs of the cushion gas for a salt cavern amount to around 0.10 and for a depleted field to at least 0.32 € per MWh of working volume per year. These are direct savings of prematurely closing a facility.

The estimate of the overhead costs (between 0.10 and 0.20 €/MWh) includes a small amount for ongoing maintenance. In addition, it is common industry practice to have larger maintenance every

[10] The difference between full option value and intrinsic value is the so-called extrinsic value. Our approach implies that we take 100% of the intrinsic value and 50% of the extrinsic value.

[11] *Cedigaz report*, "Underground gas storage in the world", 2013

4 or 5 years. This leads to the third cost component. According to different industry sources, the estimated annual reservation for large maintenance is around 2% of the investment cost (capex) of a storage, excluding the cushion gas investment. The capex for a storage is very location specific, but roughly in the range of 50 to 100 € per MWh of working volume[12], with seasonal storages on the lower end and fast-cycle storages on the higher end of this range. Combining the numbers, the annual maintenance cost reservations of the Dutch storages are in between 1 €/MWh for Norg (the slowest) and 2 €/MWh for Zuidwending (the fastest); all other storages are in between, linearly dependent on the cycles that can be made per year.

Figures 7 and 8 show the results of the profitability analysis, including all mentioned costs, and using the market value as the expected revenue. The figures show the average profitability of fast-cycle and seasonal storages, with each storage having an equal weight in the statistics. The seven Dutch storage facilities which can cycle at least 3.5 times a year are in the fast-cycle group, the other seven in the seasonal group[13].

The figures also include the transport booking costs, the main topic of this report. Figure 7 is based on an annual booking strategy, so has high transport costs, while figure 8 is based on a daily booking strategy, with much lower costs[14]. Not only the transport costs are different in both graphs, also the expected revenues are slightly different. For figure 7, the booking costs are annual and hence not included in the marginal costs for injections and withdrawals. As explained in section 3.3, this leads to more active cycling than with a daily booking strategy, which was used to estimate the revenues and margins in figure 8.

[12] See *The Oxford Institute for Energy Studies*, "Gas storage in Great-Britain", January 2013, table 11. The numbers were confirmed by various industry sources.
[13] Fast-cycle: Zuidwending (Energystock), Epe (Eneco), Epe (Nuon / Vattenfall), Nüttermoor (EWE), Etzel (Crystal), Epe (Innogy), Jemgum (Astora). Seasonal: Etzel (EKB), Etzel Freya (OMV), Alkmaar (Taqa), Jemgum (EWE), Bergermeer (Taqa), Grijpskerk (NAM), Norg (NAM)
[14] Note that the annual and daily booking costs include the current discount of 25%, and that this discount will increase to at least 50% in 2020.

