Public risk perceptions and emotions towards the earthquakes caused by gas production

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Gas production and earthquakes in Groningen

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reflection on economic and social consequences

Machiel Mulder and Peter Perey (ed.)

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1. Introduction

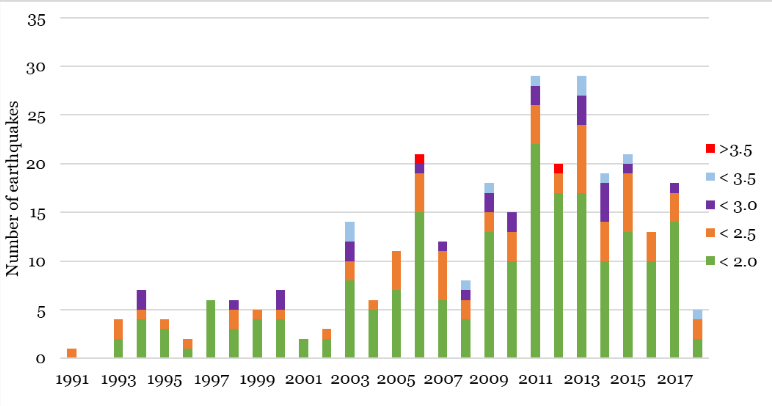
Machiel Mulder & Peter Perey

1.1 Background

In the evening of 16 August 2012, an earthquake with a magnitude of 3.6 on the scale of Richter occurred near the village of Huizinge, in the northern part of the Netherlands. Immediately after the incident, numerous complaints about damage to houses were reported. The operator of the field, the Nederlandse Aardolie Maatschappij (NAM), received over 1,000 damage reports in the week following this earthquake. It appeared that the earthquake was indeed induced by gas extraction from the Groningen gas field (Dost & Kraaijpoel, 2013).

The relation between gas extraction from the Groningen field and seismic activity in the region is not a new phenomenon. In the past decades, several studies have showed this relationship. BOA (1993) concluded that gas extraction has an influence on the robustness of the gas reservoir and the direct surroundings. This report also concluded that earthquakes can be induced by gas extraction. Although this relation has been confirmed by the latest incidents, the initial assessment of the magnitude of the problem was not correct. BOA (1993) predicted that even in the worst case, there would be a small chance of minor damage around the epicentre. With the information which is currently available it is evident that this prediction was too optimistic. The province of Groningen has been struck by earthquakes numerous times over the past 25 years. Since the earthquake of Huizinge, over 100 earthquakes with a magnitude of 1.5 or more have been registered (Figure 1.1). After the Huizinge earthquake, there was a steep increase in the number of inhabitants reporting damage to their houses. In international comparison, the level of damage in Groningen is higher than would be expected given the magnitude of the earthquakes (see Box 1.1). Until the beginning of 2018, over 85,000 damage claims have been filed (NCG, 2017).

Figure 1.1. Total number of earthquakes with a magnitude > 1.5 per year, categorised by magnitude, 1991-2018



Source: NAM

1.2 The Groningen gas field and its revenues

The operator of the Groningen gas field has been a major player in North-West European gas market. Since the discovery of this gas field, the importance of natural gas as energy source grew immensely in the Netherlands and its neighbouring countries. Natural gas became the primary energy source for households, for example for cooking and heating. The role of the gas production from Groningen changed in the following decades as the field got a more strategic function. Other small gas fields produced continuously over time, where the Groningen field was increasingly used in times of high demand. This so-called swing function of the Groningen field was meant to secure the supply of natural gas in Northwest Europe as well as to maximize the revenues. The revenues coming from this huge reservoir of natural resource had a major contribution to the economic welfare of the Netherlands in the second half of the 20th century (CBS, various years). In the 1980s the share of the gas revenues in total government income peaked at 15%, but this contribution gradually decreased to about 2% currently.

Box 1.1: Geology – what causes the earthquakes?

The natural gas of Groningen is located at 3 km deep, in a sandstone layer. Sandstone consists of sand that is pressed against each other under high pressure. When gas is pumped out of the sandstone layer, the pressure in this layer decreases. As the decreased pressure cannot support the weight of the layers on top, it results in soil subsidence that compresses the layers. When this compression occurs in an irregular way, the soil subsidence causes an earthquake. Gas-induced earthquakes in the sandstone layer occur at a shallow depth, compared to natural earthquakes that occur at 20-100 kilometres deep. As a result, the earthquakes induced by the gas production have a higher impact on buildings than natural ones. On top of that, ground movements are intensified because the seismic energy is transmitted by a subsoil of clay, sand and peat. Also, the predominant traditional construction in brick adds to the vulnerability of buildings (Koster & van Ommeren, 2015; McGarr, 1984; van Eck et al., 2006).

1.3 Policy debate

The damage caused by earthquakes was initially settled between property owners and the NAM. In January 2014, the Dutch government stepped in with a set of additional compensating measures as well as the institution of a National Coordinator. One of the tasks of this coordinator was to manage the processes of damage repair and structural reinforcement of buildings. However, the NAM continued to have a large say in the handling of damage claims and this double role of the operator caused much discontent in the area. This led to the decision to transfer the management and financial compensation of damage claims to a government agency, which charges its costs to the NAM. However, the severity and magnitude of the problem complicated the setup of a damage protocol. After the implementation of a protocol, different problems became apparent. These problems were related to the difficulty of the assessment of damage and often conflicting assessments by different experts. To tackle the problems, the government implicated a new damage protocol. Starting from March 19 2018, inhabitants can report their damage claim by the *Commissie Mijnbouwschade Groningen*. This replaced the old structure and has as purpose to accelerate the process.

In addition, the government policy was directed at reducing the risks of earthquakes in the future as much as possible. In order to do so, the government further restricted the annual level of production from the Groningen field. The initial cap, which was introduced in 2006, of 425 billion m^3 (bcm) for a period of 10 years was introduced because of security of supply concerns. In order to reduce the risk of earthquakes, the Dutch government reduced this cap to an annual level of 27 bcm in 2015. Because of the persistent earthquakes, the cap has been lowered several times since then. In the case of an abnormal cold year, however, the production is allowed to be somewhat higher, to secure domestic supply and to prevent a shortage for the inhabitants of the Netherlands. In March 2018, the Dutch government decided that the Groningen gas production will completely come to an end in 2030 (EZK, 2018).

1.4 Responses in society

The increasing intensity and frequency of the earthquakes led to a fierce debate among Dutch population, adding to the debate on the need to reduce the use of fossil energy. The debate on gas production basically boils down to the trade-off between the national revenues of gas production and the importance of the Groningen gas field for the Dutch security of gas supply on the one hand and the risks and costs for the inhabitants of the affected region. The latter group demanded immediate action of the government to prevent future quakes. Furthermore, over the past five years anger and frustration have grown regarding the compensation for the damage and value loss of their houses (KAW, 2018). Although a government agency has taken over the lead, the slow process of developing the new protocol on how to assess all the damage claims added to the dissatisfaction of the inhabitants.

Several citizen interest groups have been established, including the *Groninger Bodem Beweging* and *Schokkend Groningen*. Another active interest group is the WAG Foundation, representing over 4.500 owners of houses, which won a court claim for compensation of the devaluation of their properties. These groups protested against gas production, by occupying buildings and protesting in front of the headquarter of the NAM. On January 19 2018, inhabitants of the earthquake affected region organised a torchlight procession as a protest towards the in their view passive attitude of the government and the operator. The dissatisfaction among the population after more than 5 years of uncertainty about how the problems caused by gas extraction would be solved appeared to be huge. Over 10,000 people were present and another 53,000 signed an online protest petition.

The earthquakes did not only affect the overall wellbeing of the inhabitants of the region, it also affected the housing market. The uncertainty concerning the earthquakes makes the region less attractive and valuable. Furthermore, the inhabitants of the region are more likely to move away from the area, adding up to other factors negatively influencing the housing market in the rural and less wealthy regions of Groningen.

1.5 Structure of the paper

In this paper, we want to give an overview of the economic and social consequences of both the gas production and the resulting earthquakes. Section 2 describes the role of the Groningen gas field in the gas market, while Section 3 goes into the historical economic importance of the Groningen gas production for the Dutch state revenues and economy. In the following sections, the effect of the earthquakes on the inhabitants of the Province in Groningen is discussed. Section 4 discusses the effect of the earthquakes on the housing market, while Section 5 treats the social-psychological aspects in detail. Finally, Section 6 presents some lessons learned and discusses how to go forward.

References

Begeleidingscommissie Onderzoek Aardbevingen (BOA) (1993). Eindrapport multidisciplinair onderzoek naar de relatie tussen gaswinning en aardbevingen in Noord-Nederland.

Centraal Bureau voor de Statistiek (CBS) (various years). De Nederlandse economie.

Dost, B., & Kraaijpoel, D. (2013). The August 16, 2012 earthquake near Huizinge (Groningen). KNMI Scientific Report. Royal Netherlands Meteorological Institute (KNMI), Utrecht, The Netherlands.

Van Eck, T., Goutbeek, F., Haak, H., & Dost, B. (2006). Seismic hazard due to small-magnitude, shallow-source, induced earthquakes in The Netherlands. Engineering Geology, 87(1-2), 105-121.

KAW (2018) Woningmarkt- en bewonersonderzoek Noord- en Midden-Groningen. Overkoepelende rapportage. Groningen, KAW.

Koster, H. R., & van Ommeren, J. (2015). A shaky business: Natural gas extraction, earthquakes and house prices. European Economic Review, 80, 120-139.

McGarr, A. (1984). Scaling of ground motion parameters, state of stress, and focal depth. Journal of geophysical research: Solid earth, 89(B8), 6969-6979.

Nationaal Coördinator Groningen. (2017). Kwartaalrapportage juli tot en met september 2017.

Minister of Economic Affairs and Climate (EZK) (2018). Kamerbrief over gaswinning Groningen [letter of government on gas production Groningen], The Hague, 29 March.

2. Role of Groningen gas field in the gas market

Machiel Mulder and Peter Perey

2.1 Characteristics of the Groningen gas field

Natural gas is a natural product, which means that its characteristics vary from field to field. Different gas fields contain different types of natural gas that have different specifications and composures. The natural gas that is produced from the Groningen gas field is qualified as L-gas, referring to low-calorific gas. The qualification of natural gas, either low-calorific or high-calorific, depends on the Wobbe-Index of the gas. The Wobbe-index indicates the thermic value of a gas (Klimstra, 1986). Gas with a low-calorific value contains a higher percentage nitrogen and lower percentage of methane than high-calorific gas, resulting in a lower Wobbe-index. Therefore, the amount of thermal energy stored in a unit low-calorific gas is lower than in the same unit of high-calorific gas. The Groningen field has a higher nitrogen (14,2%) content compared to other European gas sources, such as Russian or Norwegian gas (ca. 2%).

The energetic quality of the natural gas is not the only key characteristic for a gas field. Another characteristic is how complicated the extraction of natural gas from the field is. This difficulty of extraction is reflected in the so called marginal production costs. If the price which will be received for the natural gas is lower than these marginal-extraction costs the producer will not produce at all. Looking at this characteristic, Groningen has a huge advantage compared to other fields. Its marginal costs belong to the lowest in Europe. In addition, the production level from Groningen can be adjusted from hour to hour relatively cheaply and quickly. This gives the operator of the field the advantage to vary the output level according to market circumstances. In other words, the operator can increase output when demand (and price) is high and decrease output if output falls. Therefore, the Groningen field is often referred to as a swing supplier. That this option of being a swing supplier is exploited in the past becomes apparent when looking at the detailed production data. It appears that the supply from Groningen peaks in winter periods and is relatively low in the summer. So, the Groningen gas is primarily used to meat peak demand during winter time when the gas price is higher (see Figure 2.3).

