Seismic Risk Assessment for a selection of Gas Production Scenarios for the Groningen field

Addendum to:

Induced Seismicity in Groningen
Assessment of Hazard,
Building Damage and Risk
(November 2017)

March 2018

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Summary

In the Hazard, Building Damage and Risk Assessment of November 2017 (Ref. 1), the seismic risk for a 24 Bcm/year production scenario was presented. In the current document, using the same workflow and models, the seismic risk for a larger set of theoretical and feasible production scenarios is assessed. This study started in December 2017 and was finalised in the last week of March 2018.

The feasible production scenarios are based on the Regeerakkoord (Ref. 2) and studies performed by Gasunie Transport Services (GTS) (Ref.3 and 4) and therefore also address security of supply. Starting with the production scenario of the Regeerakkoord, seismic risk for subsequently lower production scenarios is assessed. The production scenario directly impacts on the Local Personal Risk (LPR) people in Groningen experience. The lower the production from the Groningen field, the lower the number of buildings that do not meet the Meijdam-norm (Ref. 5, 6 and 7).

In addition, a number of theoretical production scenarios were analysed to gain basic insights into the seismic risk impact of sudden production reductions. These scenarios show that an immediate cessation of the gas production reduces the seismic risk such that no or only a minimal number of buildings are expected not to meet the safety norm.

Security of supply considerations require production to continue (Ref. 3 and 4), albeit with a gradual reduction in the gas production. The scenario prepared by GTS whereby imported high calorific gas is blended with nitrogen to Groningen gas quality is called the “Max Import scenario”. A lower demand for Groningen gas can be achieved by a higher utilisation of the existing nitrogen blending plant (from 85% to 100%), addition of a new gas blending plant or a more ambitious transition away from Groningen gas to other energy sources.

For each of these scenarios, the seismic risk impact was assessed. In the Max. Import scenario, the decline in production starts in 2021. The decline gradually reduces production until production is ceased in 2030. The reduction in risk is therefore not felt in the coming five years. An additional nitrogen blending plant can be on-stream in 2022 (Ref. 3) and allows production of Groningen gas to be reduced by 7 Bcm/year in one step. Combined with a more ambitious phasing out of Groningen production, local personal risk is for almost all buildings reduced to within the Meijdam-norm.

In this report NAM has not looked at the impact a reduction in production from the field has on Security of Supply as the decision-making, balancing these options to improve seismic risk for the Groningen community with impact on Security of Supply, is the responsibility of the Minister of Economic Affairs and Climate (EZK).

References

1 Induced Seismicity in Groningen, Assessment of Hazard, Building Damage and Risk – November 2017, NAM (Jan van Elk and Dirk Doornhof), November 2017.

2 Vertrouwen in de toekomst, Regeerakkoord 2017 – 2021 VVD, CDA, D66 en ChristenUnie, Section 3.3 Gaswinning, 10th October 2017.

3 Letter from GTS to Min. EZ, "L-gas capaciteit en kwaliteitsconversie", Gasunie Transport Services, 20th July 2017.

4 Letter from GTS to Min. EZK, "Advies GTS inzake leveringszekerheid", Gasunie Transport Services, 31st January 2018.

5 Eerste advies Adviescommissie 'Omgaan met risico's van geïnduceerde aardbevingen' 23rd June 2015,

6 Tweede advies Omgaan met hazard- en risicoberekeningen in het belang van handelingsperspectief voor Groningen Adviescommissie 'Omgaan met risico's van geïnduceerde aardbevingen' 29th October 2015,

7 Eindadvies Handelingsperspectief voor Groningen Adviescommissie 'Omgaan met risico's van geïnduceerde aardbevingen' (Commissie-Meijdam), 14th December 2015,

1 Introduction

In April 2016, NAM submitted the Groningen Winningsplan 2016 (Ref. 1) to the Minister of Economic Affairs. This Winningsplan was accompanied by a Technical Addendum (Ref. 2) providing further background to the assessments used in the Winningsplan. The Mining Law requires that winningsplannen are approved by the Minister of Economic Affairs. The approval was granted in the Instemmingsbesluit Winningsplan Groningenveld, issued on the 30th of September 2016 (Ref. 3).

In response to the Instemmingsbesluit, NAM prepared the report "Induced Seismicity in Groningen, Assessment of Hazard, Building Damage and Risk – November 2017" (Ref. 5), which was submitted to the Minister of EZK and to SodM on 1st November 2017. This report can be downloaded from the webpage "onderzoeksrapporten" of www.nam.nl. It describes the full hazard and risk assessment for induced seismicity in Groningen, starting from the production of gas (the cause) to the effects on people and buildings.

This seismic risk assessment was based on a gas production scenario of 24 Bcm/year. The Wijzigingsbesluit of 24th May 2017 (Ref. 4), assume that the production in an average temperature year is 21.6 Bcm/year. However, there are special circumstances where the production from the field may have to be increased. Two specific situations mentioned in the Instemmingsbesluit are described below:

1. Groningen gas is mainly used for heating of houses and office buildings. The demand for Groningen gas therefore depends on the weather, i.e. ambient temperature and wind. In a year with lower than average ambient temperatures, the gas demand is expected to be higher. The maximum required incremental production volume is specified in article 2 of the Instemmingsbesluit to be 5.4 Bcm/year. This number is based on the degree-day formula described in appendix A of the Instemmingsbesluit to a maximum additional volume of 5.4 bcm.
2. In article 2, lid 3 of the Instemmingsbesluit, a number of potential upsets in the gas production and distribution system are listed that could potentially lead to higher demand from the Groningen field. This increment in production can be used at the request of Gas Transport Services BV to a maximum of 1.5 Bcm per year.

Both these incremental volumes might increase the average production from the Groningen field above the production level set at 21.6 Bcm/year. Based on a statistical analysis of historical temperature data and Groningen-gas demand assumptions, it was estimated that the average production level from the Groningen field under this production regime (Ref. 3 and 4) will range between 23 and 24 Bcm/year. The Hazard and Risk Assessment of November 2017 (Ref. 5) was based on an average annual production level of 24 Bcm/year (see above). This was a prudent choice ensuring the risk assessment covered these eventualities.

In this current addendum to the report "Induced Seismicity in Groningen, Assessment of Hazard, Building Damage and Risk – November 2017", a complementary set of non-prescribed production scenarios is presented, covering a wide range of production levels. The objective is to assess the effect of different production scenarios on the seismic risk, utilizing the same workflow and model suite. This study started in December 2017 and was finalised in the last week of March 2018.

References

1. Winningsplan Groningen – 2016, NAM, April 2016
2. Technical Addendum to the Winningsplan Groningen 2016 - Production, Subsidence, Induced Earthquakes and Seismic Hazard and Risk Assessment in the Groningen Field, Parts I to 5, Nederlandse Aardolie Maatschappij BV (Jan van Elk, Jeroen Uilenreef and Dirk Doornhof, eds), April 2016
3. Instemmingsbesluit Winningsplan Groningenveld, Ministerie van Economische Zaken, Directoraat-generaal Energie, Telecom & Mededinging, Directie Energie en Omgeving, 30 September 2016
4. Wijziging Instemmingsbesluit Winningsplan Groningenveld, Ministerie van Economische Zaken, Directoraat-Generaal Energie, Telecom & Mededinging, Directie Energie en Omgeving, 23 May 2017
5. Induced Seismicity in Groningen, Assessment of Hazard, Building Damage and Risk – November 2017, NAM (Jan van Elk and Dirk Doornhof), November 2017.

2 Production Scenarios

This current addendum to the report "Induced Seismicity in Groningen, Assessment of Hazard, Building Damage and Risk – November 2017" (Ref. 1), extends that report by assessing the seismic risk for a set of different production scenarios. Two sets of production scenarios have been assessed:

- *Theoretical Scenarios* (labelled as T-scenarios) to gain basic insights into the development of seismic risk in response to changes (reductions) in gas production,
- Scenarios to gain insight in the development of seismicity for a set of feasible production and field *Development Scenarios* (labelled D-scenarios). These scenarios are considered feasible in the sense that the Groningen field can produce these volumes, but also that the market for Groningen gas (L-gas) can adequately be served without delivery interruptions (security of supply).

These scenarios are defined in more detail in the following sections. Each scenario has been simulated with the full field reservoir model in combination with the surface network model. The surface network model can be used to establish whether or not the requested production profiles can actually be delivered by the currently existing facilities (NFA: No Further Activities refers to development scenarios where no further new investments in production capacity are made). For some scenarios the response was tested assuming additional compression facilities would be installed (*second stage compression*).

The actual distribution of the offtake across the field (over the various production clusters) is another degree of freedom. Two possible options were tested: proportional scaling of the currently *Imposed Production* split across the regions as defined in the May 2017 Wijzigingsbesluit, and an *Optimised Production* split in line with NAM's optimisation study from December 2017 (Ref. 2).

Theoretical Scenarios

Remweg Scenarios

The theoretical scenarios also aim to improve the understanding of the delay in seismic response to a reduction of production. The imposed production policies of recent years have resulted in a pressure difference of some 30 bar across the field, decreasing from the North towards the South. A hypothetical reduction of production will be followed by an equilibration of the pressure in the reservoir, i.e. an increasing pressure in the South, and a decreasing pressure in the North. This areal pressure equilibration will cause a delay in the seismic response in the north of the field after a reduction in production is implemented. Four theoretical scenarios have been evaluated (Table 2.1). For all these scenarios, it is assumed no further changes to the production facilities, like drilling of additional wells or the installation of compressors, will be made.

	Scenario	Production case	Distribution of production
T1	Remweg 2018 / 0 Bcm	-	-
T2	Remweg 2023 / 0 Bcm	NFA	Imposed
T3	Production at 12 Bcm/year 2018	NFA	Optimized
T4	Production at 12 Bcm/year 2018	NFA	Imposed

Table 2-1 Overview of the theoretical scenarios used to gain basic insights into the development of risk, in response to changes in gas production. NFA refers to no further development activities in the field.

The first scenario (T1) assumes an immediate termination of production as of 1st January 2018 (T1). This scenario was chosen to gain insight into the reduction of risk after the field is closed-in and production is terminated. This scenario is often, in Dutch, referred to as *Remweg Scenario* ("braking distance scenario"). This delay in risk response depends on the areal pressure differences currently existing in the reservoir. Potentially this pressure difference continues to increase with continued production. A remweg scenario starting five years (T2) later, with a cessation of production on 1st January 2023 (hence five years of additional production) was therefore also included.

Reduction to 12 Bcm/year

In the report following the Zeerijp earthquake (Ref. 3), SodM advised the Minister of EZK that risk would with reasonable certainty meet the norm if the total production from the Groningen gas field is set at a maximum of 12 Bcm/year. Therefore, two scenarios have been included where the gas production is reduced at 1st January 2018 to 12 Bcm/year (instead of to 0 Bcm/year as in the first scenario, T1). In the first of these 12 Bcm/year scenarios, the areal distribution of the gas production is optimised to reduce seismicity (T3), while in the second the distribution is following the proportional *Imposed Production* split mentioned above (T4).

Feasible Production Scenarios

The feasible scenarios are primarily based on an earlier advice from GTS to the Ministry of Economic Affairs and Climate (Ref. 5 and 6). They incorporate assumptions for the development of the L-gas market and for the supply of the L-gas market from other gas sources than the Groningen field. Starting with the production scenario of the Coalition agreement[1] (Ref. 4), the seismic risk reduction resulting from increasingly lower production scenarios will be presented. The scenario with the lowest gas production is a scenario based on maximum import of gas in combination with an additional GTS nitrogen blending plant.

The advice was submitted on 20th July 2017 (Ref. 5) and addressed the minimum Groningen field volumes required to guarantee Security of Supply. Minimum volumes were presented for the period 2018 to 2030 for warm, average and cold years, and for scenarios with and without implementation of an additional nitrogen blending gas plant.

In January 2018, GTS confirmed the estimated Groningen field volume required to cover for Security of Supply for the year 2018 (Ref. 6). An additional remark was made that this volume could be smaller when the restriction on (monthly) volume fluctuations would be lifted. GTS plans to submit a new update of their advice to the minister for the period 2019 until 2030 in March 2018.

The GTS advice has been used to define the scenarios in the current hazard and risk analysis. The market demand associated with the scenarios is estimated by GTS using their market demand model. The expected decline in energy (gas) consumption in the Netherlands (NEV2016) and declining export contract volumes to Germany, Belgium and France (no export as from 2030 onwards) have also been accounted for. The annual market demand as of 2018 has been estimated on the basis of 31 historical temperature profiles. The spread in the annual Groningen volume required to cover for Security of Supply is estimated to be as large as ~13 Bcm/year: 14 Bcm/year in a year as warm as 2007 and 27 Bcm/year in a cold year such as 1996, in the 2018 gas market (Ref. 6, also see figure 2.2).

The Groningen field volume demand is calculated from the G-gas market demand minus the volume of pseudo G-gas and the G-gas supply from other sources than the Groningen field. Pseudo G-gas is produced by GTS by blending high calorific gas and nitrogen. The primary nitrogen generation capacity is some 361,000 m^3 per day. It is assumed utilisation of the primary nitrogen capacity lies between 85% and 100% of the maximum pseudo G-gas production. Daily fluctuations in demand and short periods of high demand are covered (partly) with secondary nitrogen capacity. Higher scheduled nitrogen utilisation leads to an increase in Groningen field fluctuations. Scenarios where between 85% and 100% of the nitrogen utilisation capacity is used are referred to ‘maximum import’ scenarios (D2 to D6 in Table 2-2).

The installation of additional GTS nitrogen blending capacity could lead to a further reduction of the required Groningen field volume of approximately 7 Bcm/year. The earliest on-stream date for an additional new nitrogen plant is Q1 2022 (Ref. 6).

1 The coalition agreement is referred to in Dutch as “Regeerakkoord”. In this document both words will also be used interchangeably.

	Scenario	Production case	Distribution of production	2nd stage timing
D1.a	Regeerakkoord	NFA	Imposed	-
D1.b	Regeerakkoord	NFA + 2nd	Imposed	(no LOPPZ)
D1.c	Regeerakkoord	NFA + 2nd	Optimised	no LOPPZ, BIR, KPD, SLO
D1.d	Regeerakkoord	NFA	Optimised	
D2.a	Max Import	NFA	Imposed	-
D2.b	Max Import	NFA	Optimised	-
D3.a	Max import / 12 Bcm/year	NFA	Imposed	-
D3.b	Max import / 12 Bcm/year	NFA	Optimised	-
D4.a	Max import / 5 Bcm/year	NFA	Imposed	-
D4.b	Max import / 5 Bcm/year	NFA	Optimised	-
D5.a	Max import / avg year / 100% N_2 / plant	NFA	Imposed	-
D5.b	Max import / avg year / 100% N_2 / plant	NFA	Optimised	-
D6.a	Max import / warm year / 100% N_2 / plant	NFA	Imposed	-
D6.b	Max import / warm year / 100% N_2 / plant	NFA	Optimised	-

Table 2-2 Overview of feasible production scenarios for which a seismic risk assessment is presented in this report.