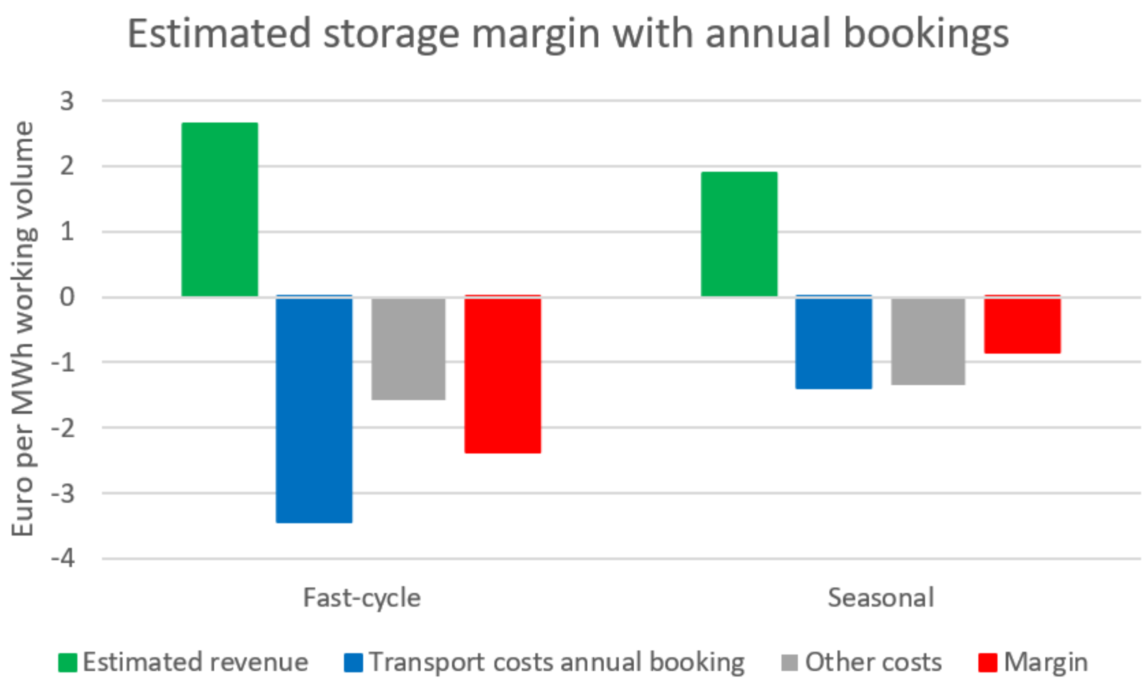

Figure 7: Estimated Margin of storage facilities connected to the Dutch market, in Euro per MWh working volume per year, assuming annual transport bookings. The revenues are estimated as the weighted average of intrinsic and full option value, calculated with the KyStore storage model. The variable (fuel-related) costs, of 0.50 €/MWh, are part of the estimated revenues. The other costs cover overhead, cushion gas capital and periodic maintenance. The margin equals the revenues minus the transport costs minus the other costs. Source: KYOS analysis.

Figure 7 makes clear that the annual bookings lead to negative margins for both fast-cycle and seasonal storage facilities. The fast storage assets have the highest market value per MWh of working volume, but also the highest transport and other costs. Hence their margins are very negative. In the past few years, storage operators of fast-cycle storage assets have continued operations probably because they have sold capacities at more favourable terms in the past under long-term agreements and they have long-term agreements with GTS. They also hope for better market conditions in the future, either as a result of higher winter-summer spreads and market price volatility, or as a result of lower transport costs. Figure 8 shows that their margins improve considerably when indeed they can switch to daily bookings. On average, the margins for the fast-cycle and seasonal storages are then just above zero. Especially the fast-cycle storages benefit from daily bookings.