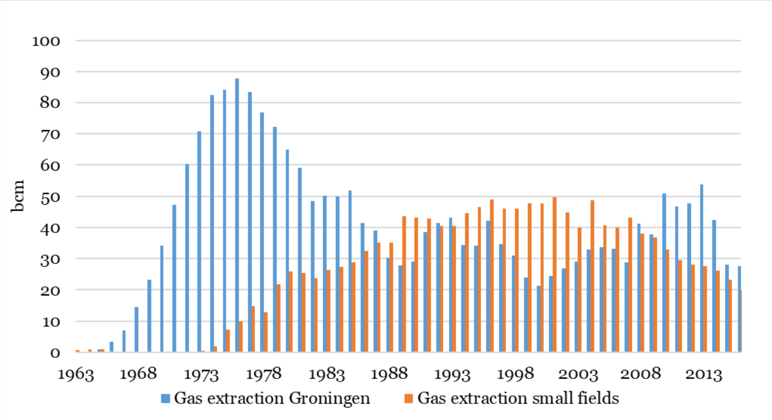
2.2 Dutch gas-market policies

Since the discovery of the Groningen gas field near the village Slochteren, the Dutch gas policy changed multiple times. At the time of discovery, gas markets did not play an important role, and the overall belief was that in the future, all energy would be retrieved from nuclear power (see Correljé & Verbong, 2004). Therefore, in the 1960's, the objective was to deplete the Groningen gas field as fast as possible. An additional objective of the Dutch government was to secure gas supply for at least 25 years.

In the following decade, the view on the domestic natural resources changed drastically. The oil crisis showed the strategic importance of natural resources. This change in view led to a transformation of the Western energy policies. In the Netherlands, the Groningen gas field was suddenly a huge strategic storage worth to preserve. In terms of policy, this was translated into the introduction of the *Kleineveldenbeleid*, an offtake guarantee for small fields, in 1974. The incumbent operator of the Dutch gas system, Gasunie, was required to buy gas from small fields in favour of gas from the Groningen field (GasTerra, 2017). This resulted into higher returns for these fields, enabling the preservation of the Groningen gas field to be used for flexibility purposes (EZ, 2004). As could be expected, the offtake guarantee led to lower production levels from the Groningen gas field (Figure 2.1). As a result, the pace of depleting the

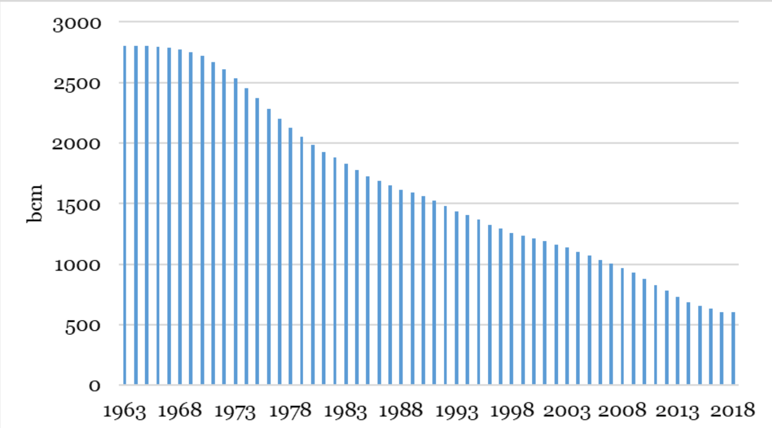
Groningen field reduced as well. The current magnitude of gas reserves in this field is estimated at about 500 bcm, which is still about 1/5 of the size more than 50 years ago (Figure 2.2).

Figure 2.1. Gas extraction in the Netherlands, 1963-2016



Source: NAM, CBS

Figure 2.2. Gas reserves in the Groningen gas field, 1963-2018



Source: NAM, CBS

Until begin 2000's, Groningen production was regulated by a maximum allowed production of *all* Dutch gas fields of 80 billion m^3 (see Table 2.1). The maximum allowed production of Groningen was thus determined by the difference between this maximum and the actual production of smaller fields (Mulder & Zwart, 2006).

Table 2.1. Production cap on the Groningen gas field per gas year

Announcement date	**Valid gas year(s)**[1]	**Maximum annual production (bcm)**	**Objective**
2000	Until 2005	80 minus production small fields	Using Groningen gas as strategic reserve
December 22, 2005	2006	42.5 (425 in period of 10 years)	
December 18, 2015	2015-2016	27	Reduce earthquake risks and damage
June 24, 2016	2016-2017	24	
April 18, 2017	2017-2018	21.6	
March 29, 2018	2022	12	
	2023-2029	*Gradual reduction*	
	2030	0	

Source: Ministry of Economic Affairs (EZ)

However, the production of small-fields was expected to decline quickly. Therefore, to prevent the rapid depletion of the Groningen gas field and to maintain the flexibility of this field, a cap on the production of Groningen was imposed (EZ, 2005). The policy implementation consisted of a cap on

[1] A gas year runs from October till September, so the cold-weather period with high demand is in the beginning of the year. This is done to minimalize the chance of a constraint with the cap.

the production level of the Groningen field over a longer period of time. For the period 2006-2015, the cap was set on 425 bcm without an annual restriction. So, the producer could choose any yearly production level, provided that the production over 10 years did not exceed 425 bcm. For the period of 2010-2020, the same cap of 425 bcm was imposed.

Box 2.1: Dutch natural resources law

In contrast to other countries, the Dutch State is owner of all natural resources and minerals from a depth of 100 metres. According to the *mijnbouwwet* the Dutch government is allowed to outsource the mining to a so-called concession holder. This concession holder has a monopoly on the resources and minerals and their revenues (Art. 143.2 Mijnbouwwet). Under normal circumstances, the concession holder can choose his production plan autonomously. The Dutch State is only allowed to interfere under special conditions. These conditions include: changed insights in the planned use or management of minerals, safety considerations and prevention of damage to properties.

Furthermore, the license holder has to take all measures that can reasonably be required to prevent that the mining activities cause damage. The Minister may stipulate that security must be provided to cover the liability for the damage that is caused by the movement of the earth as a result of the extraction of minerals.

It is established that there has to be a *Technische commissie bodembeweging*, which has to advise and inform the Minister and potential affected inhabitants about damage caused by mining activities. Finally, it is determined that there has to be a *Waarborgfonds mijnbouwschade*. From this fund, damages can be paid whenever the concession holder in unable to pay for it.

Next to compensation for damage to properties, the Dutch Government established other measures to compensate for the damage in Groningen. These measures include risk reduction, buy out, compensation for property loss and subsidies. A more detailed review of these measures is given in chapter 4.

In the 1990's, the European energy markets were liberalised. The goal was to foster competition which should lead to lower energy prices. A consequence of the restructuring of the gas market was that the gas system was no longer controllable by a single party. Despite the liberalisation of the gas market, the Dutch government remained involved in the production of Dutch gas, based on the legal framework of the natural resources law (see Box 2.1).

Although the regulation of the production volume from the Groningen field is not a new phenomenon, the reason behind the regulation from the government has changed. Where historical policies regarding the gas market where focused on future security of supply, the latest policy change has a new cause. After the earthquake of 2012 near Huizinge, the main reason for the change in policy was the risk following from gas-extraction induced earthquakes. The Dutch government announced that the cap of 425 bcm on a 10-year basis would be replaced by an annual cap of 27 bcm in 2015. This cap is now gradually lowered several years. The current production cap for the Groningen gas field is 21.6 bcm. On March 29 2018, the Dutch government announced the end of gas production in Groningen[2]. The maximum production from Groningen will decline gradually in the period 2022 and 2030. In 2030 no gas will be produced anymore from the Groningen gas field.

2.3 Groningen gas field in the European gas market

To be able to identify the role of the Groningen gas field in the gas market, it is necessary to know which components make up this market. In other words, who are the agents on the supply and demand side of the market? As told before, the quality of natural gas differs between different sources. The different types of natural gas have both different consumers and producers.

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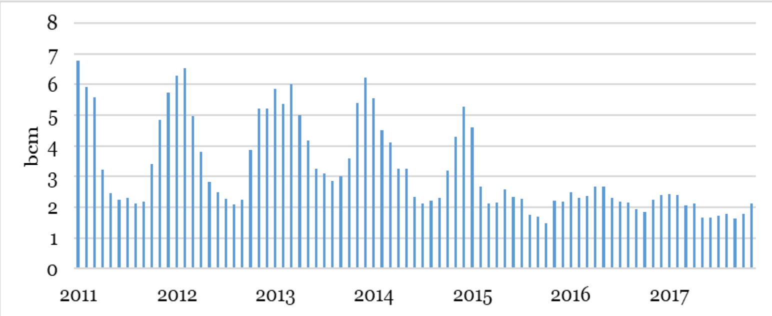
[2] https://www.rijksoverheid.nl/onderwerpen/gaswinning-in-groningen/nieuws/2018/03/29/kabinet-einde-aan-gaswinning-in-groningen

Looking at the demand profile of natural gas in the Netherlands, some clear distinctions can be seen. Industrial demand is relatively flat over time, as demand is not seasonally bounded. Industrial usage of natural gas is for the purpose of large scale heat generation or feedstock in industrial processes. Given this usage of the natural gas, the type of gas with a higher Wobbe-index is preferred by this type of user. Therefore, the natural gas that goes to industrial demand is high-calorific gas. Consumer demand and exports, which are mainly meant for foreign residential consumers, have high seasonal flexibility. This follows from the fact that the natural gas demanded by these groups is mainly used for heating. Both demand categories with high seasonal flexibility, are supplied by natural gas with a low calorific value. As a result, the demand in winter times is significantly higher than during summer time. This seasonal component of gas demand results in a seasonal fluctuations in the gas price (Mu, 2007: Hulshof et al., 2016).

Figure 2.3. Monthly production from the Groningen gas field, January 2011 – November 2017

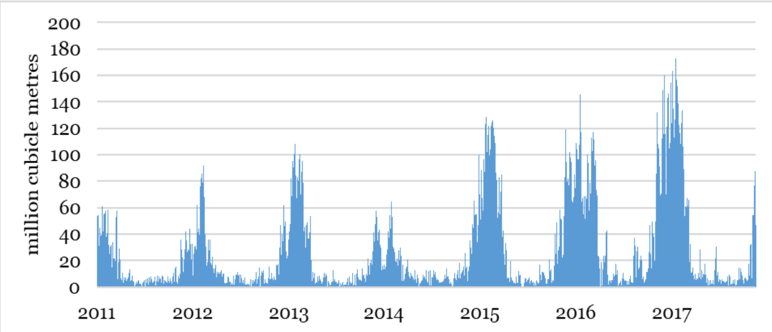


Source: Bloomberg

Looking at the supply side of the market for natural gas, both the imports and the production by small fields are relatively flat over time.

Both these types of supply contain natural gas with a high calorific value. The other two types of supply show large variability over time. These are the Groningen field, acting as a swing supplier, and the storages (see Figures 2.3 and 2.4). As can be seen, the storages are historically used only in times of peak demand. These peak demands are reached on extreme cold winter days. Note that these storages are filled up again in summer times. Both the gas from the Groningen field and (most of) the storages have a low calorific value. These storages are meant to support the Groningen gas field to deliver flexibility to the market. The supporting role of the storages has increased over time as Groningen is increasingly less able to act as swing supplier (see also Hulshof et al., 2016).

Figure 2.4. Daily net injection from storages, January 2011 – November 2017



Source: Bloomberg

Concluding, the different origins of supply serve different end-users. The high-calorific gas demand by the industry is supplied by the small-fields and imports from countries like Russia and Norway as well as the import of LNG. The low-calorific gas demanded by domestic and foreign consumers originated from the Groningen field. In summer times, storages are filled to meet excessive peak demand in winter periods. Due to the nature of their usage, the high-calorific gas has a rather flat production and consumption path, where the low-calorific gas is highly volatile.

2.4 Impact of lower production cap on gas market and consumption

As explained above, the gas-induced earthquakes were the reason for the Dutch government to lower the cap on the annual production from Groningen. Given the importance of the Groningen field one may expect that this policy change has an effect to the gas market. One can argue that the limitation of production on Groningen makes the availability of natural gas more difficult. This in turn might lead to higher prices for natural gas.

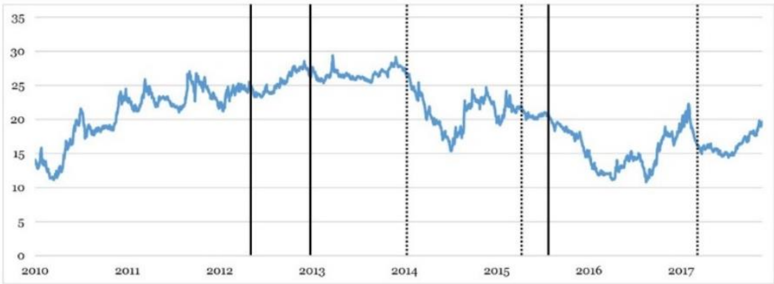
This relation of the limited availability of Groningen gas and the natural gas price is investigated by Perey (2018).[3] It was found, however, that there is no significant evidence of an effect of the lowering of the cap on the Dutch gas price (Figure 2.5). This lack of effect on the price can be explained by the existence of substitution in supply. In other words, the supply of Groningen that is gone due to the lowering of the cap is likely replaced by another source. This mechanism shows the well-functioning of the integrated European gas markets. This is in line with earlier findings of Kuper et al. (2016) of a more integrated European gas market.