Regeerakkoord (D1)

In the 10th October 2017 Coalition agreement (Ref. 4), the expectation is laid out that by the end of that coalition agreement (2021), the annual production level can have been reduced by some 1.5 Bcm/year relative to 21.6 Bcm/year as set in the Wijzigingsbesluit (*Figure* 2-1). This was implemented as a production scenario that steps down to 21 Bcm/year in 2018, and to 20 Bcm/year in 2021.

3.3 Gaswinning

Veilige en verantwoorde gaswinning

- Doel is om in de periode tot 2021 de vraag naar Groningengas met 3 miljard kubieke meter (bcm) te verminderen ten opzichte van 2017. Volgens de huidige inzichten verkleint zowel *minder* winning als een *vlakkere* winning het aardbevingsrisico. Tegelijkertijd is duidelijk dat we ruimte moeten maken en behouden om in de toekomst snel te kunnen reageren op nieuwe inzichten en gebeurtenissen als de veiligheid daarom vraagt. Het meet- en regelprotocol dat door NAM is ontwikkeld en door het Staatstoezicht op de Mijnen (SodM) getoetst wordt, kan helpen om het gasveld op een verantwoorde manier te exploiteren. Deze aanbeveling van het SodM nemen we over. De daling van de vraag zal daarom voor ongeveer de helft gebruikt worden om ruimte te creëren om ´vlakker" te winnen.
- Aan het eind van de kabinetsperiode zal de winning naar verwachting circa 1,5 bcm lager kunnen liggen dan volgens het meest recente winningsbesluit van 21.6 bcm (per okt 2017). Het verschil in de daling van de vraag (3 miljard kubieke meter) en de daling van de winning (1,5 miljard kubieke meter) geeft de buffer die nodig is om veiligheid in de ondergrond te combineren met een stabiele en veilige gasvoorziening bij de mensen thuis. Dit is de vlakke winning zoals het SodM die adviseert.

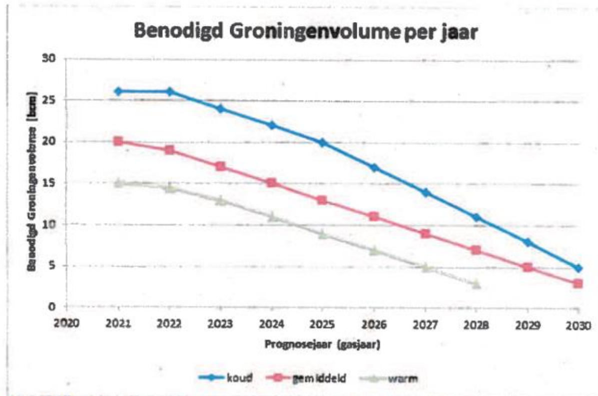
Figure 2-1 Extract from the 10/10/2017 Coalition agreement

Maximum Import (D2 – D4)

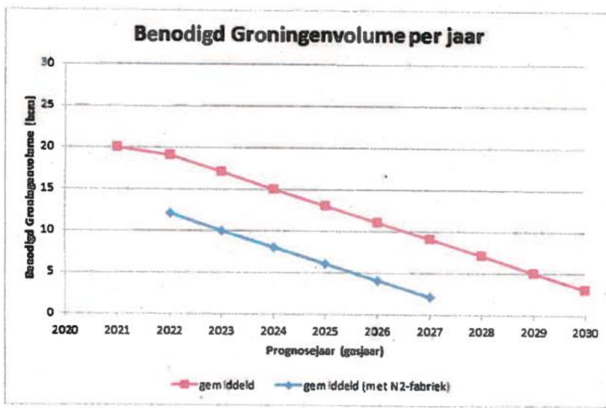
The methodology to plan for nitrogen capacity utilisation between 85% and 100% is known as the maximum import scenario. The Groningen field volume demand is the resultant of G-gas market demand minus pseudo G-gas and G-gas supply other than Groningen field.

It is assumed that the supply of high calorific gas to the Dutch market is not restrictive. The GTS conversion capacity equals an estimated gas production per year of 33 to 36 Bcm/year, depending on the utilisation rate and the quality of the available high calorific gas (Ref. 6). Conversion capacity includes pseudo G-gas production as well as "verrijking". Verrijking is the process of adding high calorific gas to the L-gas export stream. Pseudo G-gas is produced by GTS blendng high calorific gas and nitrogen, and has primary nitrogen capacity of 361,000 m3 per day. It is assumed that the utilisation of primary nitrogen capacity lies between 85% and 100%. The within-day flex demand and short periods of high demand are covered (partly) with secondary nitrogen capacity. Higher scheduled nitrogen utilisation leads to an increase in Groningen field fluctuations to cover within day demand fluctuations.

In the SodM advice to the minister (Ref. 3), gas production at a level of 12 Bcm/year is presented as the level at which the Groningen field can be safely produced. Scenario D3 assumes Groningen field volume equals the volume required to cover Security of Supply until the level of 12 Bcm/year is reached, after which the annual volume is kept constant. Same assumption for D4 but with an annual level of 5 Bcm/year. No analysis on the current or new role of the Groningen system and required capacity is part of this report.



Figuur 2 Bandbreedte benodigd volume Groningen voor leveringszekerheid



Figuur 3 Effect nieuwe stikstof installatie op het benodigde Groningen volume voor leveringszekerheid bij een gemiddeld jaar

Figure 2-2 *Prognosed requirement for Groningen gas to ensure security of supply (from L-gascapaciteit en kwaliteitsconversie, 20 juli 2017. Ref. 5)*

Tabel 1: Resultaten scenario 1 (100% stikstof)

Type gasjaar	Temp profiel	Marktomvang	H-gas verrijking	Pseudo L-gas	Groningen
		[bcm]	[bcm]	[bcm]	[bcm]
Koud	1996	60	13	23	24
Warm	2007	47	10	23	14

Tabel 2: Resultaten scenario 2 (85% stikstof)

Type gasjaar	Temp profiel	Marktomvang	H-gas verrijking	Pseudo L-gas	Groningen
		[bcm]	[bcm]	[bcm]	[bcm]
Koud	1996	60	13	20	27
Warm	2007	47	10	20	16

Figure 2-3 *Table from "Advies GTS inzake leveringszekerheid 31 januari 2018, Ref. 6)*

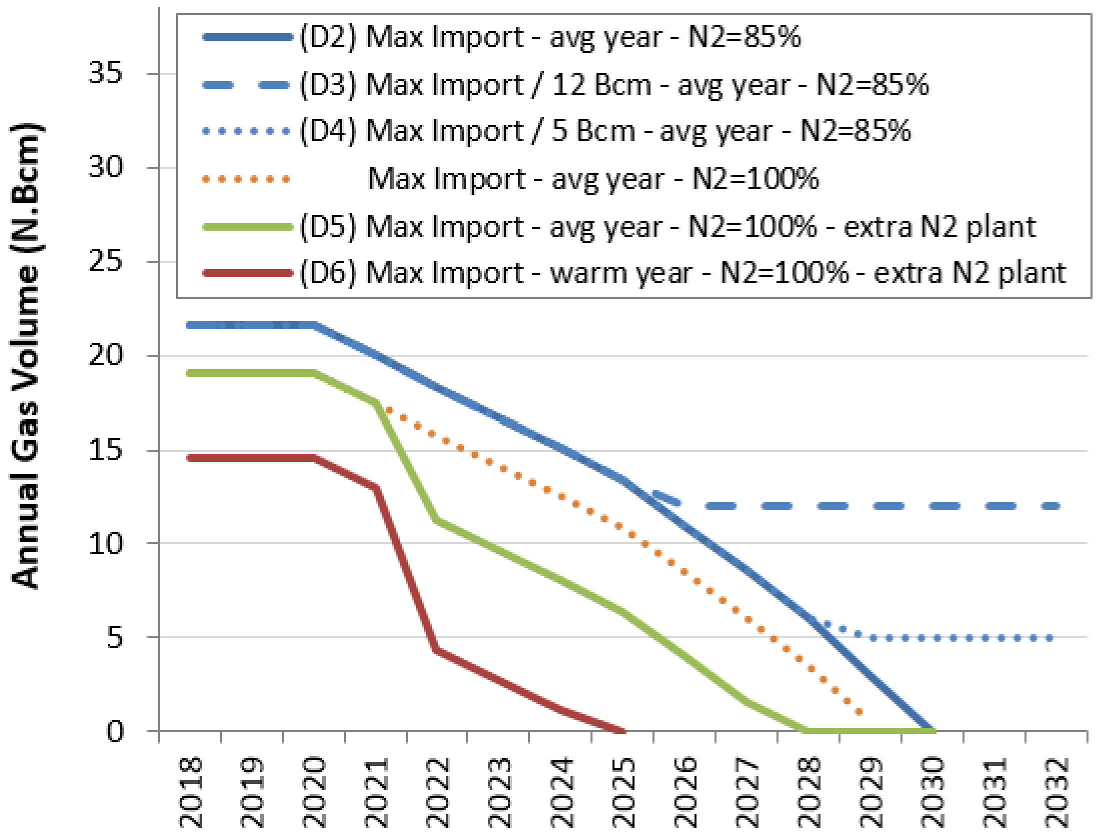


Figure 2-4 Maximum Import Scenarios used to assess seismicity in this study

Maximum Import with additional N_2-Blending Plant (D5-D6)

A capacity increase in pseudo gas production by implementation of an additional GTS nitrogen plant could lead to further reduction of Groningen field volume of approximately 7 Bcm/year. Earliest on-stream date for an additional nitrogen blending plant is Q1 2022. A decision to invest in an additional nitrogen plant has not yet been taken.

The final production scenario (D.6) is based on a 100% utilisation of the existing nitrogen blending plant, installation of an additional nitrogen blending plant and a gas demand based on warm temperature years. This scenario can be interpreted as a proxy for a scenario representing a larger effort to reduce Groningen gas demand by conversion of larger customers to high calorific gas (Ref. 5 and 6) and transition to other sustainable energy sources.

References

1 Induced Seismicity in Groningen, Assessment of Hazard, Building Damage and Risk – November 2017, NAM (Jan van Elk and Dirk Doornhof), November 2017.

2 Optimisation of the distribution of production over the Groningen field to reduce Seismicity, Leendert Geurtsen and Per Valvatne, December 2017.

3 Advies Groningen-gasveld n.a.v. aardbeving Zeerijp van 8 januari 2018, Staatstoezicht op de Mijnen, 1st February 2018.

4 Vertrouwen in de toekomst, Regeerakkoord 2017 – 2021 VVD, CDA, D66 en ChristenUnie, Section 3.3 Gaswinning, 10th October 2017.

5 Letter from GTS to Min. EZ, "L-gas capaciteit en kwaliteitsconversie", Gasunie Transport Services, 20th July 2017.

6 Letter from GTS to Min. EZK, "Advies GTS inzake leveringszekerheid", Gasunie Transport Services, 31st January 2018.

7 Letter "Uitfasering gebruik Groningengas door industrie ten behoeve van vermindering van de gasvraag", Minister van Economische Zaken en Klimaat, 1st February 2018

8 Letter "Niveau gaswinning Groningen" Minister van Economische Zaken en Klimaat, 1st February 2018

3 Hazard and Risk Assessment

In this section, the risk assessments for the analysed production scenarios will be presented and discussed. Only the results pertinent to the discussion in this section are presented. In Appendix B, for each of the production scenarios, the full hazard and risk assessments will be presented using a standardised format. The following are shown in Appendix B:

- Gas Production from the field, indicating the production distribution across field as illustrated in Figure 3-1.
- Development of the seismicity (annual number of earthquakes with magnitude ML>1.5) for the period from 2017 to 2032.
- Hazard maps for the coming five years (2018 – 2022) and the following five years (2023 – 2028).
- Number of buildings exceeding Local Personal Risk (LPR) for the coming five years (2018 – 2022) and the following five years (2023 – 2028).
- Map with location of buildings with LPR exceeding 10^{-5}/year for the coming five years (2018 – 2022) and the following five years (2023 – 2028).
- Exceedance plots (number of buildings exceeding a given probability) for the 10^{-4}/year and 10^{-5}/year norms, for the coming five years (2018 – 2022) and the following five years (2023 – 2028).
- Map of buildings indicating for each building the probability that the 10^{-4}/year of 10^{-5}/year norm is exceeded for the coming five years (2018 – 2022) and the following five years (2023 – 2028).

Figure 3-1 *Production cluster by location, as used to display the areal distribution of production in Appendix B. Note that the Loppersum clusters (LOPPZ) are lumped with the Eemskanaal cluster for display purposes (LOPPZ-E). However, in none of the forecast scenarios there is any production from the LOPPZ clusters, hence the LOPPZ clusters are shaded here.*

Theoretical Scenarios

Remweg Scenarios

T1 - Remweg Scenario – Production Cessation 1/1/2018

The Remweg Scenario (T1) is based on a sudden cessation of gas production on 1st January 2018. This is not a feasible production scenario as this would endanger security of supply to the market for Groningen quality gas (Ref.5 and 6). This scenario was analysed to gain fundamental insights into the delay between the implementation of a production measure (production reduction) and the resulting impact on seismic risk.

Figure 4.1 shows that following the close-in of field production on 1st January 2018, the seismicity drops almost instantaneously. The black line corresponds to observed seismicity until end of 2016. The grey line and grey band are simulated seismicity with the associated uncertainty band. During the last year of production (2017) the mean simulated number of earthquakes was 18 (with an uncertainty band from 12 to 33). Please note that the observed number of earthquakes during 2017 (18 greater than magnitude 1.5) are not yet shown in *Figure 3-2* or any of the subsequent seismicity plots. In the first year after close-in, the number of earthquake drops to 6 (with an uncertainty range from 2 to 13). Some of the statistical analysis of seismicity show a delay between production changes and the resulting changes in seismicity. This indicates that the drop in the seismicity could be less abrupt than these simulations indicate. Typically, the delay period found in these statistical analysis is between 2 and 6 months. This is in line with a delay in the response of compaction to a decline in reservoir pressure. The compaction model currently used (Ref. 1) is based on a linear relation between pressure and compaction.

