

23rd World Gas Conference, Amsterdam 2006

**THE NETHERLANDS:
A CASE OF OPTIMISATION OF
RECOVERY AND OPPORTUNITIES
FOR RE-USE OF NATURAL GAS ASSETS**

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ABSTRACT

The total Netherlands natural gas resource base is estimated at around 4500 bcm. Two-thirds of that volume stems from the giant Groningen field, the remainder from a few hundred other so-called small fields and exploration prospects.

The Netherlands small fields policy (1973) has been directed at giving full room for exploration and production of small fields, using Groningen to balance supply and demand. Over the last three decades, this policy has proven to be very successful in terms of the volume discovered and developed for production. The policy serves sustainability: the Groningen field technically might have been produced at a much faster rate, but it would have been depleted by now. Instead, the recovery from the Netherlands resource portfolio has been, and is being optimised.

The Netherlands portfolio of natural gas assets has become mature by now: many fields are in decline and reserves additions from exploration decrease. Indeed, the total production rate of the small fields seems to have come off plateau by now.

The aim of the paper is to analyse the mature stage of natural gas E&P in the Netherlands in terms of challenges and opportunities for the future. In particular the re-use of depleted gas fields is investigated.

Making the most out of mature fields does include the timely re-use of assets, without compromising on the natural gas recovery. Options are gas storage and sequestration of unwanted substances such as CO₂. This conversion process will require planning, since the opportunities are constraint in time and space. The paper will indicate the opportunities and constraints in the Netherlands case, perhaps also serving as an example of what might happen elsewhere in the world.

The paper starts with an evaluation of historical Netherlands E&P data. From there, the portfolio of natural gas assets will be derived and characterised. Based on simple demand scenarios for storage space for natural gas and CO₂, a supply-demand analysis is presented, which takes into account the physical availability, relevant reservoir characteristics and window of opportunity aspects.

The result is a picture of the end stage of natural gas E&P in the Netherlands and an outlook to opportunities for using depleted fields for security of supply and transition to sustainable energy purposes.

It is concluded, that the Netherlands offers excellent opportunities to make the most out of the natural gas assets portfolio, not only in terms of recovery but also in terms of value for other use, provided that the window of opportunity is carefully considered.

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1. INTRODUCTION

The total Netherlands natural gas resource base is estimated at around 4500 bcm. Two-thirds of that volume stems from the giant Groningen field, the remainder from a few hundred other so-called small fields and exploration prospects.

The Netherlands small fields policy (1973) has been directed at giving full room for exploration and production of small fields, using Groningen to balance supply and demand. Over the last three decades, this policy has proven to be very successful in terms of the volume discovered and developed for production. The policy serves sustainability: the Groningen field technically might have been produced at a much faster rate, but it would have been depleted by now. Instead, the recovery from the Netherlands resource portfolio has been, and is being optimised.

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The result is a picture of the end stage of natural gas E&P in the Netherlands and an outlook to opportunities for using depleted fields for security of supply and transition to sustainable energy purposes.

2. RESOURCE BASE

The total Netherlands natural gas resource base is estimated at around 4500 bcm (1 bcm is 10^9 m^3). Two-thirds of that volume stems from the giant Groningen field, the remainder from a few hundred other so-called small fields and exploration prospects.

The Netherlands 'small fields policy' (1973) has been directed at giving full room for exploration and production of small fields, using the Groningen field to balance supply and demand. Over the last three decades, this policy has proven to be very successful in terms of the volume discovered and developed for production. The policy serves sustainability: the Groningen field technically might have been produced at a much faster rate, but it would have been depleted by now. Instead, the recovery from the Netherlands resource portfolio has been, and is being optimised by virtue of the small fields policy.