Because the residential sector depends on L-gas, a reduced availability of the Groningen gas implies that H-gas has to be used in combination with quality conversion. Quality conversion is the conversion of H-gas to L-gas, which is done by adding nitrogen to H-gas to obtain a similar level of thermic value as L-gas. The problem with conversion is that

[3] The investigation consisted of an empirical analysis of the influence of the lower cap on the gas price of the Title Transfer Facility (TTF), a virtual gas trading hub in the Netherlands. To be able to identify the sole effect of the production cap, control variables were added to the regression.

the amount of H-gas converted to L-gas is limited to the maximal output of conversion facilities. According to Thackrah (2018), the quality conversion facilities already reached their maximum capacity at times in December 2017. This was caused by excessive demand, driven by cold weather, which could not be met by Groningen production. At the same time, around 1 billion cubicle metres (bcm) was withdrawn from the Norg storage.

Figure 2.5. Daily gas price at TTF (in €/MWh), 2010-2018



Note: Bold lines: dates of major earthquakes; dotted lines: dates of government announcement of lower production cap.
Sources: Bloomberg L.P., NAM, EZ

Given the new cap and announcement of further lowering of that cap, it becomes clear that Groningen can no longer serve as a swing supplier. To be able to meet the higher demand in times of cold weather, storages and quality conversion have to play an increasing role. Since both sources are constraint to a maximum, future investments have to be made to take over the role of Groningen. Indeed, in the announcement of the end of production in Groningen, the government also announced an investment of 500 million euro in a new quality conversion station.[4]

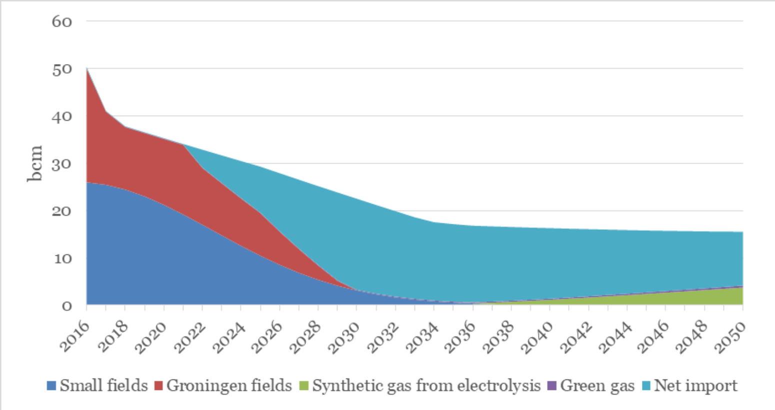
[4] https://www.rijksoverheid.nl/onderwerpen/gaswinning-in-groningen/nieuws/2018/03/29/kabinet-einde-aan-gaswinning-in-groningen

2.5 Energy transition

The policy measures to reduce and ultimately stop the gas production from Groningen fit within the policy objectives to realize an energy transition in which fossil energy is being replaced by renewable energy. Reducing the supply of gas from one source (i.e. the Groningen field) does in itself, however, not bring this energy transition. As we have seen in the previous section, the cap on Groningen has hardly affected the international price of gas, which means that the market parties expect that the Groningen gas can be easily replaced by gas from other sources because of the international integration of gas markets. Therefore, measures to reduce the gas consumption are required. The Dutch governments wants to reduce the gas use in the residential sector (housing) by electrification (e.g. heat pumps) and extending district-heat systems. Electrification means that the demand for electricity increases, on top of the autonomous increase in electricity demand.

In a scenario analysis of the Dutch energy system, Moraga and Mulder (2018) conclude that the total electricity demand will be 50% higher in 2050 compared to the current level, which is mainly due to the increased demand resulting from electrification of housing and the transport sector. Although the supply of renewable energy (in particular wind and solar) will increase strongly according to current policy objectives, this increase will not be sufficient to displace natural gas from the electricity sector. In a scenario where the current gas demand in the residential sector is gradually fully replaced by a mixture of electrification and district heating, while the transport sector is also almost fully electrified, the domestic demand for natural gas remains at about the current levels. In combination with the declining supply from both the Groningen gas field and the small fields, the import of gas has to grow strongly.

Figure 2.6. Supply of gas to meet Dutch gas demand, in case of electrification of heating and transport and strong increase of renewables, 2016-2050



Source: Moraga and Mulder (2018)

Even if the supply of renewable energy were 3 times as large as the current policy objectives, the import of natural gas would still be significant in the long term in order to meet the demand within the Dutch economy (Figure 2.6). In this scenario, the electricity sector would be fully based on renewable energy. The total supply of electricity would exceed the total demand (on an annual basis) which would make it possible to produce synthetic gas for industry usage, though the supply would not be sufficient to meet all demand. From this scenario analysis, it appears that while the Groningen gas production will stop at some point not far in the future, the gas sector will likely remain necessary to supply gas to the electricity sector, residential sector and industry in the Dutch economy for many years to come.

References

Correljé, A., & Verbong, G. (2004). The transition from coal to gas: radical change of the Dutch gas system. System innovation and the transition to sustainability: theory, evidence and policy, 114-134.

GasTerra. (2017). https://www.gasterra.nl/producten-diensten/de-markt-van-nu/kleineveldenbeleid-2.

Hulshof, D., van der Maat, J. P., & Mulder, M. (2016). Market fundamentals, competition and natural-gas prices. Energy Policy, 94, 480-491.

Klimstra, J. (1986). Interchangeability of Gaseous Fuels—the Importance of the WOBBE-INDEX (No. 861578). SAE Technical Paper.

Kuper, G. H., & Mulder, M. (2016). Cross-border constraints, institutional changes and integration of the Dutch-German gas market. Energy Economics, 53, 182-192.

Mijnbouwwet. (2002, October 31). Consulted on April 11, 2018. Retrieved from: http://wetten.overheid.nl/BWBR0014168/

Ministry of Economic Affairs (EZ), 2004, Gas production in the Netherlands; importance and policy, Publication code 04ME18.

Ministry of Economic Affairs (EZ), 2005, Voorzienings- en leveringszekerheid energie, Tweede Kamer der Staten Generaal, 2005-2006, 29 023, nr. 21, 22 december.

Mu, X. (2007). Weather, storage, and natural gas price dynamics: Fundamentals and volatility. Energy Economics, 29(1), 46-63.

Mulder, M., & Zwart, G. (2006). Government involvement in liberalised gas markets; a welfare-economic analysis of Dutch gas-depletion policy (No. 110). CPB Netherlands Bureau for Economic Policy Analysis.

Moraga, J.L. & Mulder, M. (2018). Electrification in heating and transport; a scenario analysis for the Netherlands up to 2050. University of Groningen, CEER Policy Papers, 2, May.

Perey, P. (2018). Shake now or extract later; a cost-benefit analysis of lowering the cap on the Groningen gas field, with special attention to earthquakes. MSc thesis, University of Groningen.

Thackrah, A. (2018). Going, Going, Groningen… ICIS Market Insight, January.

3. The Janus Face of Natural Gas Resources in the Netherlands

Bert Scholtens

3.1 Introduction

This chapter argues that the exploitation of the natural gas field in Groningen has both positive and negative effects on the Dutch economy. These effects are hard to balance due to their incommensurable nature. The chapter reflects on the role of gas in the Dutch economy, discusses the economic implications of the exploitation of natural gas as well as the externalities, and reflects on the economic impact of phasing out the exploitation of the Groningen field.

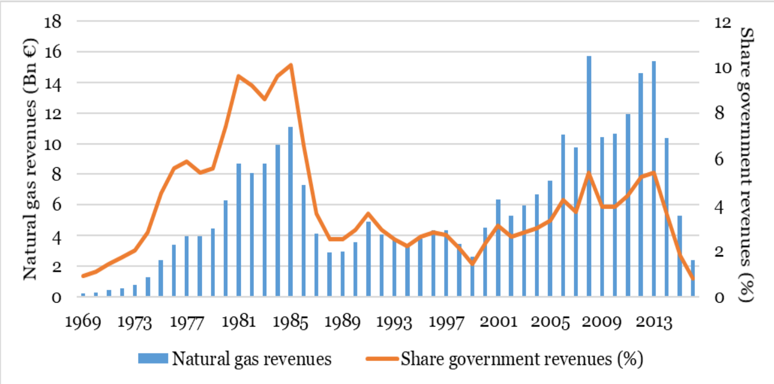
The organization of this chapter is as follows. Section 3.2 goes into gas revenues in the Netherlands. Section 3.3 highlights how to assess the revenues from natural resources from an economic perspective and reflects on the conventional wisdom that abundant natural resources are a blessing for society. Section 3.4 discusses key features of the impact of reducing the exploitation of gas from the Groningen field. A brief conclusion is in 3.5.

3.2 Gas revenues

The proceeds from natural gas exploitation go into the government budget (90%) and to the mining companies (10%). Since its discovery in 1959, the Groningen gas field has yielded about 288 billion Euros for the government's finances, whereas the mining companies (ExxonMobil and Royal Dutch Shell) earned 29 billion Euros (Algemene Rekenkamer, 2014; CBS, 2017). Figure 3.1 provides an overview of the nominal revenues and the role of these revenues in the government budget. In most years, gas revenues made up between 3 and 6% of the government's revenues.

Especially in the late 1970s and early 1980s, the contribution of gas to the government budget was relatively high. At that time, the gas revenues were a very welcome source of expenditure for the respective Dutch governments. Due to falling prices and societal pressure to reduce the exploitation, the contribution in the last few years has been low from an historical perspective.

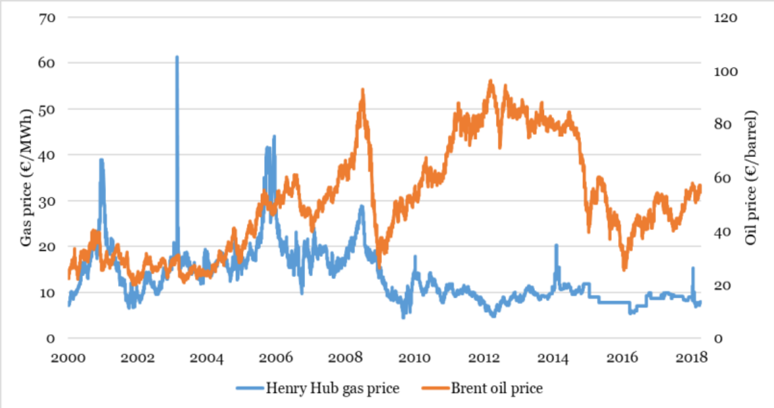
Figure 3.1. Total natural gas revenues for Dutch state and its share in the total government revenues per year



Source: CBS

One needs to realize that it is both the volume of gas exploited and the international gas prices that make up the revenues. According to the Dutch Committee on Safety (Onderzoeksraad voor Veiligheid, 2015), the desire to maximize gas revenues drives the former. In the early 1960s, there was great anxiety with the government that nuclear power would become the main energy source and would impair the value of the gas reserves. Hence, they set up long-term contracts to fix the export of gas. The gas prices relate to developments in international gas and oil markets, which have shown substantial volatility (see figure 3.2 for gas prices in the 21st century).