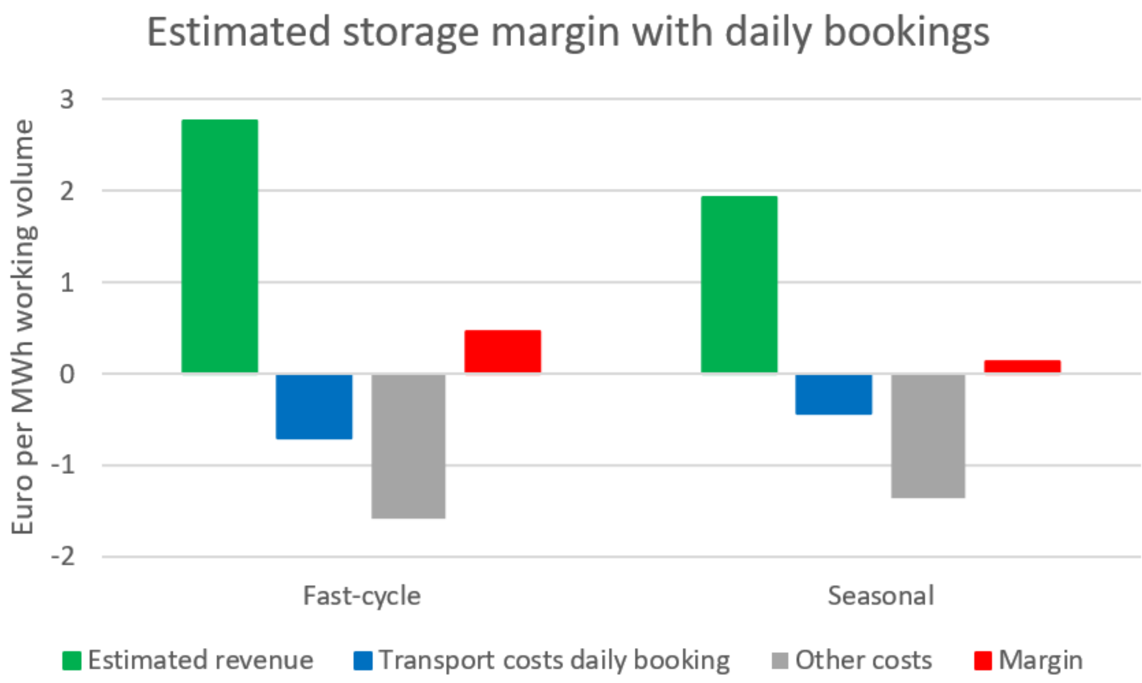

Figure 8: Estimated Margin of storage facilities connected to the Dutch market, in Euro per MWh working volume per year, assuming daily transport bookings. The revenues are estimated as the weighted average of intrinsic and full option value, calculated with the KyStore storage model. The variable (fuel-related) costs, of 0.50 €/MWh, are part of the estimated revenues. The other costs cover overhead, cushion gas capital and periodic maintenance. The margin equals the revenues minus the transport costs minus the other costs. Note that the scale (Y-axis) is different from figure 7. Source: KYOS analysis.

4.3 The risk of daily bookings in the Dutch network

Our analysis shows that switching from annual to daily transport bookings has great benefits for storage operators. The Dutch storage operators, represented by VGN, claim that the availability of entry and exit capacity is much less guaranteed in the Netherlands than in Germany, which makes it risky to book per day. One explanation is that GTS can move capacity from one location to another, away from storage operator sites. This claim is partly confirmed by GTS, which has stated to KYOS that availability of capacities is generally not a problem, but that a bottleneck could arise at Bergermeer because this facility operates in an area with scarcer capacity and competes with capacity at other entry-exit points in the area. The second explanation is that GTS does not offer interruptible capacity, as do all German TSOs.

The financial consequences of non-availability of transport capacity can be significant for a shipper using the storage. This non-availability already happens occasionally due to planned maintenance and unplanned outages of a storage site. Outages are generally not longer than a few days in length or planned well in advance. Potential unavailability arising from transport capacity problems, however, may be unexpected and extend to one or more months if capacity has been sold to other types of market players. In general, market players do not like this type of uncertainty and will apply a discount to the price they are willing to pay for access to Dutch storage facilities. This means that, albeit relatively small, the transport non-availability risk leads to a somewhat lower price which market players are willing to pay for a storage service. The exact impact though, is hard to quantify and will differ per facility.

There is only one Dutch storage whose long-term agreement with GTS recently has run out and which is therefore a potential test case: Epe Innogy. This storage operator has not made new annual bookings according to the transparency website of ENTSOG[15]. Instead, the shippers at Epe Innogy make bookings for short periods. To what extent this has affected the price of the storage service at Epe Innogy, is privately negotiated between Innogy and its customers, so cannot be assessed.

4.4 Likelihood of closures and implications for the Dutch gas market

Despite the fact that storage operators face difficult times and may never earn back their initial investments, in the past few years in the Netherlands there have not been storage closures. In surrounding countries closures have been limited to just a few. The previous analysis shows that the average margins of fast-cycle and seasonal storages are negative with annual bookings, and slightly positive with daily bookings. However, a closure or connection to the German grid does not take away the long-term obligations for booking annual transport capacities with GTS. To our knowledge, those agreements can be enforced until they reach the end date, even if a storage is closed down or no longer connected to the Dutch GTS network. Based on the information from the ENTSOG transparency website, Dutch storage operators have made long-term transport bookings until 2020 or later. Consequently, closures may not be expected until those agreements run out, and when that happens, it will mainly be due to the poor market conditions.

[15] https://transparency.entsog.eu

Although we have argued that it is not a likely scenario in the next couple of years, *when* more than one or two storage operators decide to close down or connect to the German grid, we expect the attractiveness of the TTF market to decline. It will reduce TTF market liquidity and increase transport costs for other gas market players. For example, transport tariffs may have to rise if GTS receives payments from fewer gas storage operations. A lower market liquidity can also lead to higher costs for market transactions.

The Dutch TTF market is well connected to surrounding markets and currently very liquid. Because the western European markets are generally oversupplied with storage, the closure of a storage or the withdrawal of a storage from the TTF market, is not likely to cause general gas supply problems in the Netherlands. Actually, the closure of a storage is good news for the other storage operators, because it reduces the oversupply and helps to improve storage prices.