	Produced	To be produced
Groningen field	1600	1172
other onshore gas fields	624	133
offshore gas fields	544	267
Total	2768	1572

Table 1 Production of natural gas in the Netherlands (in mrd.Sm³); situation at 1.1.2005

3. DEPLETION

Figure 1, in a 25 year time window, shows the yearly gas production in the Netherlands from 1990 onwards and the forecast as of 2005 until the year 2014 (1). The Netherlands portfolio of natural gas assets has become mature by now: many fields are in decline and reserves additions from exploration decrease. Indeed, the total production rate of the small fields seems to come off from a plateau rate of around 45 bcm/year and is expected to decline over the coming years. Two-thirds of the total discovered reserves have been produced already. So, in terms of depletion, the Netherlands is to be considered a mature area.

From discovered fields outside the Groningen field, some 400 bcm will be produced in the next 25 years. Production from future discoveries in the coming 10 years will be in the order of 50 bcm in total.

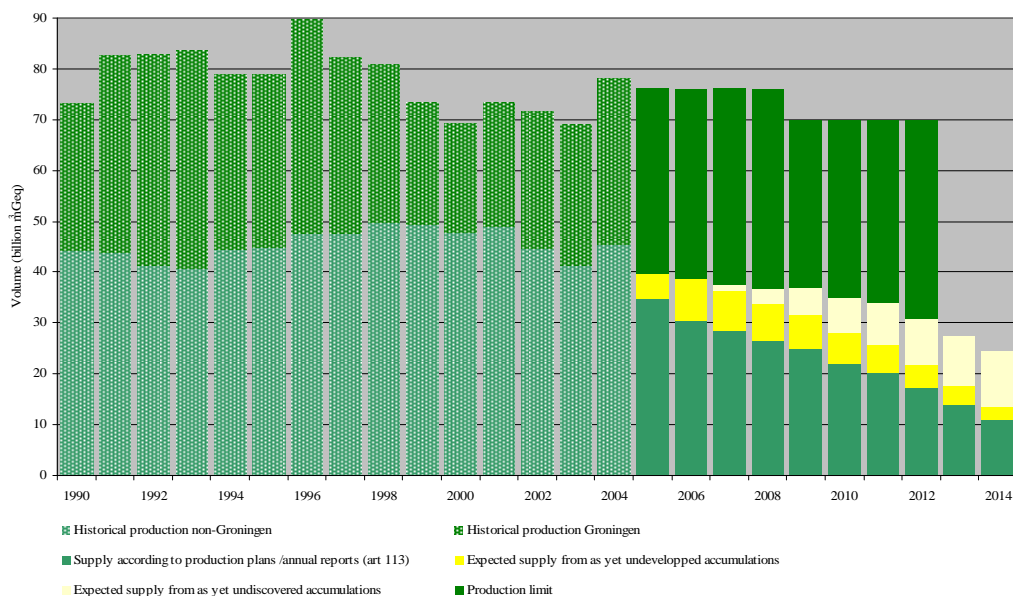


Figure 1 Natural gas production in the Netherlands

4. UNDERGROUND STORAGE SPACE

Table 2 shows estimates for the potential underground storage space as calculated from the data in Table 1 on an equivalent hydrocarbon pore volume basis. The depletion of Dutch gas fields has generated a significant potential underground storage volume of 11 km³. Future production is likely to add another 6+ km³, but that storage volume will only become available over the next decades.

	Generated	To be generated
Groningen field	6,4	4,7
Other onshore gas fields	2,5	0,5
Offshore gas fields	2,2	1,1
Total	11,1	6,3

Table 2 *Underground storage space in depleted gas field*
(in mrd.m³ or km³); situation at 1.1.2005

It is important to note, that the data in Table 2 only indicate the potential for storage and not the actual availability for specific storage purposes and projects. The various constraints on the availability of underground storage space are the main theme of the remainder of this paper.

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5. RE-USE OF DEPLETED GAS FIELDS

In various recent policy reports (3, 4, 5, 6), two distinct options for the re-use of depleted gas fields in the Netherlands are proposed:

- Large scale buffering of natural gas, serving the security of supply for the west European market in an internationalising gas market, where the sources of gas will become more and more geographically remote, while the supply from domestic production declines;
- Large scale sequestration of carbon dioxide (CO₂), as an transitional measure towards non fossil sustainable energy supply and one of the possible measures to comply with the Kyoto protocol on greenhouse gas emissions (and its successors).