Figure 3.2. Natural gas price at Henry Hub and Brent oil price, January 2000 – March 2018



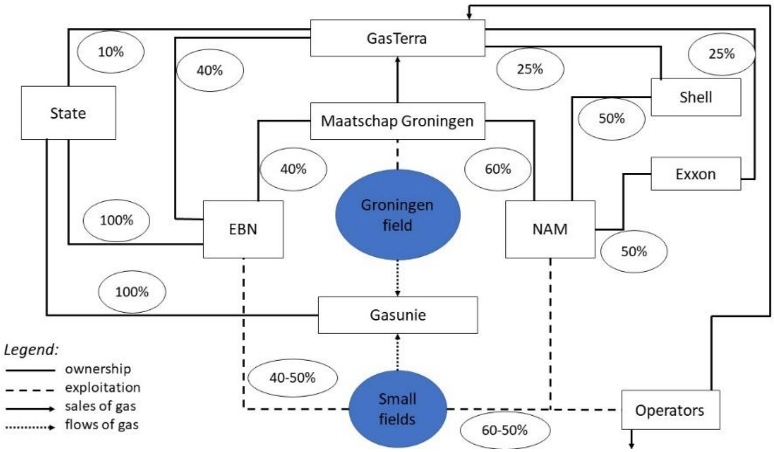
Source: Bloomberg

As to the externalities of the exploitation of natural gas, it is important to realize that the main agents (See Box 3.1) were fully informed about these but did not engage with either mitigation or adaptation (Malm, 2016; Supron and Oreskes, 2017). Further, the first earthquakes in relation to the exploitation of natural gas were already occurring in the 1960s and brought to the attention of the authorities (Van der Sluis, 1989; Reijnders and Van der Sluis, 1997). These externalities were left unpriced and hence did not influence the revenues until the 21st century.

The exploration and exploitation of gas is capital intense, but operational costs are quite limited. Gas exploration and exploitation currently involves about 7000 jobs (<0.1% of total employment). The Netherlands exports the majority of its gas. The gas reserves from the Groningen field will run out in 2030. The estimated value of the current (remaining) gas reserves is about 100 billion euros (Algemene Rekenkamer, 2014; CBS, 2017). Hence, overall, the gas resources could yield revenues of 400 billion Euros for the Dutch government. Figure 3.3

and Box 3.1 show the governance structure of gas exploitation in the Netherlands.

Figure 3.3. Organisation of the Dutch natural gas system



Source: updated version of Mulder and Zwart (2006)

The gas revenues fund the general government's expenses and support the Dutch welfare system. During a 17-year period, part of the gas revenues funded specific projects that aimed at improving the economic structure. These projects previously had been on the regular government budget. In total, these projects amounted to € 17 billion of investments. Examples are a high-speed railway track between Amsterdam and the Belgian border, the extension of the Rotterdam harbour, a freight-carrier railway track to the German border, and applied scientific research. Although an ex ante cost-benefit analysis was being used (Mulder and Zwart, 2006), there was no systematic reporting about the economic impact of these projects, and there is no proof they actually improved the economic structure and earning capacity. The investments did not occur in the region were the exploitation of gas was located; less than 1% of the investments materialized there, which was generally perceived as unfair (IOO, 2006).

Box 3.1: Governance of Dutch natural gas system

The Dutch government participates in gas mining activities via its fully owned company Energie Beheer Nederland (EBN). Together with the Nederlandse Aardolie Maatschappij (subsidiary of Royal Dutch Shell and ExxonMobil), it has set up the Maatschap Groningen to manage the exploitation of the Groningen field. The Maatschap Groningen sells to GasTerra, which is a joint venture of EBN, the Dutch State, Royal Dutch Shell and ExxonMobil. Gasunie is responsible for transport and fully owned by the Dutch State.

The Maatschap Groningen does not need to register with the Chamber of Commerce, and does not need to disclose its operations and organization. Officially, the concession for exploitation is exclusively to NAM. However, in a side-letter it reads that the concession to Maatschap Groningen is a limited company with two shareholders (the Dutch State and NAM). Appendix 3.A shows this letter (in Dutch). The side-letter may become crucial in the debate about the role of the Dutch State in the settlement of the claims regarding the impact of the exploitation of gas on climatic changes and of the earthquake damage and as such may have an impact on the gas revenues as it reveals that the State is a shareholder and is committed to the exploitation.

Alternatively, one might want to investigate the international impact of investments in Dutch gas infrastructure (Bouwmeester and Scholtens, 2017). To this extent, they estimated the cost-side impact of investments in gas transmission by quantifying the direct and indirect, national and international impacts based on a multi-regional input-output model. They estimated the value of investment projects included in the EU's Ten Year Network Development Plans. The overall budgets for these plans translate into gross fixed capital formation by the industries that manufacture the pipelines, compressor station elements, storage facilities, and interconnectors. It appears that two-thirds of employment compensation and four-fifths of the gross operating surplus of gas projects in the Netherlands lands abroad (Bouwmeester and Scholtens, 2017, p.376). This clearly shows the openness of the Dutch economy.

The gas revenues make up part of the central government's revenues and as such contribute to general government spending. Most of it supported the design and maintenance of the social welfare system, the health system, and the education system. This has been helpful for the social and economic development of the Netherlands. However, we lack a proper metric to assess the use of the gas revenues, especially in relation to externalities such as climate change and earthquakes.

3.2 How to assess resource use?

A conventional approach to assess the use of revenues from natural resources is the Hartwick (1977) rule (see also Asheim et al., 2003). This rule holds that countries need to invest the proceeds from their natural resources in reproducible capital that yields enough to keep per capita wealth intact. Of course, in practice, it is hard to specify which part of natural resources revenues should be invested in which type of capital. Important is to realize though that from an economic point of view the investments should allow for the sustainability of the aggregated stock of capital. Future generations are entitled to at least the same stock of capital as current ones. In the case of the natural gas resources, one might imagine that part of the funds are used to allow for the development of alternative sources of energy generation. There is no compelling evidence that the consecutive Dutch cabinets explicitly accounted for this intergenerational perspective when they decided about spending the proceeds.

Until the 1990s, natural resources usually were regarded as a blessing for the domestic economy. The rents would accrue to the Dutch State, which would have additional financial resources that could help strengthen the country's economic structure. However, the new economic growth theory and the accompanying empirical research came up with a very different perspective. Sachs and Warner (1997) established that countries highly reliant on primary exports did underperform in relation to countries that relied less on natural resources. This finding appeared to be robust after controlling for various factors, such as initial GNP, openness, legal system, institutions, endowment of all kinds of capital, price shocks, etc. (Gylfason, 2001; Mehlum et al., 2006). Please realize that there are contrasting views (see Alexeev et al., 2009), and that the heterogeneity between countries and natural resources is substantial (Torvik, 2009). This means that it is not possible to arrive at general statements about the exact impact of the availability of particular natural resources on wealth in a specific country. Therefore, it seems relevant to have a closer look at the transmission mechanisms that might be at work regarding the impact of resource endowment on economic performance.

Several factors might play a role regarding the impact of resource abundance on economic development. The most famous one probably is the Dutch disease. The Economist coined this qualification to describe the effect of gas revenues on the Dutch economy. It relates to the effect of an increase in export revenues of a natural resource on the exchange rate. This might result in a real appreciation of the exchange rate. Appreciation implies that the exports become relative expensive and therefore less attractive for international markets. This has a negative impact on the competitive position of those industries that are not highly reliant on the abundant natural resource. Consequently, there is a (relative) reduction in the role of the industry in the economy and there will be less economic diversification (Sachs and Warner, 1995). In the Netherlands during the 1970s, the high revenue generated by the natural gas discovery led to a sharp decline in the competitiveness of its other, non-booming tradable sector (Corden, 1984). Despite the revenue windfall, the Netherlands experienced a drastic relative decline in economic growth. When the Netherlands swapped the national currency for the Euro, the impact of the Dutch disease watered down considerably. When gas revenues make up a smaller part of total revenues, this of course too has a dampening effect.

Other adverse factors that play a role in the relationship between natural resources and the economy are price volatility, education and research, and rent-seeking. Van der Ploeg and Poelhekke (2009) show that the volatility of oil prices, which usually anchored natural gas prices until a couple of years ago, has a negative impact on growth. Revenues fluctuate and this makes it difficult to project the returns on investments within the economy. Further, Gylfason (2001) highlights that in resource-rich countries, the opportunity costs to accumulating human capital are very high. Due to myopic policies, there is too little investment in human capital. This too depresses the growth potential. A fourth factor is rent-seeking. The existence of natural resources attracts firms and institutions that try to benefit from their abundance. They tend to focus more on keeping a privileged position than on productive activities. Such rent-seeking is reflected in lobbying and results in suboptimal government spending (Papyrakis and Gerlagh, 1997).

It is not possible to pinpoint at a detailed and exact level how each of these factors has affected the Dutch economy in relation to its natural gas resources. They highlight that next to benefits from the presence of these resources, there also is a cost. This also signals that the use of the revenues might have been not highly efficient and that the behavioural changes that resulted from having the gas may have led to a welfare loss. These effects occur next to the negative externalities of exploiting fossil resources. The greenhouse gas emissions from using natural gas contribute to the concentration of these gases in the atmosphere and, as such, to climate change. The fossil mining companies have been staunch supporters of denying any such relationship (see Supron and Oreskes, 2017), and most Dutch consumers have been keen to use their services. The increasing damage of the earthquakes resulting from the mining of gas in the northern regions of the Netherlands also adds to the costs of natural resources. Until recently, ExxonMobil and Royal Dutch qualified allegations of the earthquakes resulting from mining gas as 'nonsense' (van der Sluis, 1989; Reijnders and Van der Sluis, 1997). This showed that next to the positive side (the revenues), the exploitation of the gas resources also had a negative side (growth distortion and externalities.

Maximizing the exploitation is in the interest of the government (on behalf of society as a whole) and the mining companies, but also has the largest negative impact on the communities living in the areas where the gas is exploited. Thus, there is a conflict. How much and how fast should gas fields be exploited? From a pure economic point of view, according to the Hotelling rule, one should decide this based by comparing the returns from the risk-free investment of the net revenues (i.e. revenues after deducting the exploration, development and exploitation costs, and the compensation of the negative externalities) and the result of non-mining the natural resource. If fuels become scarcer, it might be attractive to postpone gas mining, as the future prices may be even higher. The same holds if the negative externalities increase. Further, in a situation of almost zero or even negative interest rates, it is attractive to postpone mining. There is no evidence that government and mining companies accounted for these considerations when making decisions to mine the gas and to maximize the revenues from exploitation (Algemene Rekenkamer, 2014; Onderzoeksraad voor Veiligheid, 2015).

3.3 Impact of reducing gas exploitation

In March 2018, the Dutch government announced that the exploitation of the Groningen gas field will be gradually phased out and should end in 2030. Details are not available yet, but the expectation is that the revenues may be halved (i.e., be 50 billion Euros). It is not clear how this phasing out relates to the already foreseen end of the exploitation of the field. Would slowing down the exploitation of gas affect the future wealth of the Netherlands? This is not very likely as the exhaustion of the Groningen field is well-known and any gas remaining in the gas fields is an asset. Reducing the speed of exploitation implies that revenues will be lower now, but they may be higher in the future, given the price of natural gas and the volume that can be safely mined. Implicitly, the government seems to have made a trade-off between maximizing the revenues from exploitation and facing the increasing burden of climate change and earthquake claims.

An issue might be that the partners in the exploitation of the Groningen gas field, i.e. ExxonMobil and Royal Dutch Shell, put a claim with the Dutch government due to income lost. However, this is unlikely, as the contract reads that both the commercial parties and the government are in it together (see Appendix 3.A). The government will 'lose out' much more than the two companies, as it gains much more from exploitation than the commercial parties. Further, all three are liable for the repairs (and probably compensation) of the damage done and any damages that might occur in the future. Both the tapering off of the exploitation of the Groningen field as well as the increasing costs regarding the reparations from earthquake damage will have a negative impact on the Dutch government budget. In part, this was already projected in the past. But what differs is that the speed of the tapering is higher, as are the reparation costs.

The negative externalities from exploiting the gas fields (i.e. higher probability of flooding, lowering of the underground, earthquakes) require adaptation and mitigation and, hence, expenditures. Here, it is quite straightforward that this will reduce the revenues from owning the gas resource as this is the cause of the negative externalities and the government is committed to its exploitation (see Appendix 3.A). For the mining companies, it might translate in the stranding of part of their assets.[5] Stranded assets are investments that have already been made but which, at some time prior to the end of their economic life (as assumed at the investment decision point), are no longer able to earn an economic return. The extent of strandedness of the gas reserves relates to the advent of new technologies and/or regulation (see also Van der Ploeg and Withagen, 2015). In this respect, it is frequently mentioned that it would have been welcome to set aside part of the gas revenues (as in the case of Norway). Nevertheless, the problems regarding fiscal policy and the strandedness of assets could have been substantially mitigated in case the externalities had been properly accounted for. From an economic point of view, this is the first best solution.

[5] Royal Dutch Shell (2018) claims that she expects none of her assets will become stranded.