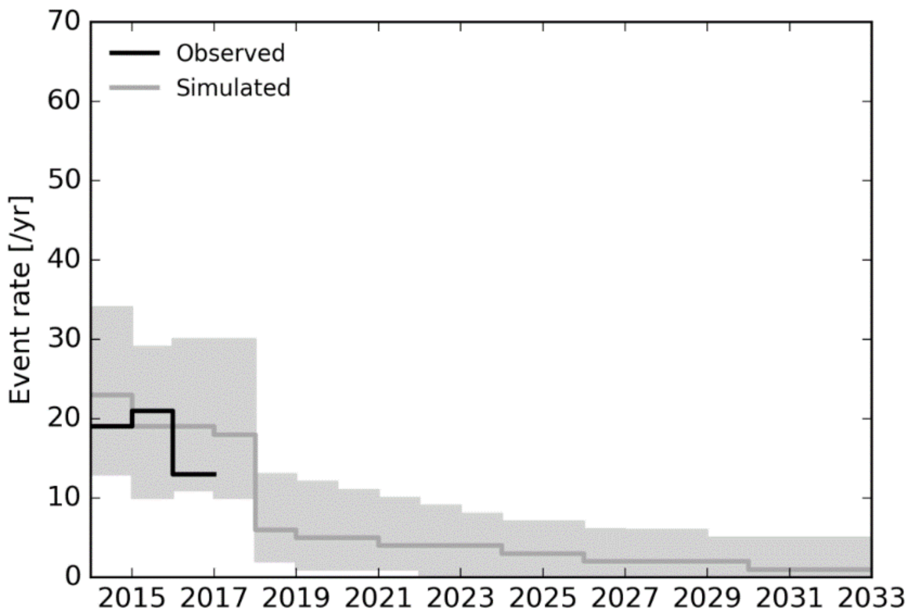


Figure 3-2 *Development of the seismicity for the Remweg Scenario with cessation of gas production on 1st January 2018. Annual number of earthquakes with magnitude M_L>1.5.*

Following this initial steep drop in seismicity, the seismicity slowly declines over the following 15 years until the number of earthquakes is reduced to a mean of zero earthquakes per year. However, the uncertainty band indicates that there remains possibility of earthquakes even after this period. This 15-year period of low and declining seismicity is the result of the equilibration of the areal reservoir pressure gradients in the reservoir.

Prior to 2014, the Groningen field was operated with a goal of minimizing areal pressure differences across the field. At any moment, the reservoir pressure everywhere in the reservoir was equal within a small tolerance. This was achieved by producing the northern clusters all year around and the southern clusters primality during the winter months (Ref. 1). With the close-in (initially stand-by) of the five clusters around Loppersum in January 2014, the pressure in the Loppersum area of the reservoir initially stabilized and remained high, while the continued production in the south and east of the field resulted in continued pressure decline in these areas. Once sufficient pressure difference had built up in the reservoir, gas started to flow from the Loppersum Area to the South-East of the field, causing the pressure in Loppersum to again decline, (see Figure *3-3* a) for the history matched areal pressure distribution. The period of slower pressure decline in the Loppersum area was estimated at some 5 years and is currently nearing its end (pressure decline in Loppersum area back to field average decline). Following cessation of production, pressure in the reservoir will equilibrate to a common value. The pressure change following 5 years of closed-in production is shown in Figure *3-3* b. In the Loppersum area the pressure decline will continue as the South re-pressurizes. Seismicity will largely align with the areas of continued pressure decline, with hazard after cessation of production concentrated in the area north-west of Loppersum while being much lower elsewhere in the Groningen field area (Appendix B).

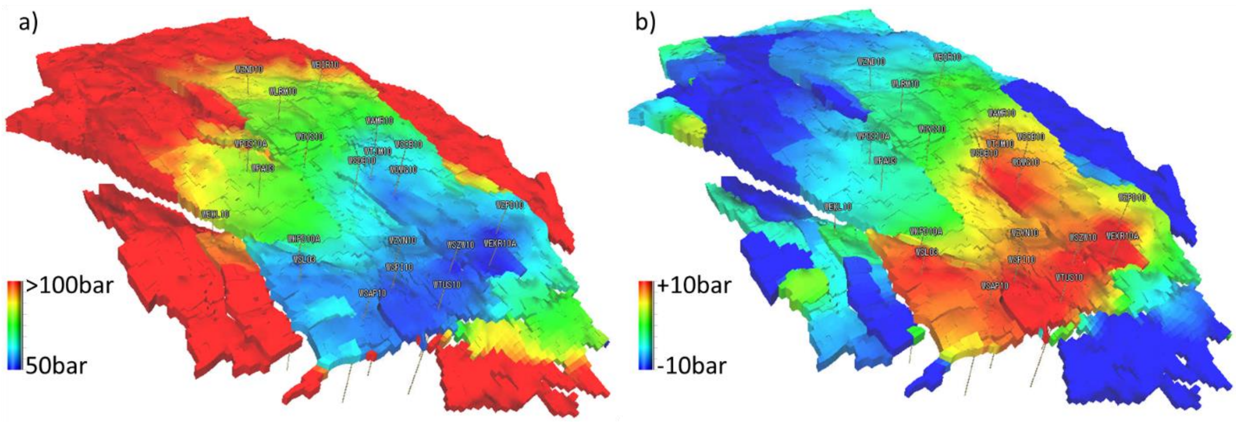


Figure 3-3 *a) History matched reservoir pressure as per 1/1/2018. b) Estimated change in reservoir pressure following 5 years of production cessation (1/1/2023). Negative values represent further decline in pressure from 2018 values.*

T2 - Remweg Scenario – Production Cessation 1/1/2023

With the subsequent decline in seismicity being dependent on the equilibration of the areal pressure differences in the field, it is interesting to assess the impact of another 5 years continued production from the field (with the five Loppersum clusters closed in). A second scenario was defined where production is continued based on the production levels of the Regeerakkoord until 1st January 2023, after which the field is closed-in.

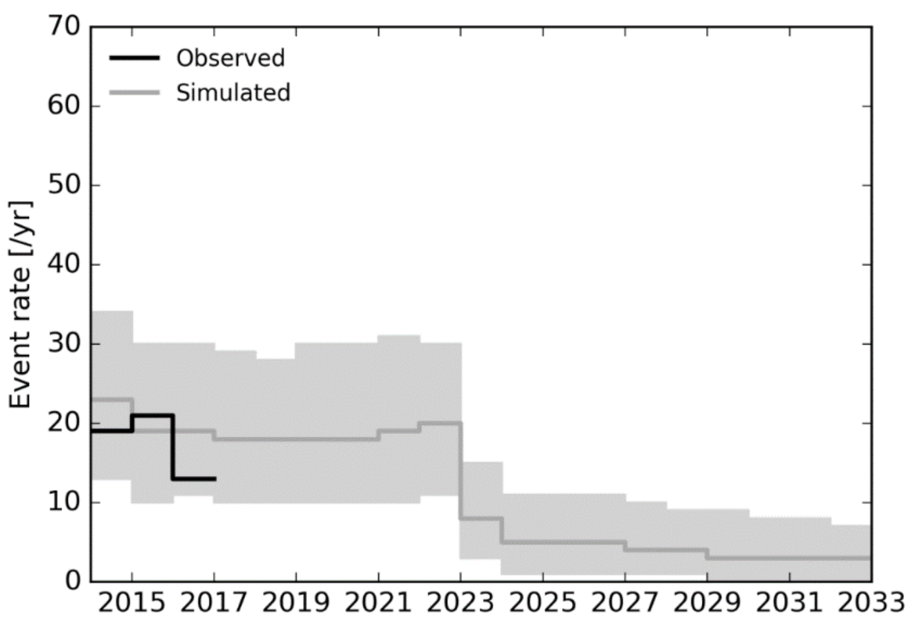


Figure 3-4 *Development of the seismicity for the Remweg Scenario with cessation of gas production on 1st January 2023*

Figure 3.4 shows the seismicity for this scenario based on a cessation of production on 1st January 2023 (T2). Figure 3.5 shows a comparison of the development of the seismicity for both these Remweg Scenarios.

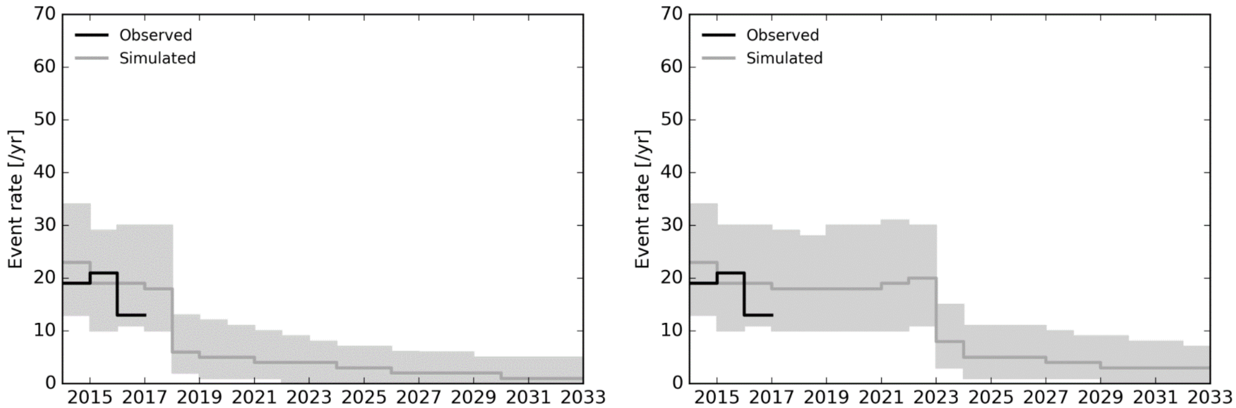


Figure 3-5 *Comparison of the development of the seismicity for the Remweg Scenarios with cessation of gas production on 1st January 2018 and 1st January 2023*

The impact of the sharp drop in seismicity following cessation of gas production and the further period of slow decline are also reflected in the seismic risk for this scenario. The LPR is shown in Figure 3-6 for the period immediately following cessation of production in respectively 2018 (left) and 2023 (right). The LPR during the 5-year period following cessation of production appears to be very similar for both scenarios (T1 and T2), indicating that the impact of the timing of cessation does not significantly impact the risk after cessation.

After cessation of gas production, there are no buildings with a larger than 10% chance of a LPR exceeding 10^{-4} /year. The number of buildings with a mean LPR exceeding 10^{-5}/year is reduced to some 10 – 30 buildings.

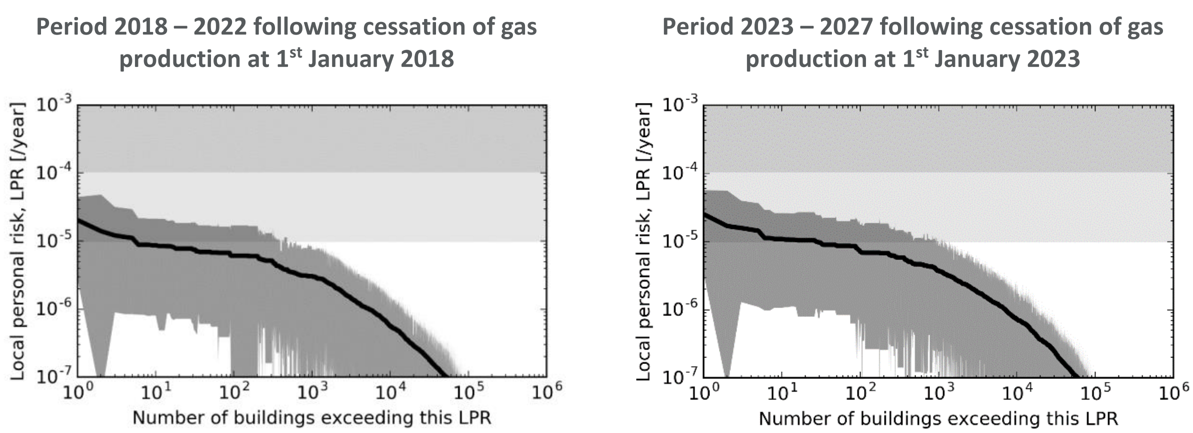


Figure 3-6 *Comparison of the LPR for both the Remweg Scenarios with cessation of gas production on 1st January 2018 and 1st January 2023. The LPR during the first 5 years following close-in of production are shown.*

Reduction to 12 Bcm/year

Apart from total cessation of gas production, the impact of an immediate reduction of gas production to 12 Bcm/year has also been studied. This is another scenario to gain fundamental insights into the delay between the implementation of a production measure (production reduction) and the resulting impact on seismic risk.

T3 - Immediate reduction to 12 Bcm per annum at 1/1/2018, optimized production distribution

Figure 3-7 shows the development of the seismicity following an immediate reduction of production to 12 Bcm/year at 1st January 2018, using an optimised production distribution. Following the reduction of the gas production to 12 Bcm/year, the seismicity drops to a mean of 11 earthquakes/year with an uncertainty range from 5 to 20. This is a higher level of seismicity than for complete cessation of production (In the previous section (production scenarios T1 and T2), the mean number of earthquakes initially dropped to 6 earthquakes per year), following close-in of production.