It could be argued that supply problems for L-gas may arise if many L-gas storages decide to close. Currently, the TTF market has access to L-gas storages in the Epe area (Innogy, Eneco, Nuon), as well as Zuidwending, Alkmaar and Norg. All of these storages are potential candidates for closure, because they can either connect to the German grid (Epe area), because they are relatively old (Alkmaar, Norg) or because they have a rather negative profitability according to our calculations (Zuidwending). Whether L-gas supply risks may arise, is beyond the scope of this research. It will depend, amongst others, on the production levels of the Groningen field, the future demand for L-gas and the costs for extra conversion capacity (from H- to L-gas).

5 Conclusion / Management summary

Dutch storage operators, or shippers using their storage, pay high fees for transport capacity, considerably more than in Germany: on average 2.8 times as much per cycled volume, and 4.9 times per working volume. Our estimates show that, on average, both fast-cycle and seasonal storages currently have negative net margins. This is partly a result of the depressed market conditions, but also a result of the high transport costs. The higher costs arise because Dutch storage users book per year, as a consequence of long-term agreements with GTS[16], while German storage users book transport capacities per day. If transport capacity for Dutch storages would be booked per day, the costs would on average be lower than in Germany.

Under their current long-term agreement with GTS, Dutch storages and shippers cannot book per day. If these contracts expire in the coming years, Dutch storage operators could improve profitability, but still face the issue that daily capacity is less guaranteed than in Germany. This means that market players are less willing to pay for storage capacity. Depending on how this risk is perceived by market players, storage operators who have this option, may decide to connect to the German instead of Dutch grid. Such a departure from the Dutch grid, requires limited investments and is not easily reversed.

Departures of storage sites from the Dutch network, or complete closures, will not easily cause supply issues in the Dutch gas market, because there are good connections with surrounding markets, the TTF market is very liquid, and there is oversupply of storage capacity in Northwest Europe. Only supply issues for L-gas could potentially arise, but the analysis of this is beyond the scope of this research.

Only after the long-term agreements with GTS have run out, storage operators effectively have the option to close down operations or connect to the German grid. Especially when that coincides with large maintenance, required every 4-5 years, continuing operations on the TTF market may no longer be justified. However, when the long-term agreements have run out, in 2020 or later, there is no more contractual obligation to book per year, storage operators will have a higher discount on transport bookings, and transport booking costs can be reduced significantly with daily bookings. Our analysis shows that, under current market and regulatory conditions, daily transport bookings lead to slightly positive margins for the average fast-cycle and seasonal storage in the Dutch market. This means that when storages decide to leave the Dutch gas market, it will be because of poor market conditions and/or because market players believe that the potential risk of daily bookings reduces the storage service value.

[16] With the exception of Epe Innogy, of which the long-term agreement with GTS has just ended.

Appendix A: Gas storage parameters

Gas storages facilities are used to balance the volumes in the portfolio of gas market players. These players are generally referred to as shippers: they move gas over the gas transmission network and acquire (third-party) access to storage facilities. For example, gas is stored during summer periods, when demand is low, and released from storage in winter periods, when demand is high.

Both the Dutch TTF gas market and the German NCG and Gaspool (GPL) gas markets are relatively liquid, with active trading in spot (day-ahead) and forward markets. Trading takes place over-the-counter (OTC) and on exchanges (ICE, EEX, PEGAS). Thanks to the existence of liquid gas markets, storage operations are primarily dictated by the development of market prices: shippers store gas when the price is relatively low and release gas when the price is relatively high.

The main parameters of a gas storage are the working volume, the injection rate and the withdrawal rate. The working volume is the amount of gas which can be stored and released, so is the part of the total storage volume which is actually available for the market operations. It is typically measured in MWh or GWh. The injection rate is the speed at which gas can be injected into the storage, while the withdrawal rate is the speed at which gas can be released from the storage. Both rates may depend on the amount of gas in the storage, with higher injection rates when the storage is empty, and higher withdrawal rates when the storage is full. Both rates are generally measured in MWh/hour or MWh/day.

Dutch storage facilities

The Dutch storage facilities, 14 in total, and their main parameters are listed in table 4. For the working volume, injection and withdrawal rate the main source of information has been the GIE website[17]. Based on the published statistics for storage year 2016, the injection and withdrawal rates and the working volumes have been estimated.