In all, it should be clear that phasing out the exploitation of the Groningen gas field will reduce government revenues. The expected revenues (of about 50 billion euros) should be able to compensate for the costs in relation to earthquake damage in the region. Here, one needs to keep in mind that the effects of mining for gas are likely to have an impact on the underground that will last for at least several decades (Bourne et al., 2014). What is 'left' after the reparations of the earthquake damage, could be considered to help support the transformation of the energy system. In the future energy system, electricity is supposed to come to play a far more dominant role. This may diminish the influence of the fossil fuel trade, reduce the choke points that have made fossils a source of global tension, put energy production into local hands and make power more accessible to the poor. It will also make the world cleaner and safer. However, the transition process is unlikely to be very smooth, given the vested interests and the costs of transiting to a new energy system. Hence, it is clear that the energy system will remain to have an effect on the government budget.

3.4 Conclusion

I studied the economics of the revenues of natural gas resources in the Netherlands. These revenues show to have a Janus face. So far, the Groningen gas field has yielded almost 290 billion Euros in government revenues. However, the Dutch policy of maximizing revenues from the exploitation of the gas fields paid insufficient attention to negative externalities. More specifically, appropriate performance and risk assessment and management never were in place regarding social and environmental externalities. As a result, there are 'nasty surprises' for all stakeholders, namely earthquake damage, environmental pollution, loss of business, loss of income, and stranded assets. The Groningen gas field will remain to play a role in Dutch government revenues, even when the exploitation is phased out. In the past 60 years, it was a profit center, but the realization of the externalities has turned it into a cost center, which is probably here to stay for several decades.

References

Alexeev, M, Conrad, R., 2009. The elusive curse of oil, Review of Economics and Statistics, 91, 586-598.

Algemene Rekenkamer, 2014. Besteding van aardgasbaten: feiten, cijfers en scenario's. Den Haag.

Asheim, G.B., Buchholz, W., Withagen, C., 2003. Hartwick's rule: Myths and facts. Environmental and Resource Economics, 25, 129-150.

Bourne, S.J., Oates, S.J., Elk, J. van, Doornhof, D., 2014. A seismological model for earthquakes induced by fluid extraction from a subsurface reservoir, Journal of Geophysical Research: Solid Earth, 119, 8991-9015.

Bouwmeester, M., Scholtens, B., 2017. Cross-border investment expenditure spillovers in European gas infrastructure. Energy Policy, 107, 371-380.

Centraal Bureau voor de Statistiek (CBS), various years. De Nederlandse economie various years.

Corden, W.M., 1984. Booming sector and Dutch disease economics: Survey and consolidation. *Oxford Economic Papers*, 36, 359–380.

Gylfason, T., 2001. Natural resources, education, and economic development, European Economic Review, 45, 847-859.

Hartwick, J.M., 1977. Intergenerational equity and the investment of rents from exhaustible resources, American Economic Review, 67, 972-974.

Instituut voor Onderzoek van Overheidsuitgaven (IOO), 2006. Quick scan regionale verdeling FES-toezeggingen. Leiden.

Malm, A., 2016. Fossil Capital. Verso.

Mehlum, H., Moene, K., Torvik, R., 2006. Institutions and the resource curse, Economic Journal, 116, 1-20.

Mulder, M., Zwart, G.T.J., 2006. Government involvement in liberalized gas markets. Den Haag.

Onderzoeksraad voor Veiligheid, 2015. Aardbevingsrisico’s in Groningen. Den Haag.

Papyrakis, E., Gerlagh, R., 2007. Resource abundance and economic growth in the United States, European Economic Review, 51, 1011-1039.

Reijnders, L., M. van der Sluis, 1997. Dutch drowning syndrome. Groningen.

Royal Dutch Shell. Shell Energy Transition Report. Den Haag.

Sachs, J.D., Warner, A.M., 1995. Natural Abundance and Economic Growth, NBER Working Paper 5398.
Sachs, J.D., Warner, A.M., 1997. Fundamental sources of long-run growth, American Economic Review, 87, 184-188.
Sluis, M. van der, 1989. Aardbevingen in Noord-Nederland. Hoogezand.
Supron, G., Oreskes, N., 2017. Assessing ExxonMobil's climate change communications (1977-2014). Environmental Research Letters 12, 084019.
Torvik, R., 2009. Why do some resource-abundant countries succeed while others do not? Oxford Review of Economic Policy, 25, 241-256.
Van der Ploeg, R., Poelhekke, S., 2009. Volatility and the natural resource curse, Oxford Economic Papers, 61, 727-760.
Van der Ploeg, R., C. Withagen, 2015. Global warming and the green paradox: A review of adverse effects of climate policies, *Review of Environmental Economics and Policy*, 9, 285–303.

Appendix 3.A Side-letter gas exploitation

GEHEIM

's-Gravenhage, 27 maart 1963.

Den Minister van Economische Zaken,

's-G R A V E N H A G E

Gronings aardgasproject.

Excellentie,

Nu heden de overeenkomst van samenwerking tussen de Staatsmijnen en de ondergetekenden inzake nevenvermeld project tot stand is gekomen, voelen de ondergetekenden er behoefte aan om Uwe Excellentie dank te zeggen voor het begrip, dat U gedurende de onderhandelingen, welke tot deze overeenkomst hebben geleid, hebt getoond, in het bijzonder voor de internationale positie van de eerste twee ondergetekenden.

Dat Uwe Excellentie met het oog op deze positie akkoord is gegaan met de door ondergetekenden bepleite maatschapsconstructie, zoals thans in de overeenkomst van samenwerking geformuleerd, hebben zij zeer gewaardeerd.

In dit verband stellen zij het op prijs tegenover Uwe Excellentie uitdrukkelijk te verklaren, dat bij het sluiten van deze overeenkomst van samenwerking - wat betreft de interne verhouding tussen de contractanten - de bedoeling heeft voorgezeten, dat de overeenkomst zo zal worden opgevat en ook zal worden uitgevoerd als ware hier sprake van een concessionaris-naamloze vennootschap, waarin de N.V. Nederlandse Aardolie Maatschappij tezamen met de Staatsmijnen als aandeelhouders participeren in dier voege, dat de Staatsmijne en de N.V. Nederlandse Aardolie Maatschappij geacht moeten worden t.a.v. de concessie en het aardgaswinningsbedrijf in feite in dezelfde positie te verkeren als waren de concessie met uitzondering van de daaruit voortvloeiende rechten, die betrekking hebben op aardolie en andere niet uit methaan of ethaan bestaande delfstoffen - en het aardgaswinningsbedrijf eigendom van een zodanige naamloze vennootschap. De ondergetekenden zullen bij de gehele samenwerking en de uitvoering van de overeenkomst van dit beginsel als leidende gedachte uitgaan.

Met verschuldigde eerbied,

BATAAFSE PETROLEUM MAATSCHAPPIJ N.V.

STANDARD OIL COMPANY (NEW JERSEY)

N.V. NEDERLANDSE AARDOLIE MAATSCHAPPIJ
Het Bestuur:
SHELL NEDERLAND N.V.

4. Taking it home: impact of earthquakes on the regional housing market

George de Kam

4.1. Introduction

The strongest seismic activity caused by gas extraction is observed in the rural part of the province of Groningen, which is located in the Northern periphery of the Netherlands. Light earthquakes and damages to buildings, however, have also been felt in the provincial capital city of Groningen. Until now, 170.000 persons have been confronted with damage, half of them twice or more times (Postmes, Stroebe et al., 2018). Two-third of the province's housing stock is located in areas where damages have been reported (De Kam, 2016). In the area with the highest seismic risk, 22.000 houses will have to be checked for their compliance with 'near collapse' building standards.

Housing is probably the most important linkage between seismic activity caused by gas extraction and the daily life of people living on top of the gas field. Because of the stress caused by damage to properties and perceived seismic risk, an increasing number of people want to move out of the affected area. At the same time, less people want to move in. Both processes have a negative effect on the housing market. In recent years several policy measures have been implemented to compensate and to mitigate the earthquake impacts on housing. In spite of these measures evidence shows that the housing market is struggling, and that the (perceived risk of) earthquakes does have a negative effect on transaction prices in the affected area. This chapter gives an overview of the effect of the earthquake risks on the regional housing market. We conclude with some suggestions for policy measures that can improve the functioning of the regional housing market.

4.2. Housing stress caused by earthquakes

For many people in the area, the impact on their housing situation is the most direct confrontation with the negative consequences of the mining activities, and due to various causes on which we will elaborate further on, it has developed into an open nerve. Housing is associated with a wide array of material and immaterial values, beliefs and emotions. It offers shelter and safety, and a private territory. Decent and undisturbed housing conditions add to the feeling of being in control of one's life (Christie, Smith et al., 2008). For home-owners, property rights in housing are generally perceived as a pathway to accumulation of wealth (Di, Belsky et al., 2007). Many people improve their housing conditions by sweat equity (Gyourko and Saiz, 2004), and are proud of their houses (Saunders, 1990).

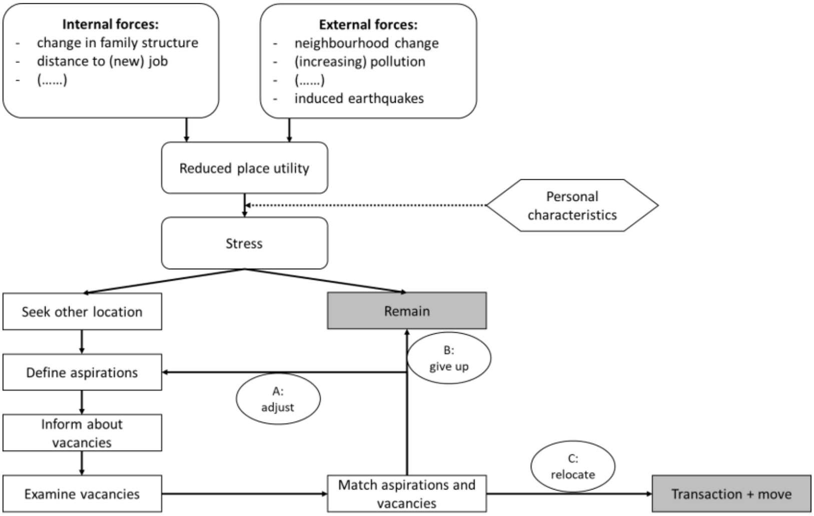
People who are dissatisfied with their present housing situation will try to move house. The reasons for relocation can be classified either as the wish for adjustment (of the house, neighborhood, or accessibility/distance to the workplace) or as induced by changes in employment or events in the life cycle (Pacione, 2005). The success of moving depends on many factors. Suitable vacant houses must be available, and in the case of home owners (about 60%, up to a 100% in small rural communities in Groningen), at a price the household can afford and finance. Prospective tenants will have to be able to pay commercial rents in the private sector, or to comply with rules of allocation in the social rented sector.

For an analysis of the impact of induced seismicity on moving house in Groningen, stress based models of the relocation process are suitable, because these explicitly take account of negative environmental conditions (Pacione, 2005; Brown and Moore, 1970). A simplified version of such a model is presented in Figure 4.1. Internal or external forces may reduce place utility for a specific household. Mediated by personal characteristics, this reduced utility can cause stress. Some households (have to) cope with this stress and remain where they live, but others decide to relocate. In the latter case, this starts a process of matching aspirations with available vacancies. The model describes three possible outcomes:

A. the need to adjust aspirations and restart the searching process because no match could be made;
B. the decision to give up searching and remain in the present house;
C. the decision to relocate by buying or renting a new house.

Needless to say that the decision to give up and remain, or to adjust aspirations may well add up to the stress that feeds the intention to move.

Figure 4.1. Stress model of housing relocation



Source: Reworked from Brown and Moore (1970) in Pacione (2005, p 206)

For Groningen, the impact of induced earthquakes is a location-specific external force. All in all, for a number of residents the large scale gas extraction in Groningen has gradually eroded – and sometimes shock-wise shattered – their housing-related wellbeing. In the worst cases, they have to leave their home for safety reasons. Others feel trapped in their once cherished properties that no one wants to take the risk of buying.

4.3. Impact of earthquakes on the housing stock

The province of Groningen includes about a quarter of a million of houses, of which 54% is occupied by the owner. The share of owner-occupied houses is much higher among the group of houses which are strongly impacted by the earthquakes (Table 4.1).