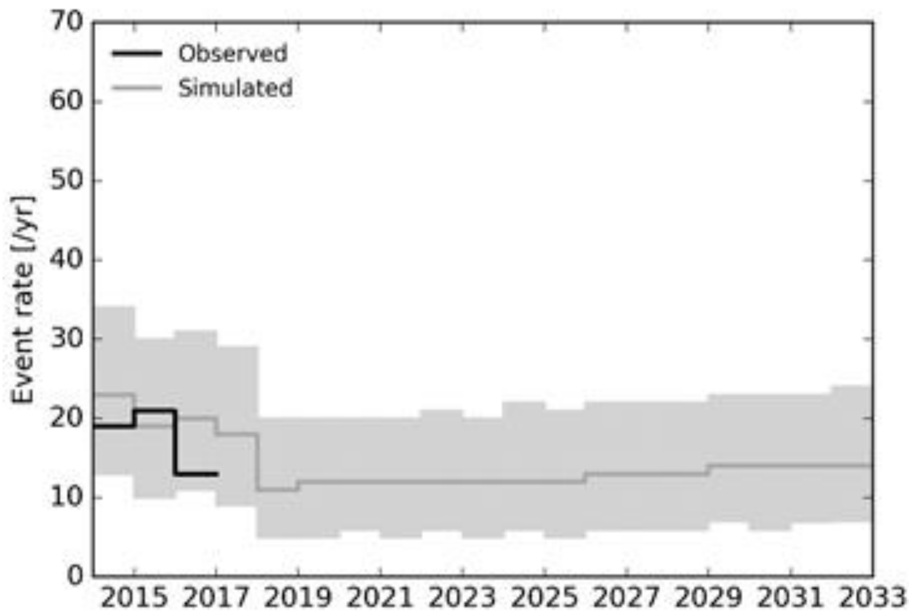
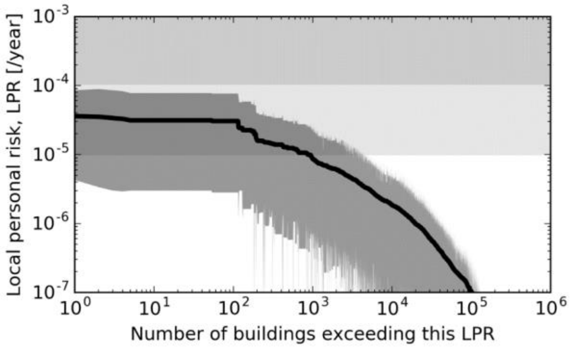


*Figure 3-***7** *Development of the seismicity for the Scenario with immediate reduction of production to 12 Bcm/year at 1st January 2018*

After the initial reduction in the seismicity, it once again slowly increases, while production is kept flat at 12 Bcm/year. Every approximate 5 years the mean simulated number of earthquakes per year increases by one. This continues until the field is not able to sustain a plateau of 12 Bcm/year and production commences to decline (approx. 2032). At a production of 12 Bcm/year, the LPR is reduced, such that no buildings have a larger than 10% chance of exceeding a LPR level of 10^{-4} /year. About 1,000 buildings would have a mean LPR above 10^{-5}/year.

Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.

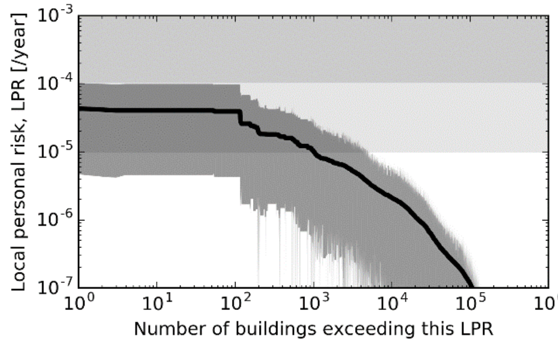
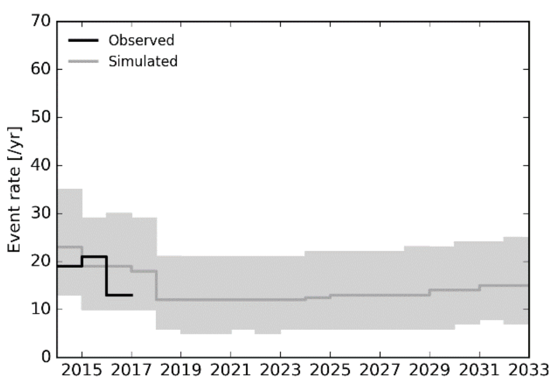


*Figure 3-**8*** *LPR for both the Scenario with immediate reduction of production to 12 Bcm/year at 1st January 2018. LPR is shown for first 5 years following the production reduction and the following 5 years*

T4 - Immediate reduction to 12 Bcm per annum at 1/1/2018, imposed production distribution

At a production level of 12 Bcm/year there is excess capacity, allowing for considerable flexibility in distribution of the production over the field and potentially achieving a reduction in the seismicity as a result. Figure 3-9 shows the seismicity for both the imposed and optimised production distribution at 12 Bcm/year. The seismicity for both scenarios is relatively similar, indicating only a modest improvement in the number of earthquakes from optimizing the production distribution.

Production scenario 12 Bcm/year with imposed distribution of gas production over the field.



Production scenario 12 Bcm/year with distribution of gas production over the field optimised to reduce seismicity.

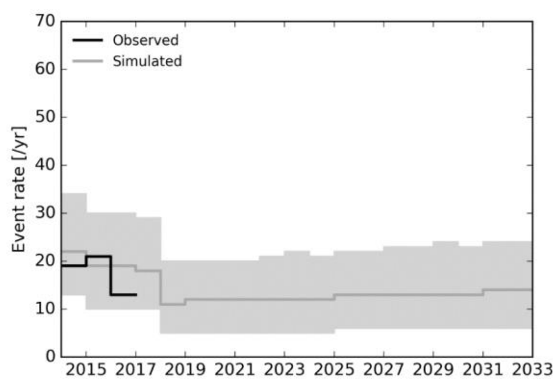


Figure 3-9 *Comparison of the development of the seismicity for the two Scenario with immediate reduction of production to 12 Bcm/year at 1st January 2018 (areal distribution of production as imposed and optimised to reduce seismicity).*

Feasible Production Scenarios

Starting with the production scenario of the Coalition agreement[2] (Ref. 1), the seismic risk reduction resulting from increasingly lower production scenarios will be presented. The scenario with the lowest gas production is a scenario of the maximum import in combination with an additional GTS nitrogen blending plant.

Regeerakkoord

D1a - Production as per Regeerakkoord 2017, imposed production distribution, NFA

When producing in line with the 10th October 2017 Coalition Agreement (Ref. 2), the seismicity level in the next 5 years (2018-2022) is predicted to stay relatively stable and close to current levels, at or slightly below 20 events per year (M>1.5). Also over the subsequent 5-year period (2023-2027) the production can be largely sustained at the 20 Bcm/year plateau (decline starts at the end of 2026, Appendix B). A slight increase in the associated seismicity is predicted. Ultimately, the seismicity is expected to decline with reducing total field production.

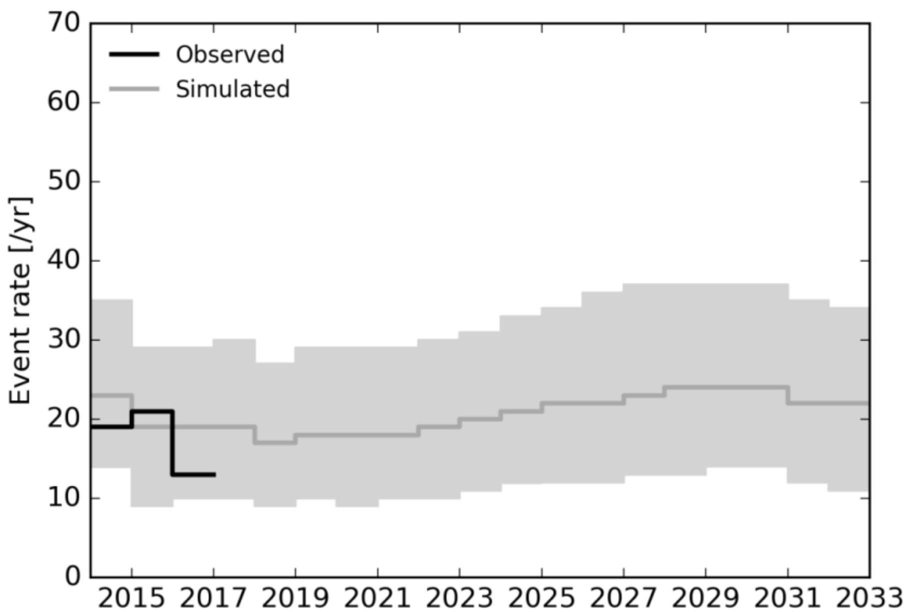


Figure 3-10 *Development of the seismicity for the Scenario as per the Regeerakkoord, with Imposed production distribution*

D1b - Production as per Regeerakkoord 2017, imposed production distribution, additional compression

With the installation of an additional compression facilities step at the production clusters, the production plateau can be sustained until 2030. This would cause the predicted decline in seismicity (as observed in the D1a scenario around 2031) to be delayed and the sustained upward trend in seismicity set to continue (Figure 3-11).

D1c - Production as per Regeerakkoord 2017, optimized production distribution, additional compression

It was investigated whether redistribution of production as per the optimisation study (Ref. 4) could mitigate this increasing trend. However, at these production levels, the spare capacity in the South and East (where the

2 The coalition agreement is referred to in Dutch as "Regeerakkoord". In this document both word will also be used interchangeably.

optimisation would prefer to shift production) is limited. Consequently, the potential for optimisation is also limited, and mainly constrained to the first 5 years (Figure 3-11).

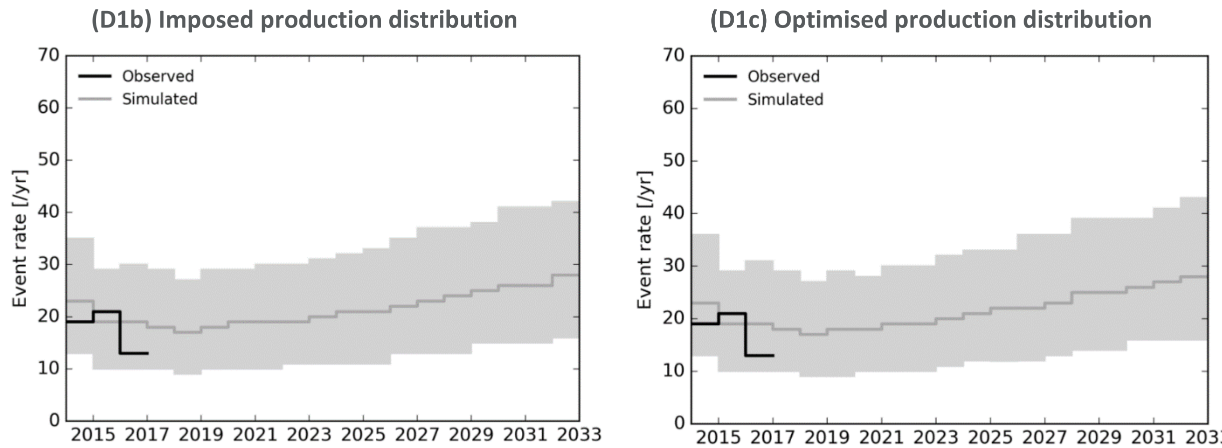


*Figure 3-**11*** *Development of the seismicity for the production scenario as per the Regeerakkoord, comparing the Imposed production distribution (left) to the optimised (right)*

Maximum Import

D2 - Max Import scenario at 85% N_2 utilization

With a Maximum Import Scenario where production is declining to zero in 2030 (based on 85% utilization of the GTS nitrogen blending plants) the increasing trend in seismicity in the 2023-2028 period is arrested, and actually starts to decline (Figure 3-12).

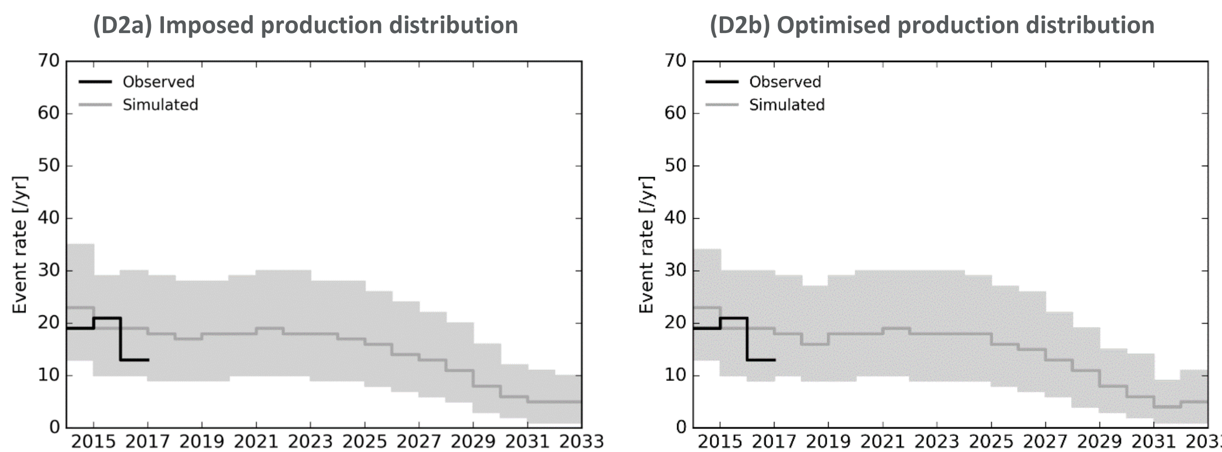


*Figure 3-**12*** *Development of the seismicity for the production scenario as per the Maximum Import at 85% N2, comparing the Imposed production distribution (left) to the optimised (right)*

D3 - Max Import scenario with 12 Bcm/year plateau at 85% N_2 utilization

In its report of 1st February 2018 (Ref. 3), SodM advises to bring Groningen production down to 12 Bcm/year. When assuming such a 12 Bcm/year plateau at the end of the Max Import scenario, the seismicity is predicted to be below 20 events per year throughout the entire forecasting window (Figure 3-13).

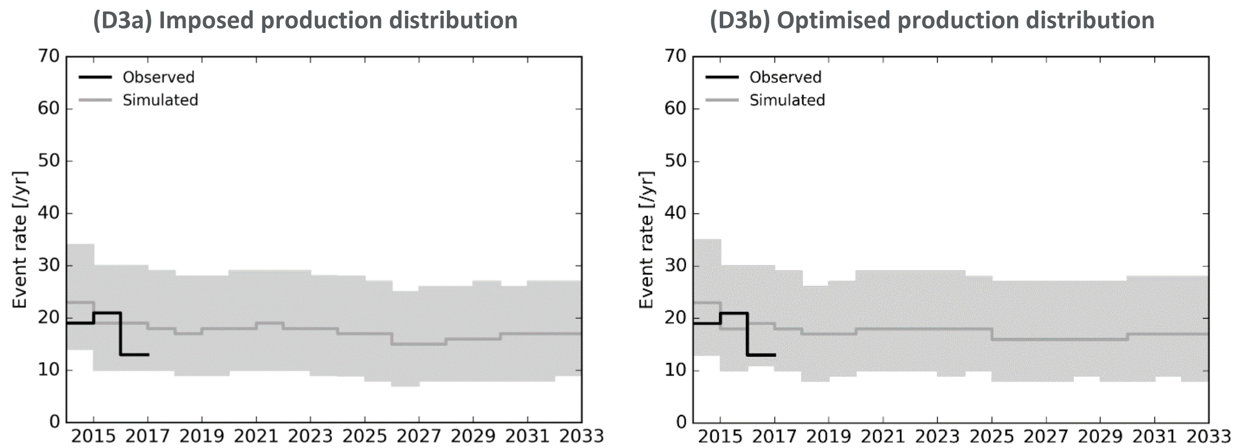


Figure 3-13 *Development of the seismicity for the production scenario as per the Maximum Import at 85% N2 with a 12 Bcm plateau, comparing the Imposed production distribution (left) to the optimised (right)*

D4 - Max Import scenario with 5 Bcm/year plateau at 85% N2 utilization

A more rigorous reduction was considered by assuming a 5 Bcm/year plateau at the end of the Max Import Scenario. This further reduces the expected seismicity level from 2027 onwards to about 10 per year (Figure 3-14), as opposed to an annual rate of about 15-20 for the 12 Bcm/year case (D3).