Both forms of re-use compete for the same portfolio of depleted natural gas fields.

Per option, below it is discussed, what 'large scale' actually means and what specific requirements exist regarding field size, location etc. Demand scenario for underground storage space are investigated, together with an outlook to the opportunities and constraints of large scale re-use of depleted gas fields.

6. BUFFERING OF NATURAL GAS

- **Existing projects**

At present there are two large underground gas storages in the northern part of Netherlands in the vicinity of the Groningen field:

- Norg (Langelo), containing Groningen quality gas (15% N₂), and
- Grijpskerk, containing high calorific gas.

In addition, there is a Peak Shave Installation (PSI) on the former Alkmaar gas field and an LNG (surface) peak shaver in the Rotterdam harbour area. Table 3 gives some characteristics of the underground storages.

The total installed workvolume in the Netherlands is around 5 bcm, which is modest compared to the total yearly 'turnover' of natural gas of some 80 bcm. In fact, the Groningen field is delivering most of the seasonal capacity for the domestic Dutch market and also contributes to the capacity needs of other EU-countries.

	<i>Workvolume</i>	<i>Ratio work/total gas</i>	<i>Duration of withdrawal</i>	<i>Peak output</i>
	10 ⁹ m ³	%	days	10 ⁶ m ³ /d
Norg	3	11	69	54
Grijpskerk	1,5	12	29	54
Alkmaar	0,5	14	14	36

Table 3 *Characteristics of UGS facilities in the Netherlands*

- **Future gas storage demand scenario**

Since the Groningen field is running at a low base load production, the field – in its present function - may be considered a giant UGS with a workvolume close to its annual production of around 30 bcm, albeit that the send out volume is not compensated by injection (yet).

Recently, a regulatory cap was put on the Groningen production for the coming 10 years at an average of 42,5 bcm/yr. This measure was taken to extend the balancing capabilities of Groningen in the framework of the small fields policy. Yet, it is expected that the field will loose its swing capacity somewhere between 2020 and 2030 and turn into a 'normal' small field in production decline.

Various policy reports point out the strategy, that the Netherlands should turn into a Gas Hub in the west European gas market. That strategy implies, that the role of the Groningen field will be have to be taken over by additional workvolume in underground gas storages. That additional (seasonal) workvolume of around 25 – 30 bcm then should be installed in the next 15 to 20 years. Clearly, the very small fields will not be suitable for this task. A minimum field size of 5 bcm of reserves is envisaged, but preferably field sizes would be larger than 10 bcm, the size of the present UGS'es Norg and Grijpskerk. If it is assumed, that the ratio working / total gas would be 20%, then the equivalent of 15 fields of 10 bcm would be required, to be developed between 2010 and say 2025. Geographically, these new storages should be located close to the larger transport network and Hub.

For peak demand, smaller storages may be needed close to consumers with a high swing demand. These peak shavers probably would be in fields with sizes smaller than 5 bcm and even down to 1 bcm.

7. STORAGE OF CO₂

The Kyoto target for the Netherlands is clear: in 2020, the CO₂-emissions should have been reduced to the 1990 level, i.e. 162 Mt per year. Various measures have been investigated to reach that target. The 2005 Dutch Energy Report (3) envisages that energy saving measures, combined with 10% sustainable energy and progress of the European emission trading market, can lead to 194 Mt in 2020. For the remaining 32 Mt/yr, supplementary measures will be required. One of those measures might be large scale underground storage in depleted gas fields.

- **Demonstration projects**

In the Dutch offshore, a demonstration project for CO₂ injection and storage is running at the K12-B field operated by Gaz de France. The CO₂ is obtained from the CO₂-rich gas stream from the same field.

Within the CRUST initiative (7), the De Lier depleted gas field has been proposed as a sink for (pure) CO₂ coming from the nearby Pernis refinery near Rotterdam.