The cycle costs are the variable cost for a full cycle of injection and withdrawal. The exact costs are often confidential and not published. We have therefore used a general estimate of these costs of 50 €ct/MWh, based on information gathered from different storage operators. Bergermeer storage is an exception with 25 €ct/MWh, derived from information on its website[18].

Of the 14 “Dutch” storage facilities, nine are actually located just across the border in Germany, and some are connected to the network of a German TSO. The remaining five are located on Dutch territory (Bergermeer , Alkmaar, Norg, Grijpskerk and Zuidwending). Of these five, two offer third party access (Zuidwending and Bergermeer) and have a number of different shippers as customer, while the other three are contracted by GasTerra. For example, Norg is mainly used to store gas from the Groningen field.

[17] https://agsi.gie.eu

[18] http://www.gasstoragebergermeer.com/remit

Figure 9: Some of the Dutch storage facilities and their location on Google Maps. Source: KYOS Analytical Platform.

Storage name	Storage owner	TSO		Working Volume GWh	Inj Max GWh/day	Wdr Max GWh/day	Cycle Cost EUR/MWh	Cycle Time days
Zuidwending	Energystock	GTS	L-gas	3,008	258	431	0.50	19
Epe Eneco	Eneco	GTS	L-gas	1,435	94	94	0.50	31
Epe Nuon	Nuon	GTS	L-gas	3,338	101	177	0.50	52
Nüttermoor	EWE	GTS		1,832	49	70	0.50	64
Etzel Crystal H	EdF and EnBW	GTS		2,102	48	84	0.50	69
Epe Innogy	Innogy	GTS	L-gas	2,986	47	118	0.50	88
Jemgum Astora	Astora	GTS		2,892	47	72	0.50	102
Etzel EKB	BP, Dong and Gazprom	GTS		7,654	109	168	0.50	116
Etzel Freya H	OMV	GTS		5,800	72	107	0.50	135
Alkmaar PGI	Taqa	GTS	L-gas	4,951	40	357	0.50	139
Jemgum EWE	EWE	GTS		4,313	55	69	0.50	141
Bergermeer	Taqa	GTS		45,652	468	634	0.25	170
Grijpskerk	NAM	GTS	L-gas	27,667	173	719	0.50	198
Norg	NAM	GTS	L-gas	58,238	449	779	0.50	205
	Average or Total			171,867	143	277	0.48	109

Table 4: Main parameters of the Dutch storages used in the analysis. Source: GIE, GTS, storage operator websites, KYOS analysis.

German storage facilities

There are quite a large number of German gas storage facilities, some of which are connected to multiple TSOs within Germany or outside of Germany (the Netherlands and Austria). We made a representative selection of 25 storages for this study, both fast-cycle and seasonal, with different owners and involving different TSOs. For example, each TSO with a storage is included at least once, but not more than four times. Furthermore, the list contains a fair mix of fast-cycle and seasonal storages.

Storage name	Storage owner	TSO	Working Volume GWh	Inj Max GWh/day	Wdr Max GWh/day	Cycle Cost EUR/MWh	Cycle Time days
Epe H-Gas	Trianel	Thyssengas	2,290	83	166	0.50	41
Fronhofen	Storengy	Terranets	136	5	8	0.50	42
Harsefeld	Storengy	Gasunie	1,263	25	82	0.50	67
Etzel ESE, Crystal	EdF and EnBW	Jordgas	2,102	48	84	0.50	69
Etzel Crystal	EdF and EnBW	OGE	2,102	48	84	0.50	69
Etzel EGL	Statoil	Jordgas	1,885	40	86	0.50	69
Peckensen	Storengy	Ontras	4,394	85	232	0.50	71
Empelde	Stadtwerke Hannover	Nowega	1,856	26	103	0.50	90
Lesum	Storengy	Gasunie	1,507	25	52	0.50	90
Bierwang	Uniper	OGE	11,200	188	320	0.50	95
Nüttermoor H-3	EWE	Gasunie	2,690	41	82	0.50	98
Kraak	Uniper	Ontras	3,163	46	108	0.50	99
Kirchheilingen	VNG	Ontras	2,020	38	34	0.50	114
Etzel EKB	BP, Dong and Gazprom	Jordgas	7,654	109	168	0.50	116
Nuttermoor H-2	EWE	Thyssengas	1,955	25	50	0.50	118
VGS Storage Hub	VNG	Ontras	22,256	284	478	0.50	125
Krummhörn	Uniper	OGE	2,506	25	79	0.50	132
Jemgum	EWE	Gascade	4,312	55	69	0.50	141
Inzenham-West	DEA	Bayernets	4,768	54	81	0.50	148
Wolfersberg	Bayerngas, DEA	Bayernets	4,121	38	65	0.50	172
Haiming / 7Fields	Uniper, RAG	Bayernets	19,415	162	243	0.50	200
Uelsen	Storengy	Gasunie	9,492	81	108	0.50	205
Haidach	RAG, Gazprom, Wingas	Bayernets	19,536	178	195	0.50	210
Rehden	Astora	Gascade	48,620	345	530	0.50	233
Breitbrunn	Storengy, DEA	OGE	11,110	67	140	0.50	245
	Average or Total		192,354	85	146	0.50	122