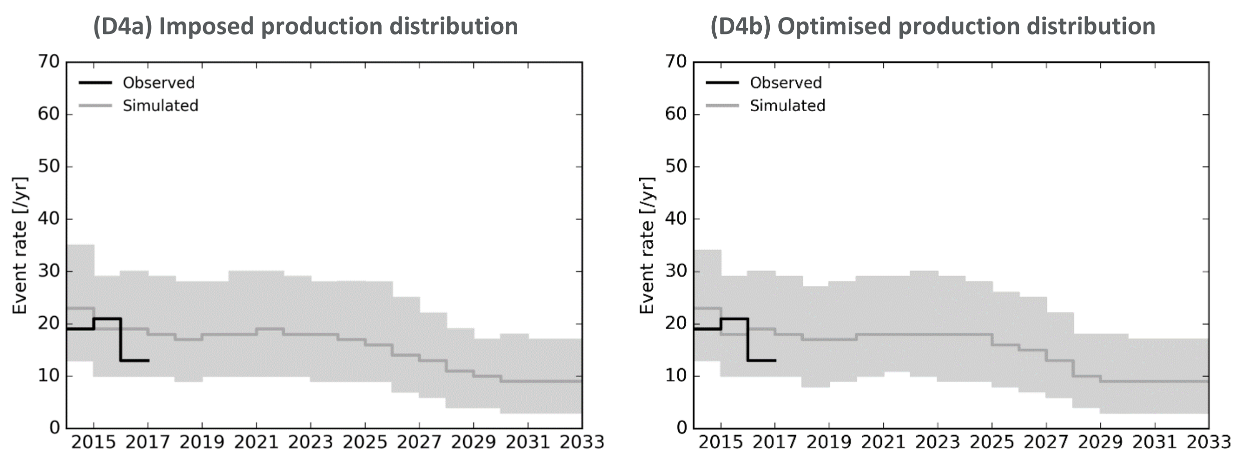


Figure 3-14 *Development of the seismicity for the production scenario as per the Maximum Import at 85% N2 with a 5 Bcm/year plateau, comparing the Imposed production distribution (left) to the optimised (right)*

Maximum Import with additional N_2-Blending Plant

D5 - Max Import scenario at 100% N2 utilization including a new N_2 plant as per 2022

Based on the assumption that an additional Nitrogen blending plant will become operational as per 2022, a further reduction of the required Groningen gas can be achieved. In addition, it was assumed that the existing Nitrogen blending plants will be utilized at 100% of their capacity, to explore the impact of more rigorous production reductions. Production reduction in 2022 (from 17.5 to 11.3 Bcm/year) does indeed result in a step reduction in seismicity, with further decline in the subsequent years as production further declines (Figure 3-15).

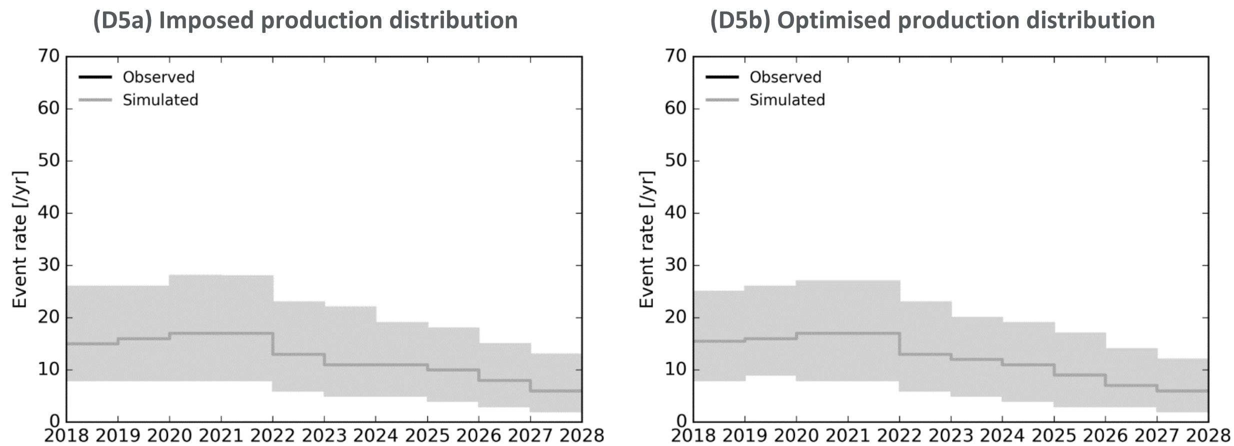
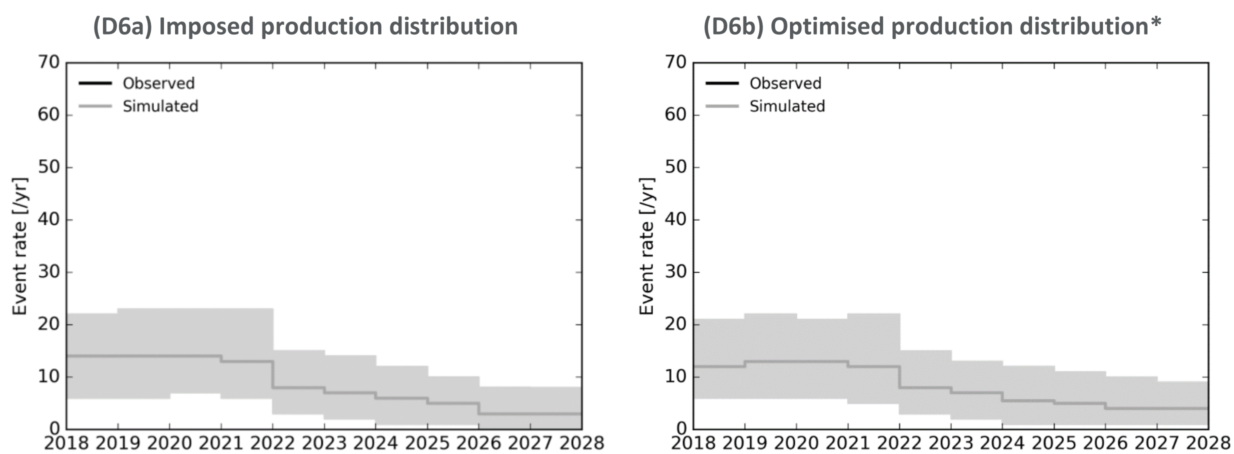


Figure 3-15 *Development of the seismicity for the production scenario as per Maximum Import with 100% N2 utilization and additional N2 plant in 2022, comparing the imposed production distribution (left) to the optimised (right).*

D6 - Max Import scenario at 100% N_2 utilization including a new N2 plant as per 2022 for a warm year

The required Groningen volume estimates for D2-D5 scenarios were estimated assuming an average temperature year. When assuming only warm years, an even lower possible production scenario that can currently be envisaged can be constructed. With this profile Groningen production ceases at 2025. Estimated seismicity is shown in Figure 3-16 and is considerably below those of the D5 scenario.



* This scenario can be seen as a proxy for an acceleration of the transition of the gas market from Groningen gas to other energy sources.

Figure 3-16 *Development of the seismicity for the production scenario as per Maximum Import with 100% N2 utilization, additional N2 plant in 2022 and warm temperature years, comparing the imposed production distribution (left) to the optimised (right).*

* This scenario can be seen as a proxy for an acceleration of the transition of the gas market from Groningen gas to other energy sources.

Table 3-1 summarizes the Risk Metrics for the various feasible scenarios as investigated in this chapter (details in Appendix B). Only those of the optimized production distributions are shown since those will in general result in lower seismicity and risk. Scenarios with 12 and 5 Bcm/year plateau production (D3-4) are not shown since they are essentially the same as the Max Import scenario for the time window 2018-2027.

Production Scenario → Metric ↓	(D1d) Regeer Akkoord NFA Optimised		(D2b) Max. Import Scenario 85% utilization N2-blending NFA Optimised		(D5b) Max. Import Scenario 100% utilization N2-blending + N2 Plant Average Temp. Year NFA Optimised		(D6b) Max. Import Scenario 100% utilization N2-blending + N2 Plant Warm Temp. Year NFA Optimised*	
	2018 - 2022	2023-2027	2018 - 2022	2023-2027	2018 - 2022	2023-2027	2018 - 2022	2023-2027
Average Yearly Event count (M>1.5)	18	21	18	16	15	9	12	5
Annual Probability (M≥3.6)	15.4%	18.0%	15.2%	14.3%	13.1%	8.1%	10.0%	4.7%
Annual Probability (M≥4.0)	6.3%	7.5%	6.3%	5.9%	5.2%	3.3%	4.0%	1.9%
Annual Probability (M≥5.0)	0.4%	0.5%	0.4%	0.3%	0.3%	0.2%	0.2%	0.1%
Maximum PGA (475yr) [g]	0.176	0.189	0.176	0.189	0.180	0.142	0.151	0.121
No. of buildings with mean LPR > 10^{-4}/year	0	0	0	0	0	0	0	0
No. of buildings with P10 LPR > 10^{-4}/year	153	202	154	117	115	0	0	0
No. of buildings with mean LPR > 10^{-5}/year	1819	2876	1869	1713	1178	465	645	18

* This scenario can be seen as a proxy for an acceleration of the transition of the gas market from Groningen gas to other energy sources.

Table 3-1 Overview of Risk Metrics used for the probabilistic seismic risk assessment of induced seismicity in Groningen for four gas production scenarios

References

1 Induced Seismicity in Groningen Assessment of Hazard, Building Damage and Risk – November 2017, NAM (Jan van Elk and Dirk Doornhof), November 2017.

2 Vertrouwen in de toekomst, Regeerakkoord 2017 – 2021 VVD, CDA, D66 en ChristenUnie, Section 3.3 Gaswinning, 10th October 2017.

3 Advies Groningen-gasveld n.a.v. aardbeving Zeerijp van 8 januari 2018, Staatstoezicht op de Mijnen, 1st February 2018.

4 Optimisation of the distribution of production over the Groningen field to reduce Seismicity, Leendert Geurtsen and Per Valvatne, December 2017.

4 Observations

In this report NAM shares seismic risk assessments for a selection of production scenarios. Analysis of the risk assessments prepared for the different production scenarios presented in this report allows comparison of the effectiveness of measures intended to achieve a reduction in the Local Personal Risk (LPR) and compliance with the Meijdam safety-norm. In particular, the effectiveness of a reduction in the overall production from the field, the optimization of the distribution of the offtake over the different areas of the field and the structural upgrading of buildings can be evaluated and compared. The requirement to strengthen buildings is strongly dependent on the production outlook for the Groningen field.

A reduction in the production from the total field, will increase safety for all people present in the Groningen field area. Both people exposed to a LPR above 10^{-5}/year and those exposed to a much lower seismic risk would have a risk benefit from a reduction in production. The areal distribution of the field offtake can reduce risk for some communities, but these effects are temporary, as the effect typically diminishes after several years. The optimisation study already showed that further optimisation of the areal distribution of the production after the close-in of the Loppersum clusters in February 2014, has only a limited safety benefit.

In contrast, structural upgrading of a building increases the safety of people present in or around this particular building. Whereas a production reduction (for the full field or a field area) effects the risk for all people in the area, structural upgrading is much more targeted to the people in the selected building.

Likewise, the other impacts of these measures to increase safety are different for each community. A reduction of the overall production of the field are primarily felt in the gas markets on a (inter)national level. The strengthening of buildings, primarily affects the people living in the building and in the immediate vicinity of the building. The impact of building strengthening of a house, can be very substantial for the occupants.

The decision-making, balancing these options to improve seismic risk for the Groningen community, needs to be done by the Minister of EZK. In this report NAM shares seismic risk assessments for a selection of production scenarios. The seismic risk consequence of different sets of production scenarios has been investigated for:

- Theoretical scenarios to gain basic insights, indicate the delay in seismic response to a reduction of production, mainly resulting from the continuing pressure equilibration.
- Range of feasible production scenarios (based on market information provided by others) to gain insight in the development of seismicity. Starting from the current (Regeerakkoord, 2017) scenario, the seismic risk reduction resulting from increasingly lower production scenarios is discussed, focussing on the maximum import scenario without and with a GTS nitrogen blending plant.

From the theoretical “Remweg Scenarios” (Braking Distance Scenarios) the following observations can be made:

- Following close-in of production (1/1/2018), the activity rate is expected to drop from expected 20 earthquakes/year to 6 earthquakes/year. In the following 10 years, the activity rate slowly declines to no expected earthquake events (while reservoir pressure equilibrates). This decline in seismicity is also reflected in the hazard map and LPR.
- In the 5-year period immediately following close in (2018 – 2022):
  - Mean LPR >10^{-4}/year = 0 buildings (P10 = 0 buildings)
  - Mean LPR >10^{-5}/year = 8 buildings

- In the following 5-year period (2023 – 2027):
    - Mean LPR >10^{-4}/year = 0 buildings (P10 = 0 buildings)
    - Mean LPR >10^{-5}/year = 0 buildings
- If the close-in is postponed by 5-years (to 1st January 2023), the seismic response and development after close-in are similar.
- If instead of close-in, the production is reduced to 12 Bcm/year (on 1/1/2018), the activity rate is expected to drop from approx. 20 #/year to 11 #/year. In the following 10 years the activity rate very slowly increases again. Optimisation of the production distribution does not significantly reduce this. The initial decline in seismicity is also reflected in the hazard map and LPR.
- In the 5-year period immediately following reduction to 12 Bcm/year (2018 – 2022):
    - Mean LPR >10^{-4}/year = 0 buildings (P10 = 0 buildings)
    - Mean LPR >10^{-5}/year = 1,000 buildings
- In the following 5-year period (2023 – 2027):
    - Mean LPR >10^{-4}/year = 0 buildings (P10 = 0 buildings)
    - Mean LPR >10^{-5}/year = 1,000 buildings

Additionally, the seismic risk consequence of several feasible production scenarios has been assessed. These production scenarios are primarily from GTS reports and are based on assumptions on the gas market and conversion of hi-cal gas to Groningen gas quality through nitrogen blending.