In the northern province of Friesland, SEQ is planning CO₂ storage in the depleted Akkrum gas fields. The source of CO₂ would be a so-called Zero Emission Power Plant (ZEPP) to be built nearby.

The Dutch government recently has allocated 80 MEu for supporting further CO₂ projects and as an incentive towards implementation of CO₂ storage on a larger scale.

- **Future CO₂ storage capacity demand scenario**

The total CO₂-emissions in the Netherlands at present amount to around 200 Mt per year. This includes large stationary sources and small stationary and mobile sources. The largest stationary sources emit in order of a few Mt CO₂ per year each. Large scale underground storage of CO₂ would be directed at the larger point sources, i.e. electrical power plants, refineries and chemical industries. The CO₂ 'sinks' (depleted gas fields) should preferably close to the sources in order to reduce transportation costs.

Large scale underground storage of CO₂ starts at a level of 10 Mt/yr, or 5% of the total emissions in the Netherlands. Investing in smaller amounts probably is not worthwhile in view of the reduction target set. Meeting the Kyoto target only by using underground CO₂ storage, on the other hand, would imply a 32 Mt/yr injection rate. A 20 Mt/yr scenario already seems very ambitious, certainly on the short term.

- **Storage capacity of individual gas fields**

Here it is assumed, that CO₂ will be stored in supercritical state, i.e. at depths of over 800 meters, which applies to virtually all gas fields in the Netherlands. Under normal geothermal and geo-pressure (i.e. hydrostatic) gradients, the mass density of pure supercritical CO₂ is only weakly dependent on reservoir depth. In theory, 1 bcm of produced gas can be replaced by 2 Mt of CO₂ on an equivalent pore volume basis.

However, there are various reasons, why in practice the degree of filling a depleted gas field may be lower than the theoretical ratio of 2Mt CO₂ per 1 bcm gas produced. Firstly, for thermodynamic reasons, a mixture of the natural gas remaining in the field and the injected CO₂ has a lower mass density than the weighed average of the individual components. Therefore, it is not advisable to fill a depleted gas field with CO₂ up to the original reservoir pressure. Secondly, completely filling a depleted gas field with CO₂ may require extra compression, which should be justified against the alternative of switching the injection to a new nearby still empty storage reservoir. Therefore, storage of 1 Mt CO₂ per 1 bcm gas produced (50% of the theoretical value) is considered here as a practical value.

In terms of field size, a large scale CO₂ project would need a depleted gas field with initial reserves in the order of at least 10 bcm. Only then can a stream of 1 Mt per year be accommodated in a project life time of 10 years. An additional requirement in the case of a large scale CO₂ storage project is, that the constant stream of CO₂ be accommodated, Therefore, there has to be some surplus storage capacity available to guarantee the constant injection rates.

8. TIMING OF UNDERGROUND STORAGE PROJECTS

Figure 2 shows two curves pertaining to the Dutch onshore gas fields (excluding Groningen):

- the cumulative gas production;
- the cumulative gas production in fields at their (prognosed) year of abandonment.

The first curve clearly shows the anticipated strong decline in gas production (apart from new field developments and exploration). The second curve shows that, until now, very little volume has become available in depleted and abandoned gas fields; but also, that over the 20 year period 2005 – 2025 the Dutch onshore fields are expected to be successively abandoned.

Although not shown here, a very similar trend holds for the Dutch offshore gas fields.

- **UGS**

The conversion of a gas field into a UGS facility does not have to wait until the field is fully depleted. In fact, the two larger existing UGS facilities (cf. Table 3) in the Netherlands were installed much earlier in their field life cycles:

- Norg when it was about 50% depleted;
- Grijpskerk even before any depletion.

The advantage is, that less time and costs are involved in filling the UGS with cushion gas.