Table 4.1. Composition of the housing stock in Groningen and impact of earthquakes

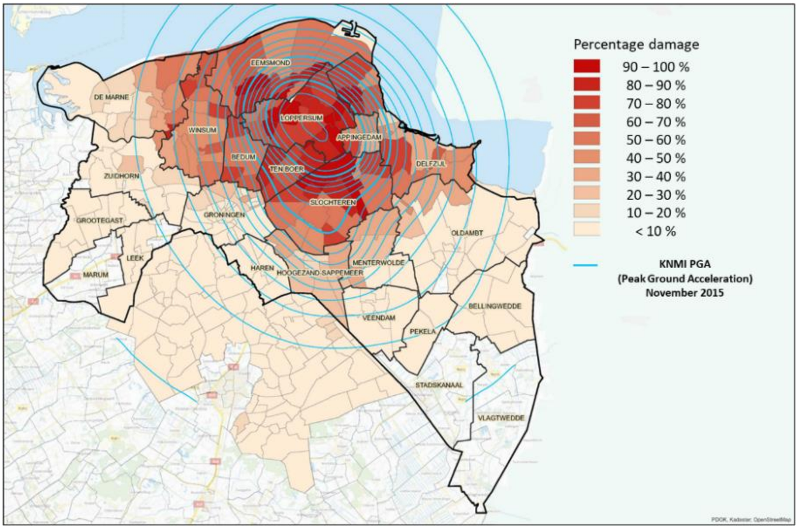
	All houses in Groningen province	**Houses with no or minimal impact (0 – 5% damage claims)**	**Houses with low impact (5-39% damage claims)**	**Houses with medium impact (39-60% damage claims)**	**Houses with high impact (> 60% damage claims)**
Houses (2017)	276.000	219.800	21.800	27.000	7.400
Owner occupied	54%	50%	58%	60%	79%
Percentage built before 1945	26%	27%	n.a.	n.a	42%[6]
Detached housing [7]	n.a	n.a	28%	42%	76%

n.a.: not available
Sources: Hoekstra et al (2016); Boelhouwer et al (2016), de Kam (2016)

[6] Percentage for municipality of Loppersum.
[7] Boelhouwer et al (2016), p 30.

In a large part of the regional housing stock the induced seismicity has caused damage, which often manifests itself in cracks in walls or other parts of the structure. Also the integrity of the building as a whole or its foundations may be endangered. Until now no buildings have collapsed because of the earthquakes, but 147 properties have been classified as acutely unsafe buildings (NCG, 2017), and another 95 have already been demolished.[8]

Figure 4.2. Expected peak ground acceleration and level of damage claims in the province of Groningen



Source: National Coordinator Groningen

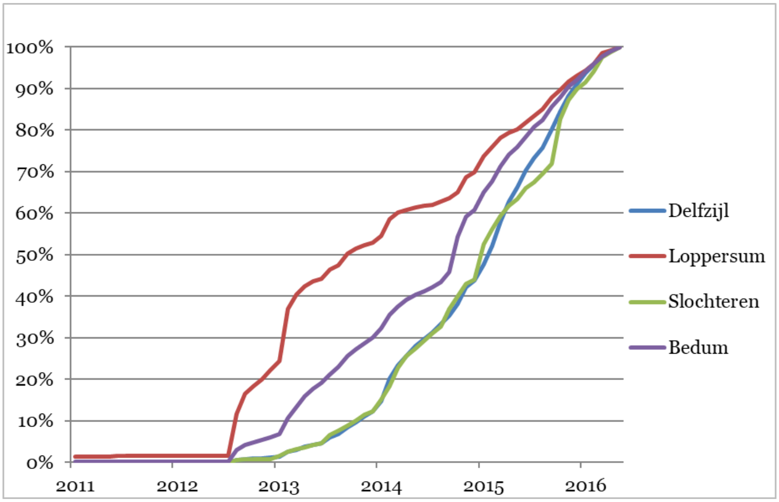
The spatial distribution of affected houses is strongly related to the spatial dimension of the earthquakes. In Figure 4.2, the curved lines show the expected peak ground acceleration across the area, based upon a seismic

[8] Retrieved from http://database.hetverdwenengroningen.nl/ on March 29 2018.

model and the pattern of observed earthquakes, as well as the spatial distribution of various intensities of damage claims that have been reported.

A review of the cumulative percentage of reported damages (specified by time and municipality) is presented in Figure 4.3. Obviously, the core municipality of Loppersum got a large number of damage claims immediately after the 2012 earthquake of Huizinge, which is a hamlet in Loppersum. In Slochteren the number of damage claims only started to rise more than a year later, illustrating the spatio-temporal change in the pattern of earthquakes.

Figure 4.3. Cumulative percentage of damage claims for a selection of municipalities in the Province of Groningen, 2006-2016



Source: NAM

4.4 Different effects for home-owners and tenants

The shock of having damage to one's own house and the efforts that are needed to have that damage compensated have a negative effect on the wellbeing of many people living in the area[9]. On top of that, seeing other damaged properties, communication in personal networks, media attention and uncertainty about the future with regard to gas extraction and the risk of new earthquakes also contribute to a negative image of the region. This has consequences for the performance of the regional housing market as personal experience and images of the region all add up to potential mover's information about vacancies, and are well taken in mind when vacancies are inspected (de Kam and Mey, 2017).

Both the 'earthquake track-record' of an individual property and the earthquake-related image of the location of the house are determinants of the behavior of its residents and its potential buyers or tenants in the housing market. But - although they may live next-door and may even have the same amount of damage -, the impact of earthquakes is different for home owners and tenants (Raemaekers, 2009; Hoekstra et al., 2016; Postmes et al., 2018). This is because tenants are not responsible for the structural repairs and physical condition of their houses[10], and because they do not experience the consequences of earthquakes for the value of their house. Of course, housing associations (being the principal landlords in the area) do experience the impact of earthquakes on the direct as well as the indirect returns of their rented stock, and they have recently had their claim for compensation of this damage rewarded in court. On the other hand, there are some signs that the perceived risk of home

[9] For more detail on this, see chapter 5 of this publication, Perlaviciute (2017).
[10] An internal survey by housing associations shows that tenants appear to be less active in reporting damages then home owners. In all areas with reported damages up to July 2015, 7 percent of the properties of housing associations have reported damage, against 20 percent in the other properties.

ownership may result in a stronger preference for rented accommodation.[11]

4.5 Earthquakes and the decision to move into the area of risk

Tenure related differences in the perception of earthquake impacts are also reflected in the pattern of immigration to the area. After the 2012 earthquake, many home owners have observed a decrease of interest of prospective buyers from outside the area (De Kam and Idsardi, 2014; de Kam and Raemaekers, 2014; De Kam and Mey, 2017). This is confirmed by surveys at low spatial scale. In the municipality of Eemsmond, a large proportion of low income tenants in the immigration was reported, whereas Boes (2016), in his survey of households that recently bought a home in Loppersum, found that the proportion of people from outside did go down, and that the influx is dominated by middle-income single households[12]. Grounded in micro-data analysis, Hoekstra et al. (2016) show that the total amount of incoming households has not diminished substantially, but we see less long distance movers. Also the share of single households and lower income groups in immigration from outside the area has gone up in the period 2013-2014, following the 2012 earthquake.

The tentative conclusion is that the earthquakes contribute to a lower level of immigration to the area, while the composition of the immigration changes towards tenants and lower income groups.

4.6 Earthquakes and the decision to leave the area of risk

The flipside of the coin is people wanting to leave the area because of the earthquake risk. A year after the earthquake of Huizinge, 30% of the

[11] See Raemaekers (2009, 2014), and Hoekstra et al. (2016).

[12] Of the buyers of properties in the municipality of Loppersum between 2009 and April 2016, only 25 out of 391 buyers moved from outside the region, but 20 of them moved before 2012, only 5 after the heavy earthquake of august 2012[12].

persons who had their house for sale in locations within 10 km distance from the epicenter explicitly mentioned the earthquakes as the reason to move out of the area. In a larger sample of a provincial panel survey in 2014, 6% said that they would leave the risk area. Interestingly, in a nation-wide panel survey in 2015 23% said that if they lived in an area with earthquake risk they would try to move house as soon as possible. Obviously, responses differ for reasons such as the exact phrasing of survey questions, the personal experience with and attitude towards earthquakes, and the perception of the size of the risk area.

It is important to note that about half of the municipalities in the earthquake area did already experience a decline in population size because of their peripheral location and low levels of jobs and amenities. Apparently, the effects of earthquake risks and low attractiveness of local communities because of (other) factors that underpin population decline mutually reinforce each other. This is illustrated by Hoekstra et al (2016) showing that in the nine municipalities at the core of the impact area, only 27%[13] of households that consider moving want to stay in their own municipality, while the national average on this variable is well over 60%. The wish to leave the area is stronger with owners than with tenants. Figures show that for most people the intention or urge to move out of the risk area does not yet seem to have materialized in a major exodus. The number of moves out of the most affected area, however, is rising (Boumeester and Lamain, 2016). Jansen et al. (2017) found that the effect of earthquakes on the intention to move is mediated by psychological distress (anxiety, insecurity and concern). The authors conclude that the way in which residents handle the earthquake experience determines their intention to move, not the experience in itself. This provides opportunities

[13] Varying from 44% in Bedum to a lowest 15% in the most affected municipality of Loppersum

to prevent out-migration by supporting residents and by providing them psychological care and security regarding the market value of their dwellings.

4.6 The effects of earthquake impacts on the housing market

Damage to properties and the perceived risk of earthquakes are an incentive for people to leave the area, and at the same time they reduce its attractiveness for new residents. These negative tendencies have various effects in the housing market.

The basic effect is a lower demand for housing, resulting in longer time on the market. Sometimes properties do not sell at all. This leads to a reduction of list prices, and to lower transaction prices (Raemaekers, 2013; De Kam and Raemaekers, 2014; Hoekstra et al., 2016; Atlas voor gemeenten, 2017; Elhorst and Duran, 2018). Lower transaction prices contribute to a loss of property values. This may result in a higher loan to value ratio, and subsequent problems related to mortgages, such as a risk premium on interest rates, or the refusal of additional finance (De Kam et al., 2018)

Because property values are at risk, owners are less willing to invest in maintenance or renewal of their properties (Hoekstra et al., 2016; De Kam and Raemaekers, 2014). On the other hand, compensating measures do recover some of the value losses (Atlas voor gemeenten, 2017), also because owners make additional investments at their own expense when repairs paid by NAM are executed (De Kam and Mey, 2017).

The level of the negative price effect of the induced seismicity in Groningen has been estimated with various hedonic price models. The assumption in hedonic models is that all properties of a house are valued at a specific price. So when prices of houses with similar properties are compared, of which one is affected by earthquakes and the other is not, the price difference is assumed to reflect the willingness to pay (less) for houses with earthquake risk.

The current set of hedonic models all produce different price effects. This is due to different assumptions on the area and the time-span over which effects are expected. One of the disputed issues is the way earthquake impacts should be measured. For these reasons, an exact comparison of the outcome of the price models is not possible. In a review by the end of 2016, the average negative price effect since the 2012 earthquake across the affected area has been estimated in the range between 2 and 4 percent (Derksen, 2017). But a recently developed model by Elhorst and Duran (2018, forthcoming) dates the first price effect back in 2007 in the most heavily affected area, with price effects spreading across the whole of the province in later years. Several models show a decreasing price effect after the shock in the first years after the 2012 earthquake (Atlas voor gemeenten, 2017). The general assumption is that this is (at least partly) due to the cap on gas production, a slightly reduced seismic activity in that period, and the measures that have been taken to compensate property owners.

4.7 Policy measures related to housing: way forward?

In the wake of the 2012 earthquake, various policy measures have been implemented for compensating and mitigating the effects of earthquakes on the housing stock. As Table 2 shows, most of these measures are financed by NAM, because of its liability for any damage caused by its mining activities.[14] In total approximately 1.5 billion Euros have been spent.

[14] See chapter 2 in this publication: Mulder and Perey (2018).