- The production scenario of the Regeerakkoord 2017 is very similar to the Hazard and Risk Assessment – November 2017.
- In the 5-year period immediately (2018 – 2022), expected activity rate is around 20 #/year:
    - Mean LPR >10-4/year = 0 buildings (P10 = 150 buildings)
    - Mean LPR >10-5/year = 1,800 buildings
- In the following 5-year period (2023 – 2027) seismicity increases slowly to 23 #/year. The LPR is similar to the first period.
- Without 2nd stage compression end-of-plateau is 2025. With 2nd stage compression this is postponed to 2030.
- Optimisation of production distribution has small effect (also in plateau length).
- Max Import Scenario in first 5-year period (2018-2022) very similar to Regeerakkoord Scenario. Only small reduction in production rate in 2021 and 2022. As a result, no significant risk impact in this period.
- During the second 5 years (2023 – 2027), the number of buildings exceeding 10^{-4}/ year and 10^{-5} /year LPR-norm is reduced.
    - Mean LPR >10^{-4}/year = 0 buildings (P10 = 120 buildings)
    - Mean LPR >10^{-5}/year = 1,700 buildings
- Optimisation of production distribution has relative minor effect.

- If minimum rate is set on 12 Bcm/year this will be reached in 2026. If minimum rate is set on 5 Bcm/year this will be reached in 2029.
- Additional nitrogen unit operational in 2022, has a significant impact on production and resulting seismicity in the period 2023-2027. Both normal utilisation (85%) and full utilisation of existing the N2-plant are shown.
- Both average temperature year and warm year production scenario are evaluated.
- During the second 5 years (2018 – 2022), the number of buildings exceeding 10^{-4}/ year and 10^{-5} /year LPR-norm is reduced for the production scenario for 100% nitrogen utilisation and warm years.
    - Mean LPR >10^{-4}/year = 0 buildings (P10 = 0 buildings)
    - Mean LPR >10^{-5}/year = 650 buildings
- During the second 5 years (2023 – 2027), the number of buildings exceeding 10^{-4}/ year and 10^{-5} /year LPR-norm is reduced.
    - Mean LPR >10^{-4}/year = 0 buildings (P10 = 0 buildings)
    - Mean LPR >10^{-5}/year = 20 buildings

The scenario of maximum import of gas combined with an additional nitrogen blending plant, is the most rigorous production reduction scenario that is feasible from a gas-market perspective. This production scenario leads to a progressive reduction in earthquakes, damage and nuisance. In this scenario a lower number of buildings do not meet the Meijdam-norm (in the order of several 100 houses, some of these are already included in the structural upgrading plan). Due to the decline in production, the mean LPR (Local Personal Risk) would for all buildings decline to below 10^{-5}/year by 2025-2026.

In this report NAM has not looked at the impact of reduction in production from the field has on Security of Supply, as the decision-making and balancing of the options to improve seismic risk for the Groningen community with impact on Security of Supply, is the responsibility of the Minister of EZK.

Appendix A – Abbreviations

EZK	Ministry of Economic Affairs and Climate
GTS	Gasunie Transport Services BV
H-gas	High Calorific Gas (Gas from most gas field has a higher calorific content than gas from the Groningen gasfield)
L-Gas	Low Calorific Gas (Groningen gas had due to the nitrogen content a lower calorific content than gas from many other gas fields)
LPR	Local Personal Risk
N_2	Nitrogen
NAM	Nederlandse Aardolie Maatschappij BV
NFA	No Further Activity

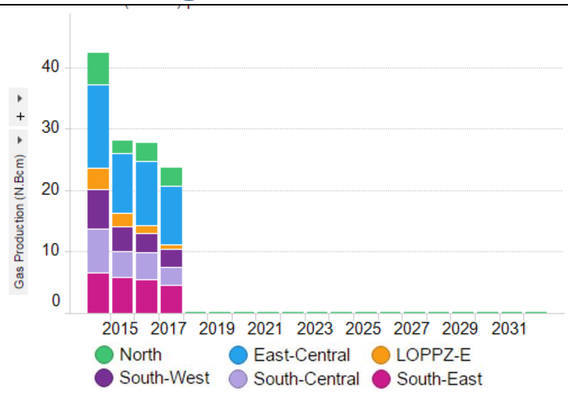
Appendix B – Overview Production, Hazard and Risk Assessment for Scenarios

In this appendix, the results of the hazard and risk assessment for the different production scenarios are presented using a consistent standardised format. This allows easy comparison between these results. The following are shown:

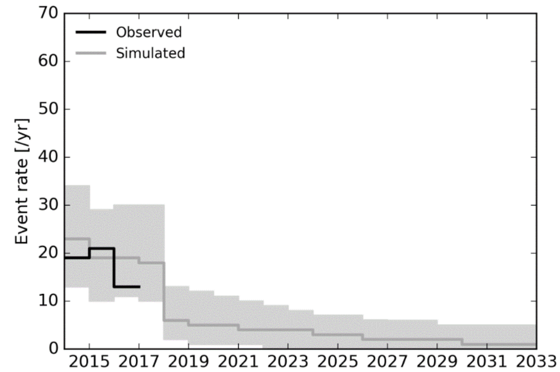
- Gas Production Scenario. Production for the period 2014 to 2032 is shown. This includes three historical years (2014 – 2017) for reference and a forecast for 15 years (2018 to 3032). The colours indicate the production areas of the instemmingsbesluit.
- Seismicity. The observed number of earthquakes (with magnitude larger than M_L>1.5) for the three historical years is shown in black. The simulated number of earthquakes (with magnitude larger than M_L>1.5) in shown in grey. The grey line indicates the mean number of earthquakes and the grey band the uncertainty range (10% - 90%).
- Hazard Map with a return period of 475 years for the period 2018 – 2022. As much as possible the same colour scale has been used throughout this appendix and report text. The maximum PGA is indicated at the top of the map together with the coordinates of the location where this maximum PGA occurs.
- Hazard Map with a return period of 475 years for the period 2023 – 2027.
- Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.
- Number of buildings exceeding Local Personal Risk (LPR) for the period 2022 – 2027. As above.
- Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022. A colour scale from red to yellow is used to indicate the buildings, with red for buildings with a LPR of 10^{-4} / year and yellow for buildings with a LPR of 10^{-5} /year. Buildings with highest LPR are plotted on top.
- Location of buildings with LPR exceeding 10^{-5}/year for the period 2022 – 2027. As above.

Production cluster by location, as used to display the areal distribution of production. Note that the Loppersum clusters (LOPPZ) are lumped with the Eemskanaal cluster for display purposes (LOPPZ-E). However, in none of the forecast scenarios there is any production from the LOPPZ clusters (only for the imposed production distribution there is production from Eemskanaal), hence the LOPPZ clusters are shaded here.

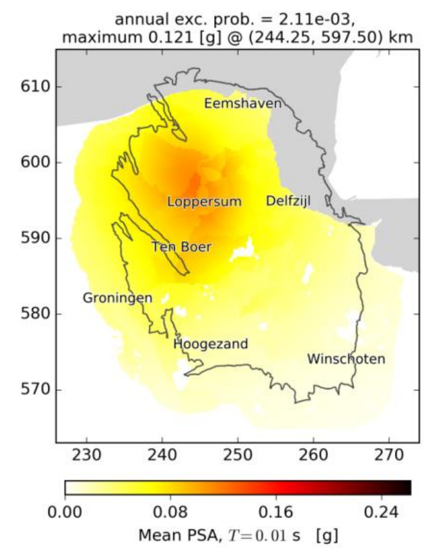
T1 - Remweg Scenario – Production Cessation 1/1/2018



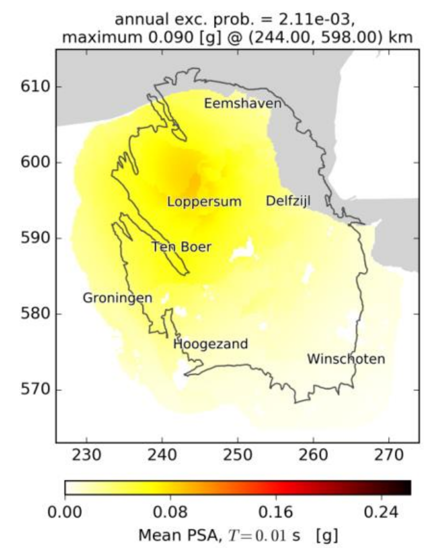
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



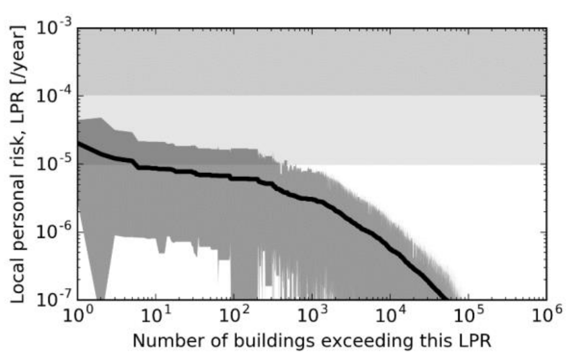
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



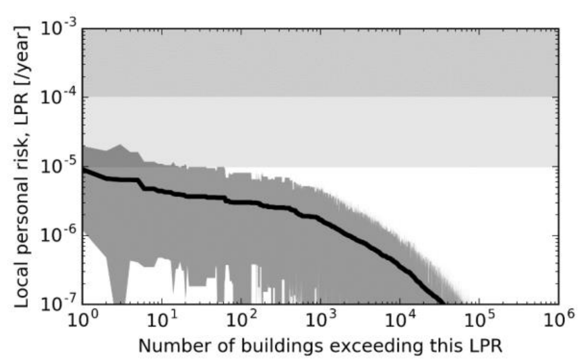
Hazard Map for the period 2018 – 2022.



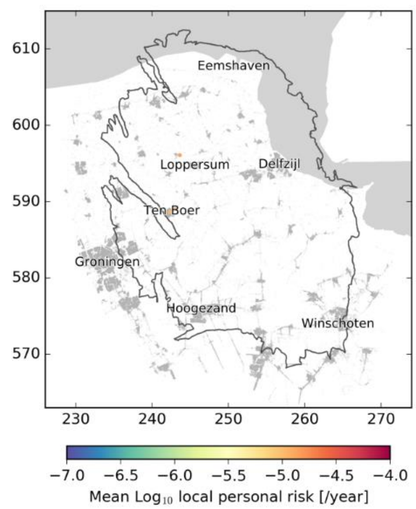
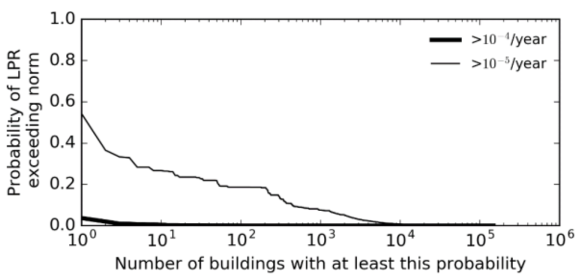
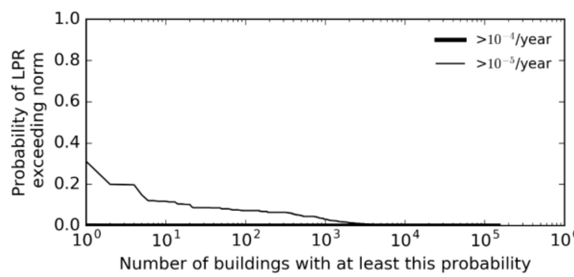
Hazard Map for the period 2023 – 2027.

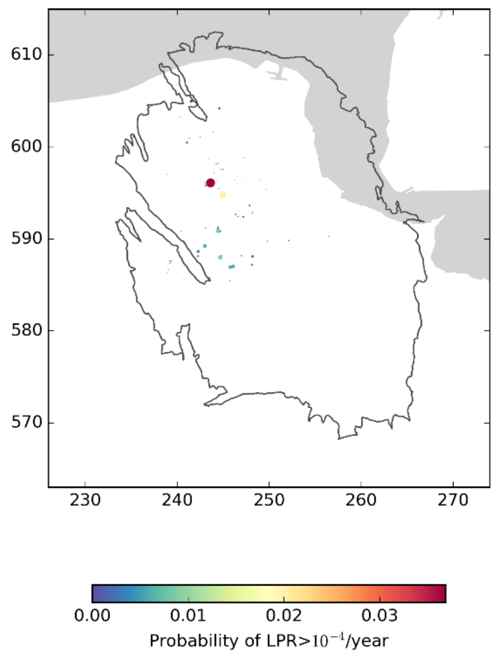


Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.

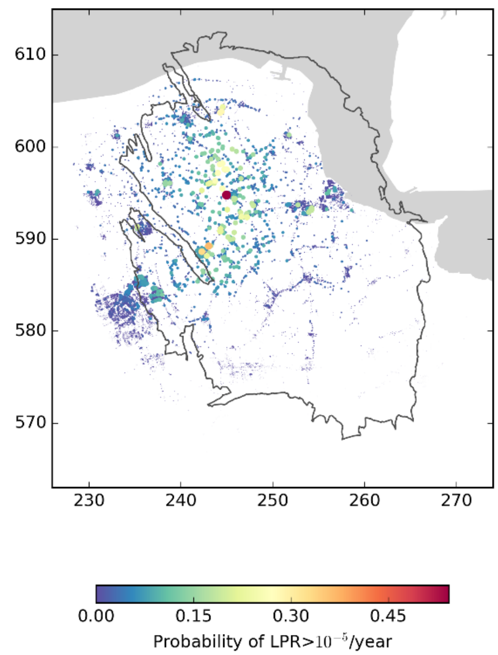


Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.