- **CO₂ storage**

The timing of converting gas field into a CO₂ storage facility is less straightforward. The risk is, that the injected CO₂ will mix with the resident gas and/or breakthrough at the gas producing wells, thus spoiling the valuable natural gas resource. In order to stay on the safe side, one might wait until the field is fully depleted. But in that scenario, there is no flexibility in time for connecting the sink to the source. Flexibility may be gained by already starting CO₂ injection in the tail end stage of gas production. The risk of losing gas reserves then is minimal. The advantages of this scenario are, that a gradual transition from gas production to CO₂ injection is possible and operations may be continued rather than discontinued for some years. Finally, there may even be a spin off in terms of Enhanced Gas Recovery (EGR). One of the aims of the K12-B pilot project mentioned earlier is to investigate this option in a real field case.

- **Window of Opportunity**

For the conversion of gas fields into storages, the general rule is 'the sooner, the better'. Most importantly, one should not wait too long after cessation of production of an individual field:

- Wells and facilities are allowed to be 'mothballed' for only a limited amount of time;
- There will be pressure to remove the production location for other purposes, e.g. building;
- Infrastructure may be removed;
- Information on the actual status of a field gets obsolete (or even lost).

From this perspective, the curve 'cumulative production @ abandonment' in Figure 2 represents an important time line, which should not be exceeded by more than a few years for using the opportunities offered for re-use of depleted gas fields onshore the Netherlands. Indeed, a very similar curve holds for the Dutch offshore gas fields. The dashed curves in Figure 2 represent a Window of Opportunity. Clearly, the window has opened up already!

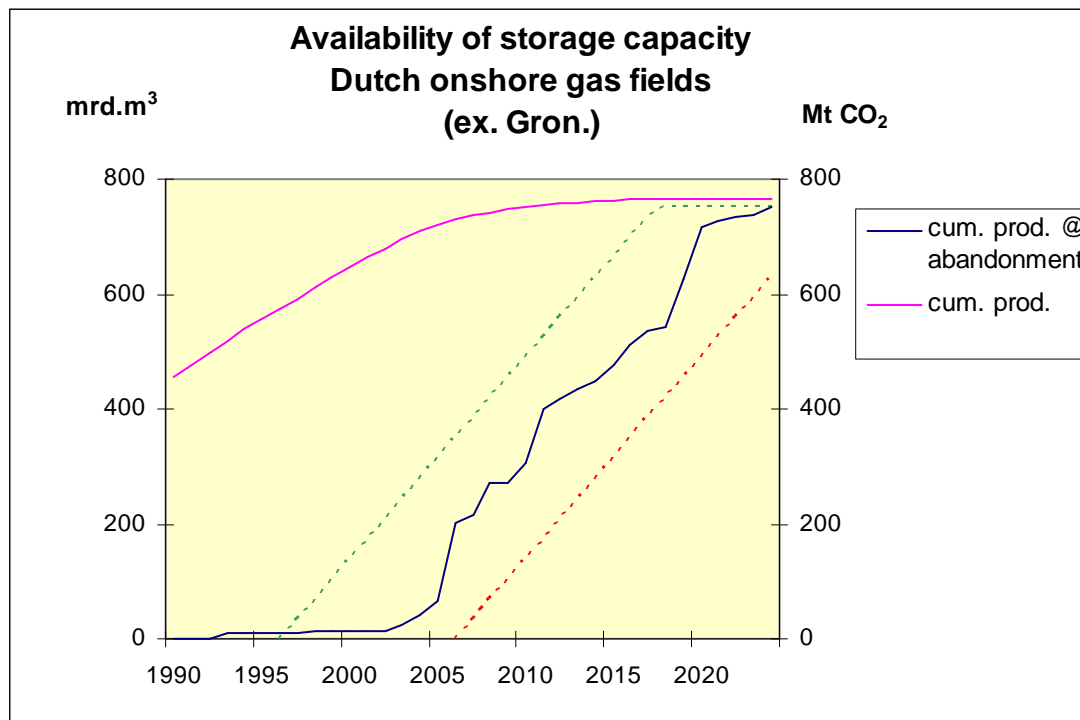


Figure 2 Availability of storage capacity in Dutch onshore gas fields

9. FIELD SIZE CONSTRAINTS

The total number of gas fields discovered in the Netherlands is around 350.