Table 4.2. Measures for compensation and mitigation of earthquake impacts on housing

Measure	Since	Financed by	Estimated # claims and budget
Compensation for damage repair to	1996	NAM 36%, State 64%[15]	80.982 claims[16] ; 1.172 million euros[17]
Structural reinforcement	2015		3.217 properties inspected, 571 properties reinforced
Buy out of severely damaged properties	2012	NAM	74 houses, 15 demolished; value 15 million euros[18]
Compensation for value losses	April 2014	NAM	2.175 properties, 12 million euros[19]
Subsidy (1st round) for improvement	2014	State	4.000 euro per house. Budget spent is 125 million euros
Idem 2nd round	2016	State	714 units, 2.8 million euro (NCG, 2017)[20]
Buy-out of hard to sell properties (1st pilot)	2016	NAM	42 properties,,(revolving) budget of 10 million euros (NCG, 2017)
Buy-out scheme (follow-up)	2018	NAM	30 million for 2018-2020

Sources: NCG, NAM

[15] Retrieved from https://www.nu.nl/gaswinning-groningen/5089997/nederlandse-staat-betaalt-grootste-deel-van-aardbevingsschade-groningen.html on March 12 2018
[16] Until June 2017
[17] Until October 2017
[18] Estimated value own calculation at 200.000 euro per unit
[19] 86% of 2.529 requests have been agreed by NAM, average compensation between 1.1% and 4.7% (lowest and highest 15% of observations excluded). Estimate of total compensation 2.175 units*2.9%* 190.000 = 11,984,250 euros. Data Retrieved from: https://www.nam.nl/feiten-en-cijfers/voortgang-waarderegeling.html#iframe=L2VtYmVkL2NvbXBvbmVudC8/aWQ9d2FhcmRlcmVnZWxpbmc=(Retrieved 12 March 2018)
[20] The total budget for the second round is 89 million euros .ref https://www.rijksoverheid.nl/documenten/kamerstukken/2016/12/06/invulling-nieuwe-waardevermeerderingsregeling-groningen. (Retrieved 13 March 2018)

Until the present day, however, the compensation and mitigating measures have not resulted in restoring a 'shake-free' price level in the regional housing market. In the long term, the decision to put an end to gas extraction will take away the cause of induced seismicity. In the short term, however, relatively strong earthquakes like the recent one of the 8th of January 2018 are expected to occur every three or four years. The decision of the Dutch government to take over responsibility for the handling of damage claims and reinforcement is generally welcomed as a positive step, but the material and financial consequences for owners of real estate have not yet been elaborated. Another unknown factor is the price effect of the large scale structural reinforcement scheme that is meant to pick up speed in the near future.

What we do know is that policy changes and proper measures are highly relevant for people's behaviour in the housing market. For example, Jansen et al (2017) concluded that because the intention to move from the area is mediated by psychological distress, the provision of psychological care and security with regard to the value and saleability of their properties could reduce their intention to move. The overarching focus of policy measures should be to put people back in control of their housing situation. To achieve that, the material and financial content of measures have to go hand in hand with a participative style of governing the implementation of these measures. A fair, generous and transparent procedure for assessment and compensation of damages, should be offered with free choice of contractors, enabling inhabitants to choose for local procurement.

Moreover, the public body that is in charge of structural reinforcement of properties should switch from its present rather technocratic style of operating to a really bottom-up approach, taking full account of individual arguments for wanting to move house. This would include the offer of a quick scan of the need of structural reinforcement and the allocation of a corresponding budget to any owner who would want to put his house for sale. This would enable potential buyers to take this essential information about the condition of the property into account in their decision to buy and refurbish the house. That would result in higher numbers of houses sold and reinforced, at much lower transaction costs than the current top down policies.

Finally, all measures targeted at individual properties should be embedded in local socio-spatial plans which present a vision for the future of communities, and a frame for accommodating high quality reinforcement or rebuilding of houses – sometimes accounting for a decline in population by taking out low quality housing stock - , with respect for heritage, cultural identity and sustainability issues. Such a package can restore trust in the functioning of the housing market, and sustain or even enhance the possibilities to enjoy the residential qualities of the region.

References

Atlas voor gemeenten (2017). Vijf jaar na Huizinge. Het effect van aardbevingen op de huizenprijzen in Groningen. Utrecht, Atlas voor gemeenten.

Boelhouwer, P. et. al. (2016). Woningmarkt- en leefbaarheidsonderzoek aardbevingsgebied Groningen, TU Delft - OTB Onderzoek voor de gebouwde Omgeving

Boes, J. (2016). Verhuizen naar de aardbevingen: een onderzoek naar een verhuisbeweging in de gemeente Loppersum. Masterthesis Real Estate. Groningen. Faculty of Spatial Sciences University of Groningen.

Boumeester, H. and C. Lamain (2016). Migratiestromen in Noord-Oost Groningen. Delft, TU Delft, OTB Onderzoek voor de gebouwde Omgeving.

Brown, L. and E. Moore (1970) "The intra-urban migration process." Geografiska Annaler Series B 52 (1), 1-13

Christie, H., Smith, S. and M. Munro (2008). "The emotional economy of housing." Environment and Planning A **40**(10): 2296-2312.

De Kam, G. and E. Idsardi (2014). Opvattingen van Stichting WAG-deelnemers over de effecten van aardbevingen op het woongenot en de woningwaarde in Groningen. URSI Research Report 347 .Groningen, Faculteit Ruimtelijke Wetenschappen Rijksuniversiteit Groningen

De Kam, G. and J. Raemaekers (2014). Opvattingen van bewoners over de effecten van aardbevingen op het woongenot en de woningwaarde in Groningen. Een vergelijkend onderzoek in drie woonbuurten in Middelstum, Loppersum en Slochteren in 2009 en 2013. URSI Research Report 346. Groningen, Faculteit Ruimtelijke Wetenschappen Rijksuniversiteit Groningen.

De Kam, G. (2016). Waardedaling van woningen door aardbevingen in de provincie Groningen. Een doorrekening op postcode 4 niveau. URSI Research Report 352. Groningen, Faculteit Ruimtelijke Wetenschappen Rijksuniversiteit Groningen.

De Kam, G. and E. Mey (2017). Ervaringen bij verkoop woningen in aardbevingsgebied - Eindrapport. URSI Report 361. Groningen, Faculteit Ruimtelijke Wetenschappen Rijksuniversiteit Groningen.

De Kam, G., van den Broek, J. and J. van Maanen (2018). Gegijzeld in eigen huis; Zorgen en problemen rond hypotheken in het Groningse aardbevingsgebied. URSI Research Report. 363. Groningen, Faculteit Ruimtelijke Wetenschappen Rijksuniversiteit Groningen.

Derksen, W. (2017). Critical review woningwaarde in aardbevingsgebied. Groningen, Sustainable Society (RuG).

Di, Z., Belsky, E. and X. Liu. (2007). "Do homeowners achieve more household wealth in the long run?" Journal of Housing Economics **16**(3): 274-290.

Duran, N. and J.P. Elhorst (2018) A spatio-temporal-similarity and common factor approach of individual housing prices: the impact of many small earthquakes in the north of the Netherlands, Faculty of Economics & Business, University of Groningen, SOM research report.

Gyourko, J. and A. Saiz (2004). "Reinvestment in the housing stock: the role of construction costs and the supply side." Journal of Urban Economics **55**(2): 238-256.

Hoekstra, J., et al. (2016). Wonen en aardbevingen in Groningen; Een onderzoek in negen gemeenten. Delft, TU Delft - OTB Onderzoek voor de gebouwde Omgeving.

Jansen, S., Hoekstra, J. and H. Boumeester. (2017). "The impact of earthquakes on the intention to move: Fight or flight?" Journal of Environmental Psychology **54**: 38-49.

NCG (2017). Kwartaalrapportage april-juni 2017. Groningen, Nationaal Coordinator Groningen.

Pacione, M. (2005). Residential Mobility and Neighbourhood Change. Urban Geography
A Global Perspective. M. Pacione. Oxon, Routledge**:** 203-219.

Postmes, T., et al. (2018). Gevolgen van bodembeweging voor Groningers; Ervaren veiligheid, gezondheid en toekomstperspectief 2016-2017. Groningen, Rijksuniversiteit Groningen.
Raemaekers, J. (2013). De effecten van aardbevingen bij particulieren in het Groningse aardbevingsgebied die hun woning te koop aanbieden. Groningen, Stichting WAG.
Saunders, P. (1990). A Nation of Home Owners,. London, Unwin Hyman.

5. Public risk perceptions and emotions towards the earthquakes caused by gas production

Goda Perlaviciute

5.1 Introduction

The strongest earthquake so far in the province of Groningen – the Huizinge earthquake in 2012 (3.6 on the Richter's scale) – fuelled public debate about gas production and the induced earthquakes. The media images suggest that people in the province of Groningen perceive various high risks from the earthquakes, including health hazards and risks to properties, and that people experience strong negative emotions towards the earthquakes, such as anxiety, fear, insecurity, and anger (Van der Voort & Vanclay, 2015). Media have played an important role in getting more attention to the earthquakes in Groningen from the general public as well as policy makers (Kester, 2017).

Yet, the question remains how accurately media images represent risk perceptions and emotions of the general population in the province of Groningen. Media tend to focus on "scarce stories" and are most likely to capture views of people exposed to highest risks (Breakwell & Barnett, 2001). People who are most concerned about certain types of energy production are most likely to act, for example to protest or attend public meetings (De Groot & Steg, 2010), and hence are more likely to appear in the media. This could possibly disguise the views of other groups in society that are less willing or able to express their views publicly, resulting in a limited picture of public risk perceptions and emotions. In order to take responsible decisions about gas production in Groningen and to prevent its negative social impacts, it is important to have a more comprehensive understanding of how people in the province of Groningen perceive the risks of gas production, what emotions they experience, and which mitigation measures they demand and prefer.

To answer these questions, we conducted a longitudinal questionnaire study with a representative sample of the population in the province of Groningen (Perlaviciute, Steg, Hoekstra, & Vrieling, 2017). We included three regions varying in the level of exposure to earthquakes:

- Most affected region: municipality of Loppersum;
- Less affected region: municipalities of Bedum, Appingedam, and Slochteren;
- Least affected region: municipalities of Zuidhorn, Groningen, and Delfzijl.

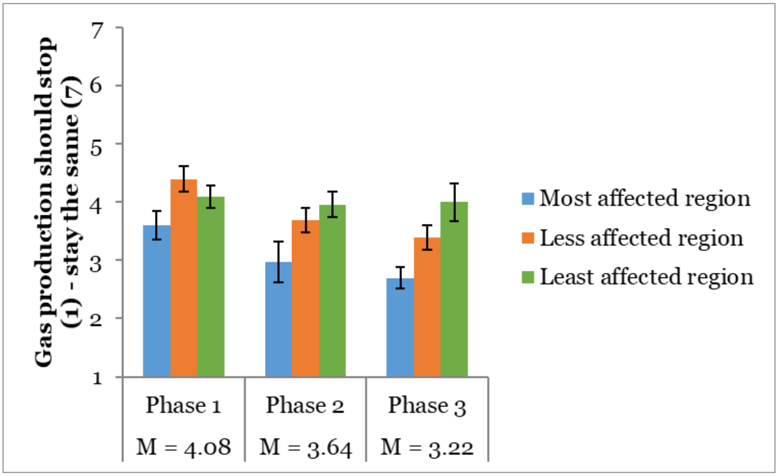
The first research phase took place in November 2013, about a year after the Huizinge earthquake. The second research phase took place in June 2014, shortly after a package with mitigation measures was introduced. The relevant mitigation measures included the decision to reduce gas production in the municipality of Loppersum, measures to reinforce houses and compensate people for damage and drop in house values, and measures to improve quality of life in the region (e.g. fast internet, renewable energy developments). The third research phase took place about half a year later, in November 2014. Throughout the course of the study, there was increased media and public attention to gas production and the induced earthquakes in the province of Groningen[21].

[21] For further details about the study and a more detailed specification of the findings, please refer to Perlaviciute, Steg, Hoekstra, & Vrieling, 2017.

5.2 Acceptability of gas production

We asked people in the province of Groningen to what extent they think that gas production should stop or stay the same (Figure 5.1). The results suggest that people think that gas production should be reduced, especially in regions that are more exposed to the earthquakes. On average, over time people thought more that gas production should stop.