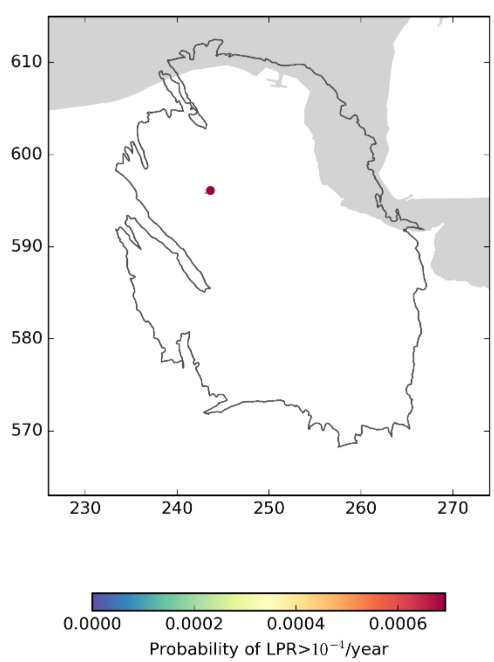
	No buildings with LPR>10^{-5} /year
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.	Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.
	
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.	Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



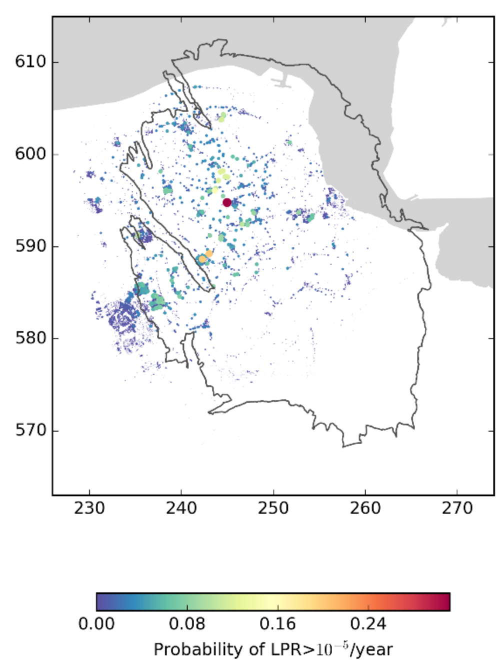
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

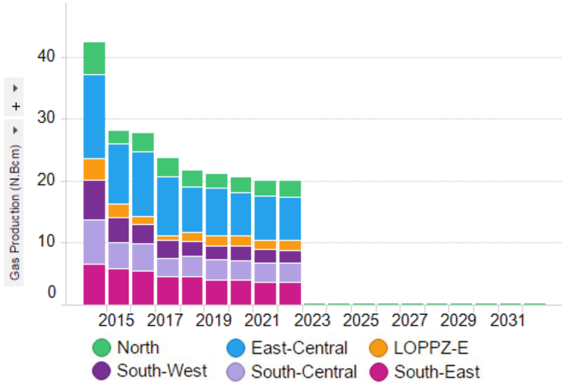


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

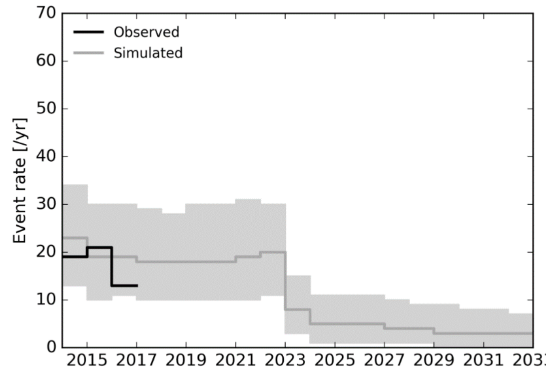


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

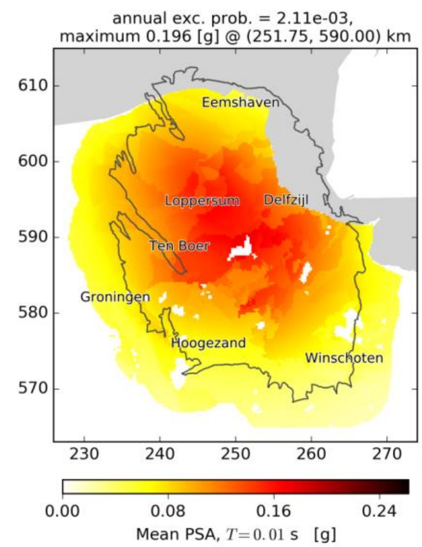
T2 - Remweg Scenario – Production Cessation 1/1/2023



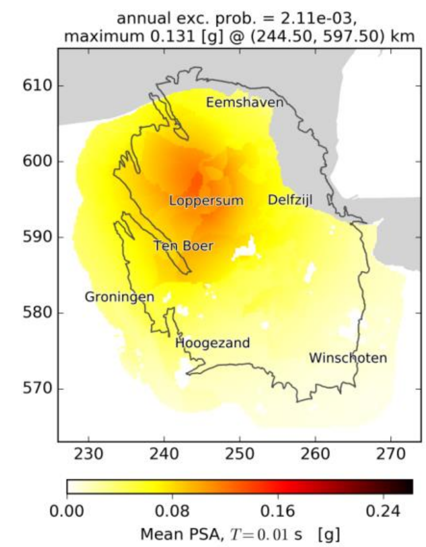
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



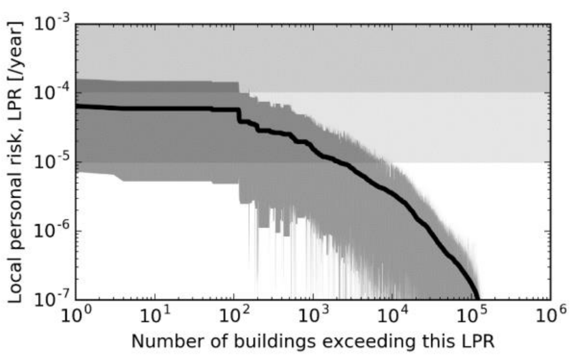
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



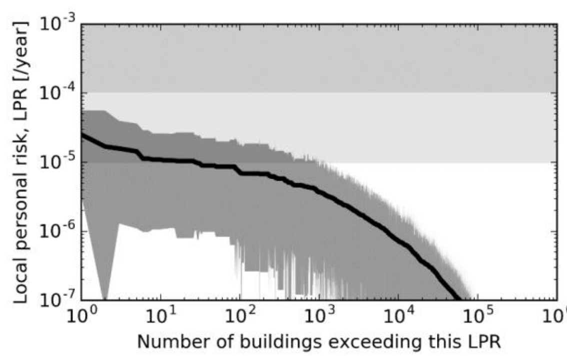
Hazard Map for the period 2018 – 2022.



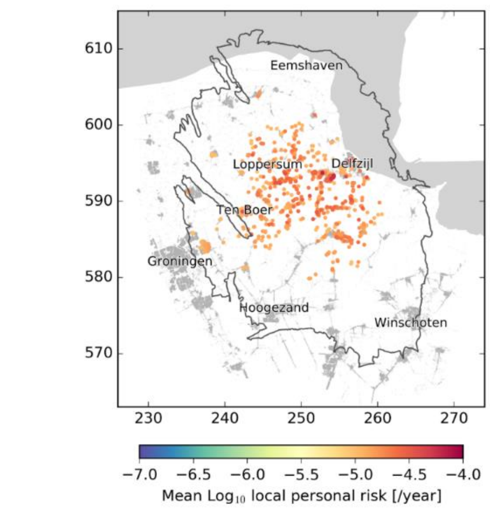
Hazard Map for the period 2023 – 2027.



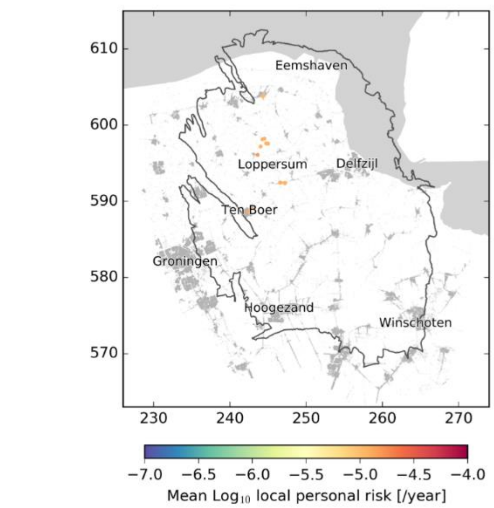
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



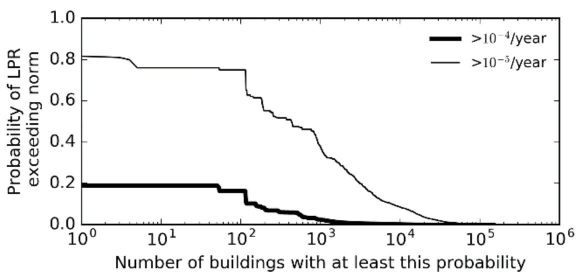
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



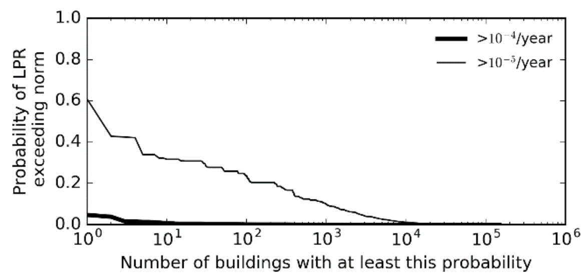
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



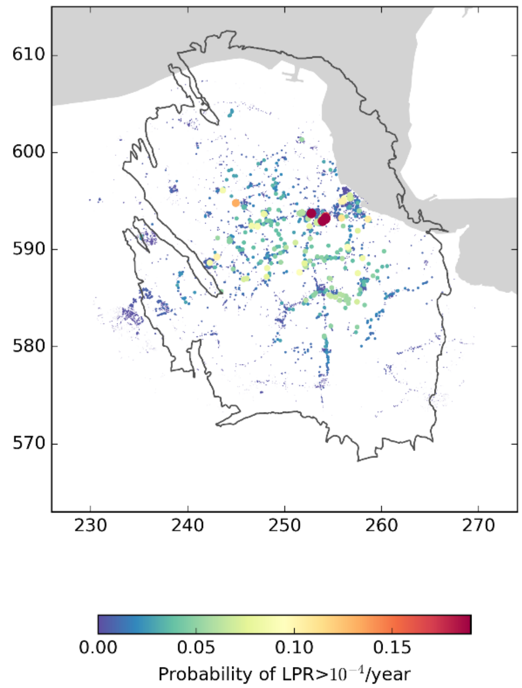
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.

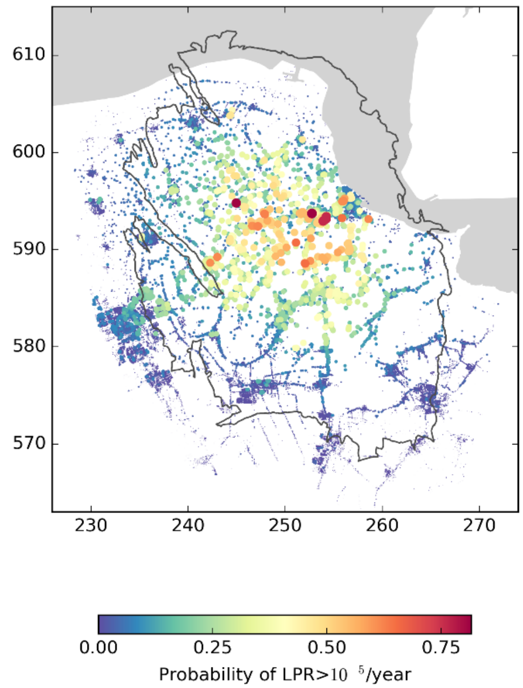


Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.

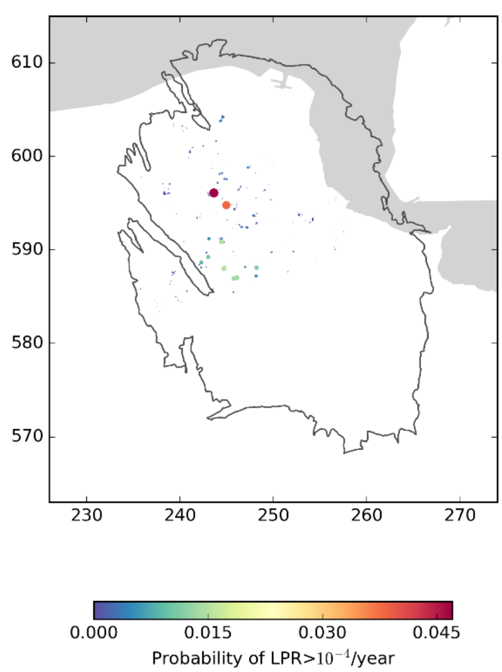


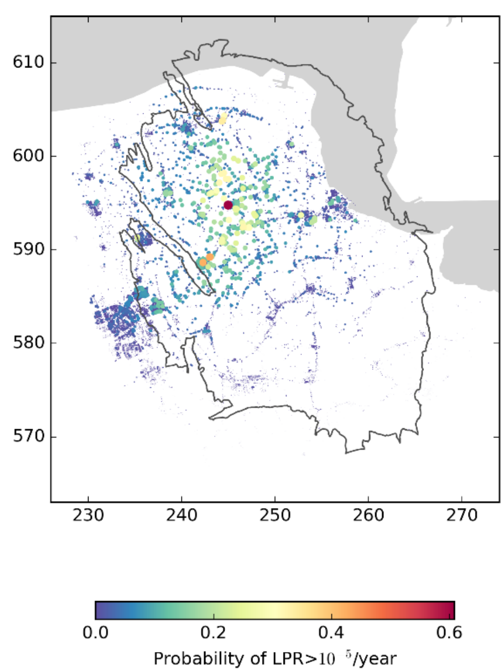
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.