The size distribution of these fields is shown in Figure 3. The distribution has the 'natural' shape of many small fields and less larger ones. The number of gas fields with an estimated initial reserve of more than 5 bcm is 43 for the onshore and 40 for the offshore area (2).

Future exploration will add new fields to this distribution. However, in view of the mature stage of exploration in The Netherlands, their number will probably be considerably less than the number of fields already discovered. Even more important in the context of re-use for storage, their individual field sizes are expected more on the low side than on the high side of the 5 bcm mark. Therefore, future discoveries are not considered here.

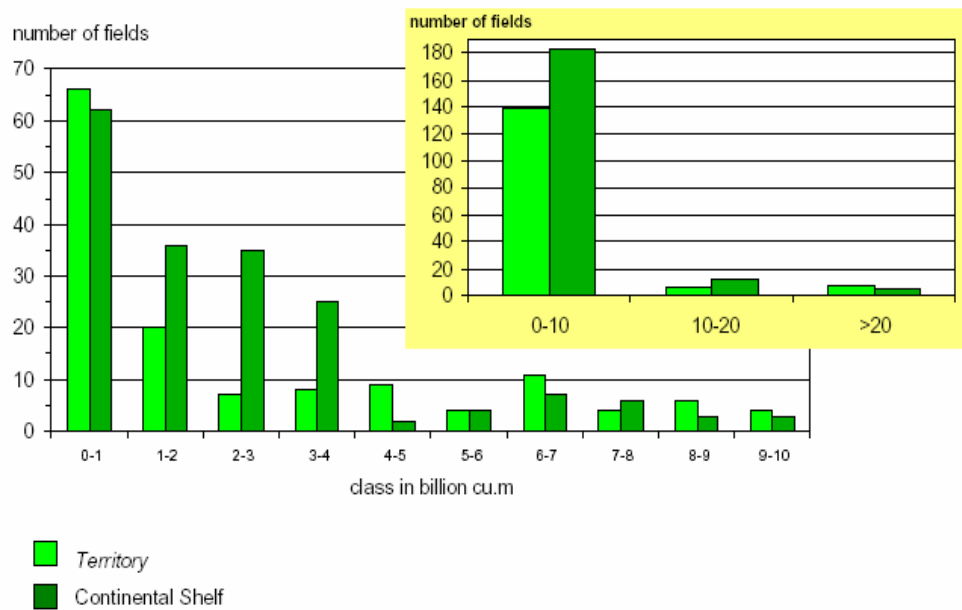


Figure 3 *Field size distribution of Dutch gas fields*

10. GEOGRAPHICAL CONSTRAINTS

In the previous paragraphs it has been noted, that large scale buffering of natural gas and large scale storage of CO₂ may have different geographical constraints.

Figure 4, as an example, shows the geographical relation between large sources and large sinks onshore the Netherlands. From the map it is clear, that most of the CO₂ generation is in the southwest, whereas most of the CO₂ storage capacity is in the northeast of the country. Therefore, making use of the storage capacity will require transportation of CO₂ over distances in the order of 200 km and/or building new power plants and industries in the north eastern part of the Netherlands. As an alternative, CO₂ may be transported offshore for storage,