Figure 5.1. Average values of the extent to which people think gas production should stop (1) or stay the same (7) in the three regions and across the three study phases



Source: Based on Perlaviciute et al. (2017)[22]

5.3 Perceptions of risks of earthquakes

People in the province of Groningen perceived primarily the risks for properties as high, namely damages to houses and drop in house values. Perceived risks of physical injury, stress and worry, and reduced quality of

[22] For further details, see Perlaviciute et al. (2017)

living were relatively lower. People in more affected regions evaluated all these risks for them as higher than people in less affected regions. Yet, in all regions people perceived high risks for the image of the province of Groningen. We asked not only how people perceive the risks for themselves, but also for other people in the province of Groningen. Irrespective of the region they live in, on average people perceived high risks of earthquakes for inhabitants of the province of Groningen. For people living in less affected regions this resulted in higher perceived risks for others than for themselves. Finally, people perceived moderate risks of damage to nature and the environment and relatively low risks of impaired relationship between people in their neighbourhood because of the earthquakes. Notably, perceived risks did not decrease over time; if anything, they increased.

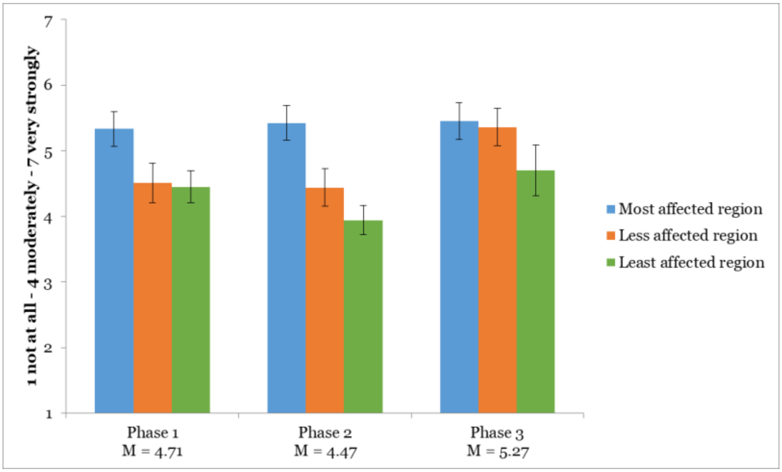
The findings on risk perceptions add some nuance to the media images. They reveal that people do not perceive all the risks the same – they see some risks, particularly for properties and for the image of the province of Groningen, as more likely than others. Other research in the province of Groningen has shown that the more damages people have faced from earthquakes, the less safe they feel in their home in relation to gas production (Sociaal Planbureau Groningen, 2014a; Postmes et al., 2017). Looking at risk perceptions could help explain these findings; for example, people may feel unsafe if they consider it highly likely that the earthquakes may damage their home. Future research could look at the relationship between risk perceptions and other impacts such as the feeling of safety or quality of life in general. While the perceived risks of physical injury, stress and worry, and quality of living were relatively lower, they were still higher in regions more affected by the earthquakes. Other research in the province of Groningen finds that people with more exposure to damages form the earthquakes in Groningen report poorer health than people with less exposure to damages (Postmes et al., 2017). We did not find a reduction in perceived risks over time. This may be due to several factors, including ongoing earthquakes, media attention to the risks, and people's rather negative evaluations of the mitigation measures (see below). There is evidence that people in the province of Groningen feel uncertain about the future earthquakes and their possible consequences (Sociaal Planbureau Groningen, 2014a), which may sustain or even strengthen high perceived risks.

5.4 Emotions

Different from the media images, the emotions that people reported towards earthquakes caused by gas production, namely feeling fearful, angry, disappointed, uneasy, and terrible, were not extremely strong. Negative emotions were somewhat stronger – but not extremely strong – in regions more affected by the earthquakes. Most strikingly, people reported that they feel powerless when thinking about the earthquakes. Feeling powerless was the strongest negative emotion, strongest among people in most affected regions but also getting stronger over time in other regions (Figure 5.2). Negative emotions did not decrease over time and some got even stronger.

The current study involved a representative sample of the population in the province of Groningen, which could explain why the negative emotions are not as strong as reported in the media. The emotion that stood out most was the relatively strong feeling of powerlessness. Other research has also pointed out the feeling of powerlessness and the feeling of being "left" among people affected by the earthquakes in Groningen (Sociaal Planbureau Groningen, 2014a). Together, the findings suggest that people in the province of Groningen feel that they themselves can do little against the risks of earthquakes.

Figure 5.2. Average values of feeling powerless when thinking about the earthquakes as a consequences of gas production from the Groningen gas field



Source: Based on Perlaviciute et al. (2017).[23]

5.5 Evaluations of mitigation measures

People thought that the measures directly addressing the risks of earthquakes (e.g. reducing gas production around Loppersum, reinforcing houses) are somewhat more urgent than the measures aimed at increasing quality of life in the region (e.g. fast internet, renewable energy developments). People considered one particular measure – creating employment by hiring local companies to repair and reinforce houses – as particularly urgent and effective for strengthening the regional economy. Notably, while all measures were considered to be relatively urgent, people evaluated the implementation of these measures rather negatively.

[23] For further details, see Perlaviciute et al. (2017)

Taken together, people evaluated the measures that address their highest perceived risks as most urgent, such as repairing damages and compensating for damages, followed by other measures to improve quality of life in the region in general. Similar findings have been reported from research with focus groups in the province of Groningen: when asked how to improve quality of life in the region, participants insisted that first the problems caused by gas production should be solved and then other measures can be implemented to improve quality of life (CMO STAMM / Sociaal Planbureau Groningen, 2016). In case there are additional resources to improve quality of life, people prioritize the building of earthquake-resistant homes and buildings, and supporting alternative energy sources and making buildings more sustainable (Sociaal Planbureau Groningen, 2016).

Most importantly, our results suggest that people are not satisfied with how mitigation measures have been implemented. This could be for various reasons, for example because people think it takes much time and energy to claim and settle damages, repairing damages can be disturbing due to noise and chaos, and people may perceive mitigation measures as not transparent and unfair, among others (Sociaal Planbureau Groningen, 2014b; CMO STAMM / Sociaal Planbureau Groningen, 2016). The way people evaluate mitigation measures could influence their evaluations of decision making process and perceived fairness of distribution of costs, risks, and benefits more generally. Initial evidence suggests that people in the province of Groningen think that their concerns are not being taken seriously (Sociaal Planbureau Groningen, 2014a; CMO STAMM / Sociaal Planbureau Groningen, 2016). Future research could study how changes in the implementation of mitigation measures, including reducing gas production, influence people's evaluation of decision making and perceived fairness of distribution of costs, risks, and benefits.

5.6 Conclusion

All in all, people in the province of Groningen are concerned about the risks of earthquakes, especially about the damages to properties and the image of the province of Groningen. People feel powerless when thinking about the earthquakes in Groningen, possibly because they think that they can do little themselves to prevent these risks and that responsible parties do not take their concerns seriously enough. This is further illustrated by the finding that people evaluate the implementation of mitigation measures rather negatively. It is important to study how future decisions regarding gas production in Groningen, including possibilities for a sustainable energy transition, influence risk perceptions and emotions of people in the province of Groningen.

References

Breakwell & Barnett (2001). Cited in G.M. Breakwell (2014), *The Psychology of Risk*, 2nd edition. Cambridge University Press, Cambridge, United Kingdom.

CMO STAMM / Sociaal Planbureau Groningen (2016). Wonen en leven met aardbevingen. Meningen, knelpunten en oplossingsrichtingen van burgers [Living with earthquakes. Opinions, bottlenecks and solutions from citizens]. Retrieved from https://sociaalplanbureaugroningen.nl/publicaties/?thema=leefbaarheid on 19 April, 2018.

De Groot, J. I. M., & Steg, L. (2010). Morality and nuclear energy: Perceptions of risks and benefits, personal norms, and willingness to take action related to nuclear energy. *Risk Analysis*, *30*(9), 1363-1373.

Kester, J. (2017). Energy security and human security in a Dutch gas quake context: A case of localized performative politics. *Energy Research & Social Science*, *24*, 12-20.

Perlaviciute, G., Steg, L., Hoekstra, E. J., & Vrieling, L. (2017). Perceived risks, emotions, and policy preferences: A longitudinal survey among the local population on gas quakes in the Netherlands. *Energy Research & Social Science*, *29*, 1-11.

Van der Voort, N., & Vanclay, F. (2015). Social impacts of earthquakes caused by gas extraction in the province of Groningen, the Netherlands. *Environmental Impact Assessment Review*, *50*, 1-15.

Postmes, T., Stroebe, K., Richardson, J., LeKander, B., & Greven, F. (2017). Veiligheidsbeleving, gezondheid en toekomstperspectief van Groningers: Wetenschappelijk rapport 3. [Feeling of safety, health and future persepctive for people in Groningen: Scientific report 3]. Heymans Institute, University of Groningen.

Sociaal Planbureau Groningen (2014a). Aardbevingen in Groningen; wat zijn de ervaringen van burgers? [Earthquakes in Groningen; what are the experiences from citizens?]. Retrievied from https://sociaalplanbureaugroningen.nl/publicaties/page/2/?thema=leefbaarheid on 16 April 16, 2018.

Sociaal Planbureau Groningen (2014b). Invloed van Groningse aardbevingen op woongenot [Effects of Groningen earthquakes on the pleasure of living]. Retrieved from https://sociaalplanbureaugroningen.nl/publicaties/page/3/ on 19 April 2016.

Sociaal Planbureau Groningen (2016). Aardbevingen en leefbaarheid: Naast misère ook nieuwe kansen voor het versterken van de leefbaarheid [Earthquakes and livability: Besides misery, also new opportunities to improve livability]. Retrieved from https://sociaalplanbureaugroningen.nl/publicaties/page/2/?thema=leefbaarheid on 19 April 2016.

6. Concluding remarks

Machiel Mulder and Peter Perey

6.1 Changing views on Groningen gas production

The discovery of the huge Groningen gas field with its unique flexibility characteristics had major consequences for the Dutch society. All houses became connected to the gas network and dependent on the L-gas from the Groningen gas field. The replacement of coal and oil by natural gas for heating raised the comfort of living as it was a cleaner carrier of energy. In addition, the swing capabilities of the Groningen gas field enabled the Dutch to base the energy demand for heating fully on natural gas without the need to build extensive storages, as several other European countries had to do, although some of them also benefited from the flexibility provided by the Groningen gas field.

Moreover, the swing capacity made it possible to maximize the revenues by selling most of the gas at relatively high prices during (cold) winter times. This ability to benefit from high seasonal prices in combination with the relatively low production costs resulted in high profit margins. Consequently, the sales of natural gas to domestic and foreign consumers generated significant revenues for the shareholders and, in particular, the Dutch government. The annual revenues from gas production contributed to 15% of the total State revenues during the oil crises in the 1980s, while its share is still about 2%.

Until a few years ago, however, there was not much attention for the downsides of the gas depletion of the Groningen field. The Huizinge earthquake of 2012, however, changed this completely. It became increasingly evident that the inhabitants of the Groningen region pay a high price for the gas production. Up to now, about 1,5 billion euro has been spent on the repairs for damages to houses resulting from the earthquakes induced by gas production. In addition to this, it is estimated that the earthquakes have reduced the average value of houses by 2 to 4%. Besides these monetary costs, there are also social-psychological costs. It appears that people feel powerless when thinking about the earthquakes in Groningen, as they cannot not do much to prevent these risks, while they also believe that the responsible parties do not take their concerns seriously enough.

Triggered by the increasingly intense protests from the Groningen region, the Dutch government has recently responded by taking the lead in the treatment of damage claims. In addition, the government has taken a fundamental decision regarding the Groningen gas field: in 2030 the gas production from these field will completely stop, although the gas reserves will still be about 250 bcm by that year.

6.2 Transition of the region

The decision to stop with the production of gas from the Groningen gas field gives a new perspective for the region. After being the major supplier of natural gas to the Northwest European gas market for about half a century, the region of Groningen has the opportunity to look for alternative economic activities. Being located in the rural region of the North of the Netherlands, close to the North Sea and with a well-developed infrastructure for energy business and research, the region Groningen may have a comparative advantage in the field of a transition towards renewable energy sources. As one should never waste a good crisis, the current political and social struggles with the gas production may act as an incentive to promote the region of Groningen as a supplier and developer of new sources of renewable energy.

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In this paper, researchers of the University of Groningen reflect on the economic and social consequences of both the gas production and the resulting earthquakes. Attention is paid to the historical role of the Groningen gas field in the European gas market, the importance of the gas revenues for the Dutch economy, the impact of the earthquakes on the regional housing market as well as the social and psychological impact of the earthquakes and how the public authorities dealt with the concerns of the inhabitants of Groningen.

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