Table 5: Main parameters of the German storages used in the analysis. Source: GIE, TSO websites, storage operator websites and KYOS analysis.

Appendix B: Transport fees

Transport costs for storage operators consist of entry and exit fees (or tariffs), and sometimes additional charges, which are paid to the Transmission System Operator (TSO). Entry fees are paid for the transport of gas to the gas transmission network, i.e. when gas is released (withdrawn) from the storage. Exit fees are paid for the transport of gas from the network, i.e. when gas is injected into the storage. The fees may be quoted in different units:

- A = €/kWh/h/a. This is Euro per kWh per hour per year.
- B = €ct/kWh/h/d. This is Eurocent per kWh per hour per day.

For example, if a shipper needs transport capacity for a whole year to allow for 1 GWh of withdrawal per day from the storage, the payment for entry capacity equals A * 1,000,000 / 24 in Euros. Or with the second definition, the payment equals B * 1,000,000 / 24 * 365 / 100 in Euros. In order to change between the two definitions, use A = B * 365 / 100. The first definition is used by the Dutch TSO, the second by the German TSOs.

Dutch transport tariffs

In the Netherlands, there is one TSO, responsible for the main gas transmission network. This is Gasunie Transport Services (GTS). The system has almost a hundred entry points and over a thousand exit points. Storage operators have both an entry and an exit point. The tariffs for entry and exit are dependent on the location within the Netherlands. Generally speaking, the further away from Groningen, the higher the tariff. Capacities for entry and exit can be booked at GTS for different periods[19]. The reference for all tariffs is the annual fee A, which applies for a period of 12 months. If a shipper books capacity for a shorter period, the following monthly factors apply:

- Winter months: January, February, December. Factor = 30%
- Shoulder months: March, April, October, November. Factor = 15%
- Summer months: May, June, July, August, September. Factor = 7.5%

For example, if 1 kWh/h of capacity is booked for 1 day in January (winter), the booking fee equals 30% * (1/30) * A = 1% * A[20]. And if the same capacity is booked for a day in June (summer), the booking fee equals 7.5% * (1/30) * A = 0.25% * A. More generally, a daily booking equals F * (1/30) * A, where F is the seasonal factor and A the annual fee.

The tariffs are set by the Dutch regulator ACM, and can be found in appendix 1a and 1b of the TSC[21]. The tariffs for the first half year of 2017 were different (higher) than for the second half of 2017. In order to have a proper comparison with the 2017 tariffs in Germany, our analysis is based on the so-called “contrafactische” tariffs, which are listed in an Excel document (“Bijlage 2 – Rekenmodule bij tarieven GTS 207”) published by ACM on its website[22]. These tariffs reflect what would have been

[19] See https://www.gasunietransportservices.nl/shippers/voorwaarden-en-contracten/tariefinformatie

[20] GTS assumes 30 days in each month of the year. Hence the monthly multiplier is divided by 30 to get a daily multiplier.

[21] See https://www.gasunietransportservices.nl/shippers/voorwaarden-en-contracten/tsc

[22] See https://www.acm.nl/nl/publicaties/publicatie/17265/Tarievenbesluit-GTS-2017/,

the tariffs if they had been set on 1 January 2017 for the whole year. They also include socialized costs for quality conversion (KC) and balancing (BT), and they include the 25% discount for gas storages.