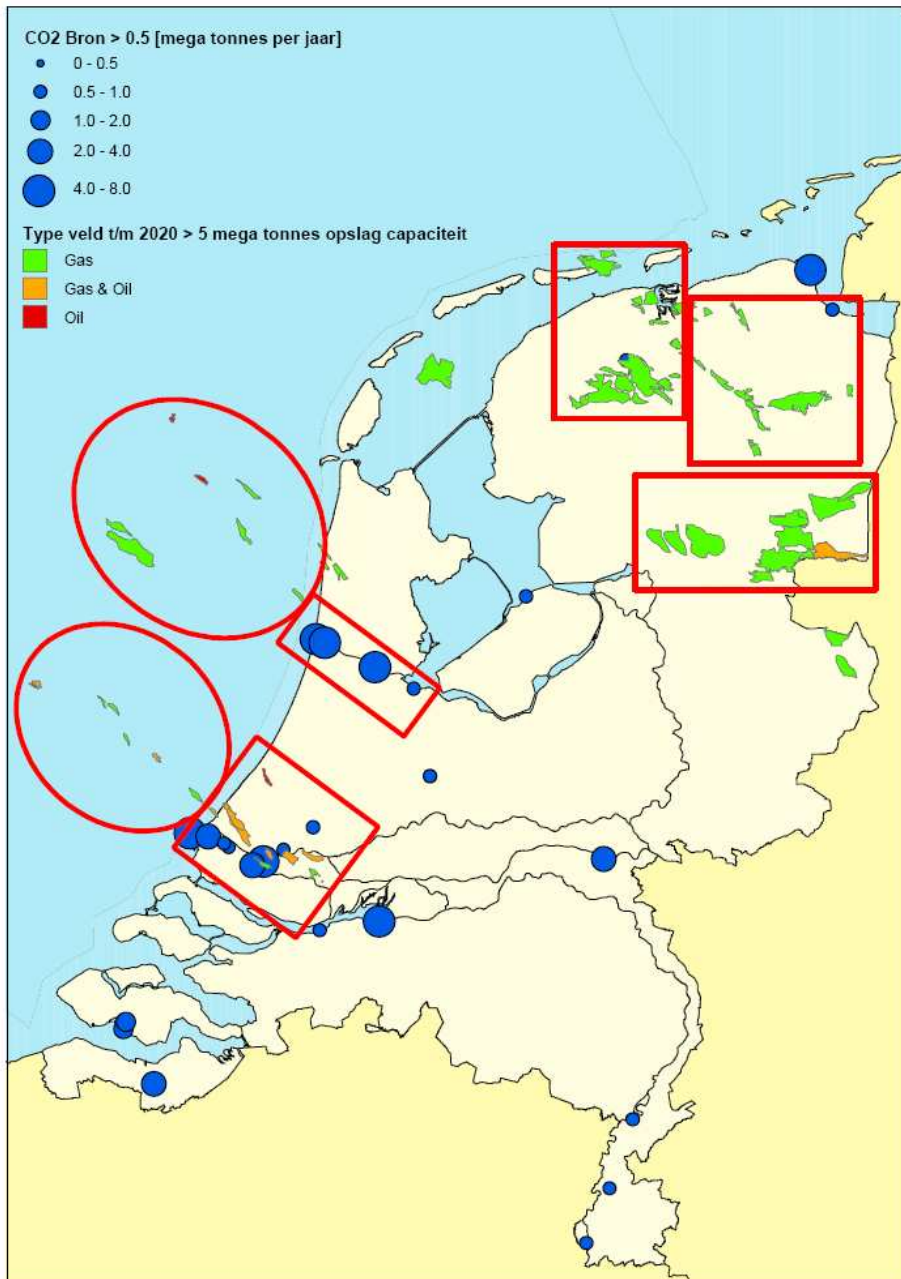


Figure 4 Map of the larger CO₂ sinks and sources in the Netherlands

11. CONCLUSIONS

It is concluded, that the Netherlands offers excellent opportunities to make the most out of the natural gas assets portfolio, not only in terms of recovery but also in terms of value for re-use, provided that the window of opportunity is carefully considered.

Buffering of natural gas and CO₂ storage are the most promising large scale re-use applications

The window of opportunity already has opened up. It is therefore of utmost importance, that upscaling of storage projects takes place on the short term.

Flexibility in the timing of CO₂-storage projects can be significantly enhanced by introducing Enhanced Gas Recovery in the decline phase of production,

It is unlikely, that the free market principle will create the optimal re-use of depleted gas fields. Some kind of Master Plan is needed.

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Figure 4 ***Map of the larger CO₂ sinks and sources in the Netherlands***

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