The Dutch storage facilities have all entered into 10-year agreements with GTS at the time they started operations. As part of these agreements, the storage operators have to book entry and exit capacities per year. Consequently, in the first ten years of their operations it is not possible to book per day or other short-term periods with GTS. Almost all storage facilities are still in their 10-year period. The only exception is Innogy's Epe storage, of which the contract with GTS ran out in June 2017.

German transport tariffs

Whereas the Netherlands has a single market area, TTF, there are two gas market areas in Germany: Gaspool (GPL) in northern and eastern Germany and NetConnect Germany (NCG) in western and southern parts of the country. Furthermore, there is not a single TSO as in the Netherlands, but over a dozen individual TSOs. The Gaspool market area is formed by the transmission systems of Gascade Gastransport GmbH, Gastransport Nord GmbH, Gasunie Deutschland Transport Services GmbH, Nowega GmbH, ONTRAS Gastransport GmbH and Jordgas Transport GmbH. The NCG market area is formed by the transmission systems of Bayernets GmbH, Fluxys TENP GmbH, GRTgaz Deutschland GmbH, Open Grid Europe GmbH, Terranets GmbH and Thyssengas GmbH.

Each TSO has its own tariffs, but generally with the same structure[23]:

- Entry and exit tariffs differ per location
- Storage operators get a 50% discount on the entry and exit tariffs, if they fulfill certain conditions
- Tariffs are published in €ct/kWh/h/d. The fee equals the daily tariff multiplied by the number of days booked and multiplied by one of the following factors:
  - From 0 to 27 days: factor = 1.40
  - From 28 to 89 days: factor = 1.25
  - From 90 to 364 days: factor = 1.10
  - 365 days or more: factor = 1.00

These factors may be compared to the Netherlands, where the factors are seasonal. For example, a daily booking in the Netherlands in winter has a multiplication factor of around 3.6 (30% * 12), while in summer it is around 0.9125 (7.5% * 12). On average, that is higher than the German factor of 1.4.

Based on our selection of German gas storages, this study requires tariff information of eight German TSOs.

The following list contains the internet addresses where the tariffs are being published:

[23] BEATE stands for "Bepreisung von Einspeise- und Ausspeise Kapazitäten" and is the regulation for pricing entry and exit capacities.

- Jordgas (GPL): http://jordgastransport.de/en/downloads-61.html?file=tl_files/INHALT/downloads/tarife/2016-10-06%20-%20Preisblatt%20JGT%202017%20Englisch.pdf
- Gascade (GPL): https://www.gascade.de/fileadmin/downloads/netzzugang/entgeltinformation/GASCADE_Price_List_January_2017_170511.pdf
- Bayernets (NCG): http://www.bayernets.de/trans_datei.aspx?token=DB-2C-11-14-F6-C8-5C-13-31-E2-B3-34-16-0A-33-C6
- Thyssengas (NCG): http://www.thyssengas.com/fileadmin/user_upload/downloads/netzzugang/entgelte/netzentgelte/2016/nov/16_Preisblatt_TG_01.01.2017_EN.pdf
- Gasunie Deutschland (GPL): https://www.gasunie.de/en/main-menu/transparancy-information/remit-disclosures/customer-information/2016-2/information-ueber-die-entgeltstruktur-der-gasunie-deutschland-tra
- Open Grid Europe, OGE (NCG): https://www.open-grid-europe.com/cps/rde/xbcr/SID-584E0FEE-8A9A5D09/oge-internet/Preisblatt_OGE_Entgelte_Produkte_Speicher_V2_2017_01_01_en.pdf
- Ontras (GPL): https://www.ontras.com/fileadmin/user_upload/Dokumente_Download/Geschaeftsbedingungen/Preisblatt_ONTRAS/2016-10-18_Preisblatt_ab_01.01.2017_EN_V10.1.pdf
- Terranets (NCG): https://www.terranets-bw.de/fileadmin/user_upload/PDF/Aktuelles/Pressemitteilungen/2016-12.16_Preisblatt_terranets_bw_2017_English.pdf
- Nowega (GPL): https://www.nowega.de/pdf_files/01_netzzugangsbedingungen-und-preisblaetter/2016-12-30-preisblatt-nowega.pdf