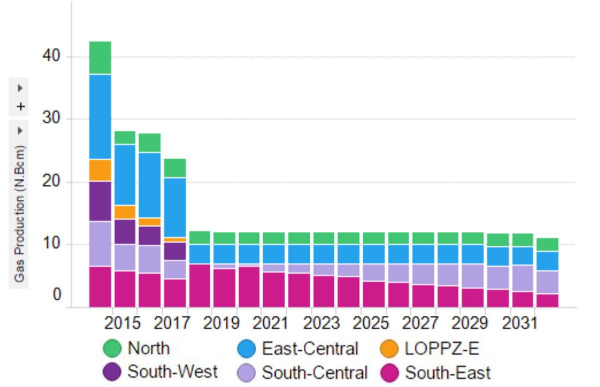
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.	Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



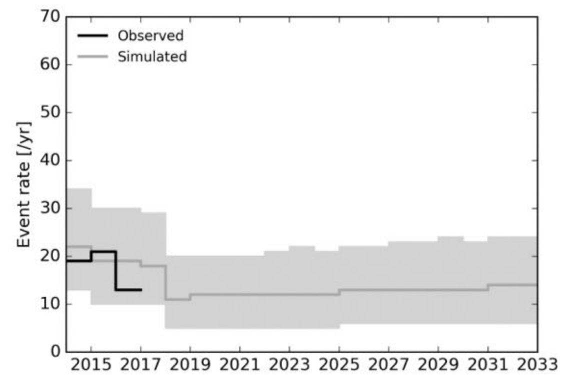


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.	Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

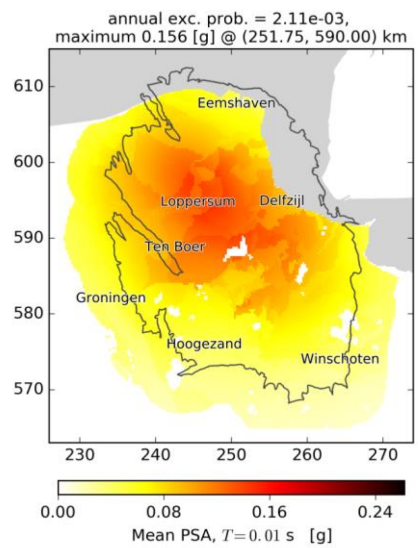
T3 - Immediate reduction to 12 N.Bcm per annum at 1/1/2018, optimized production distribution



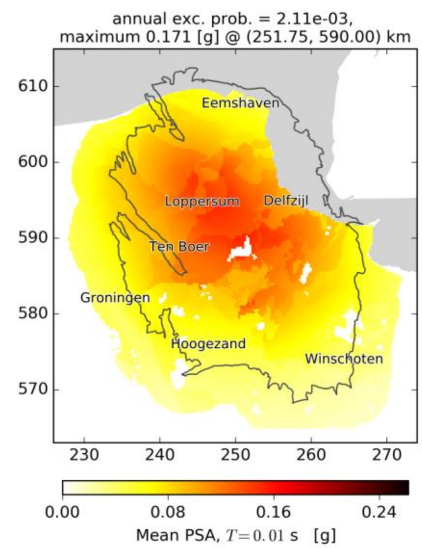
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



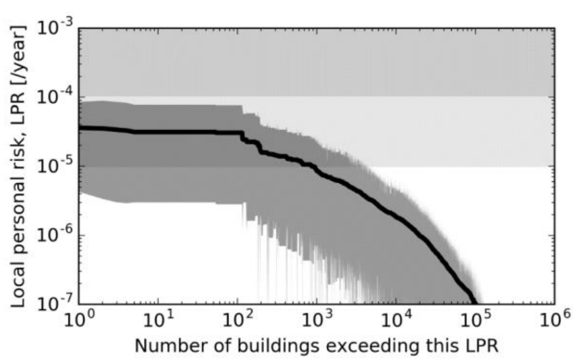
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



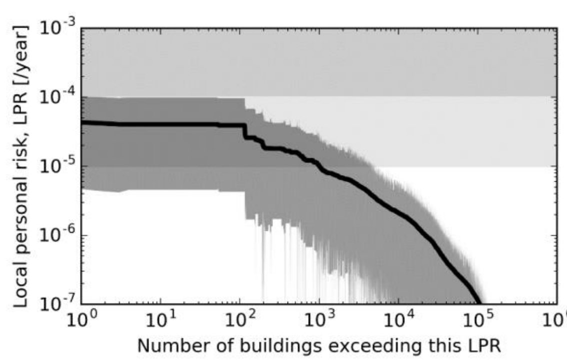
Hazard Map for the period 2018 – 2022.



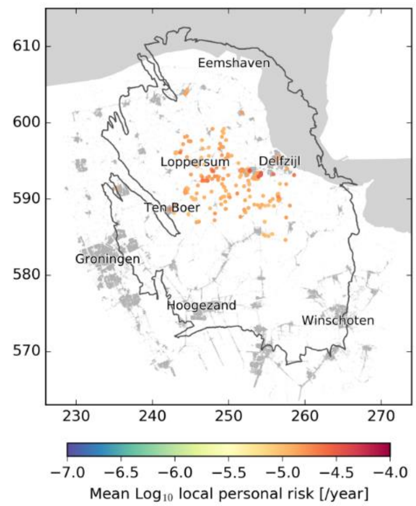
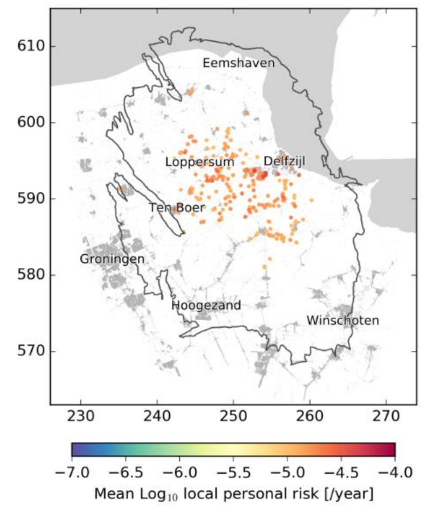
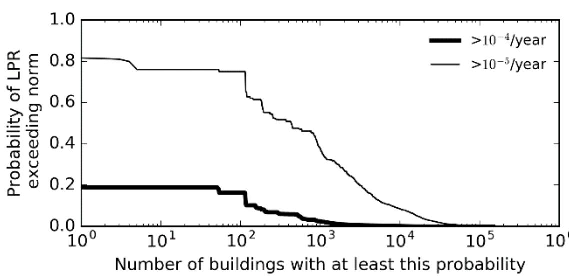
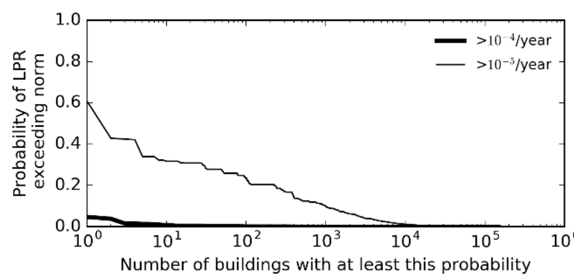
Hazard Map for the period 2023 – 2027.

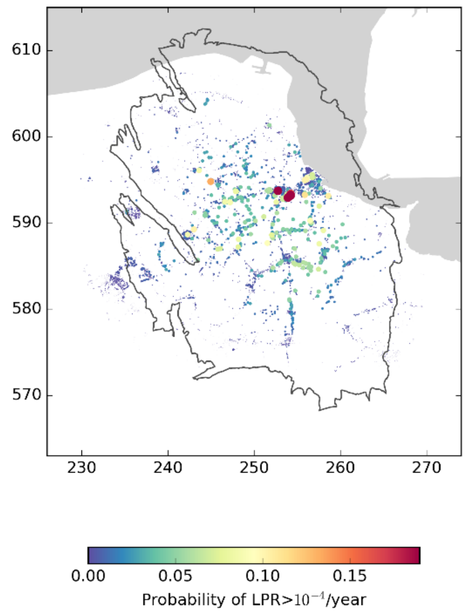


Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.

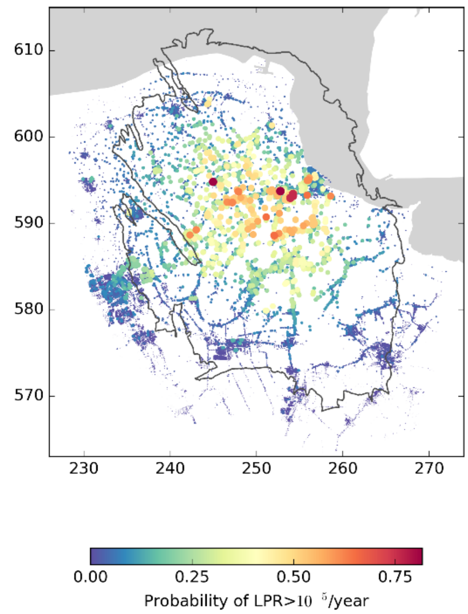


Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.

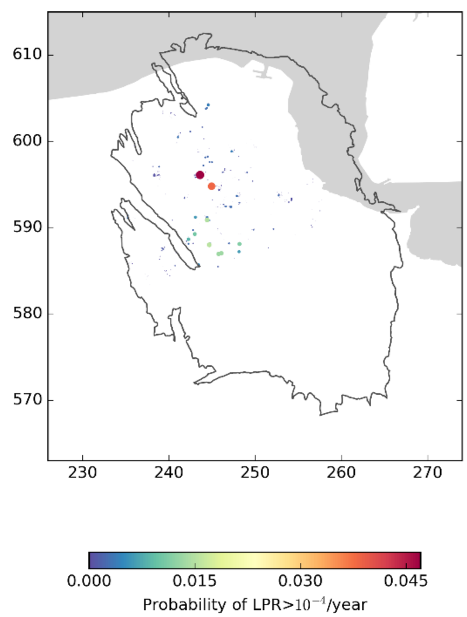
	
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.	Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.
	
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.	Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



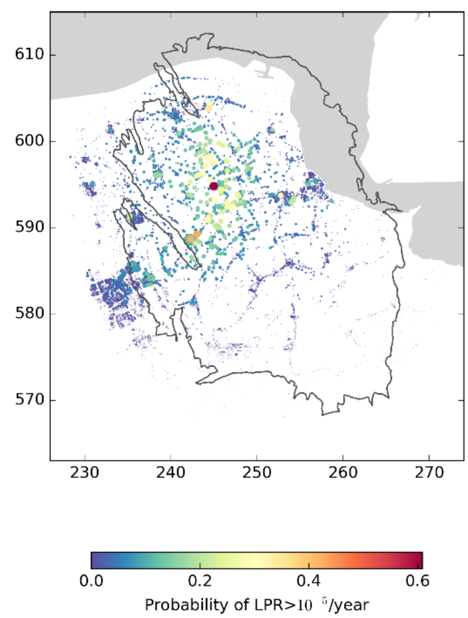
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

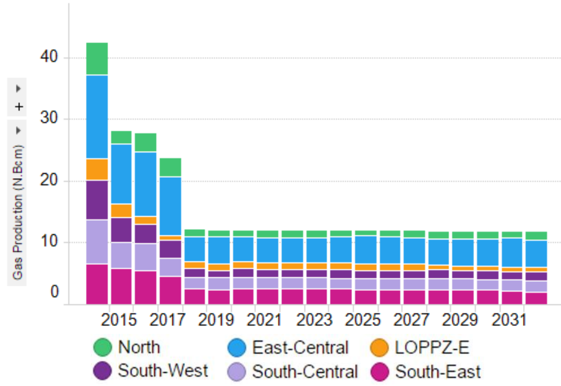


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

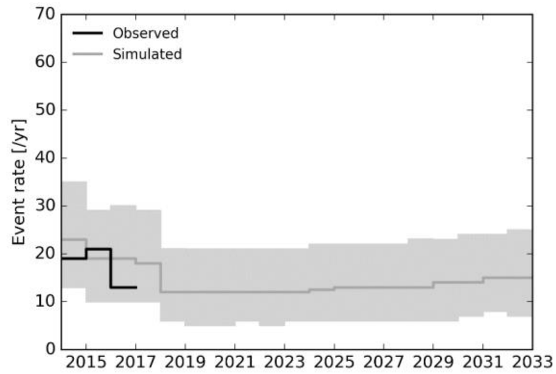


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

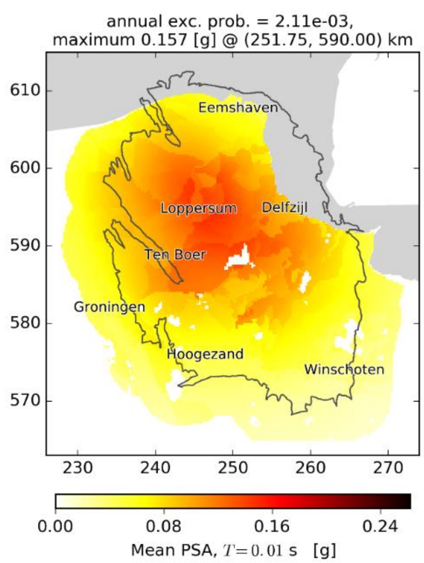
T4 - Immediate reduction to 12 N.Bcm per annum at 1/1/2018, imposed production distribution



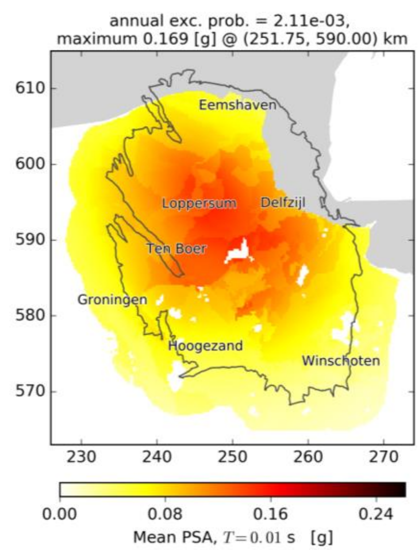
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



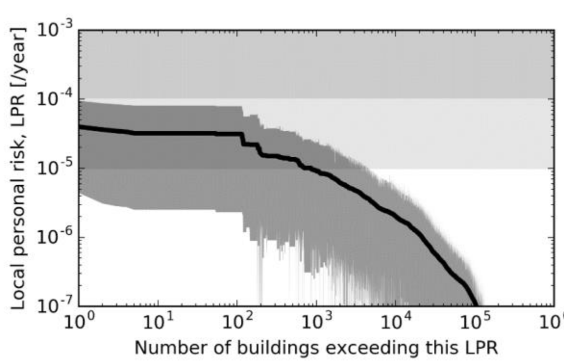
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



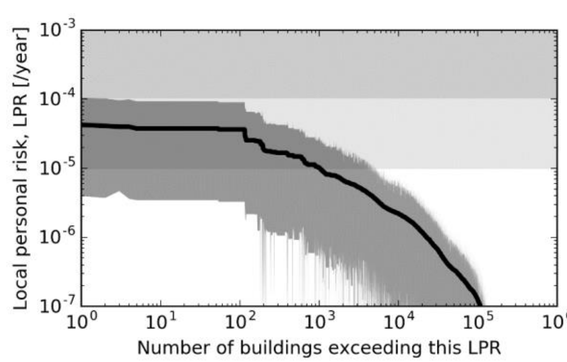
Hazard Map for the period 2018 – 2022.



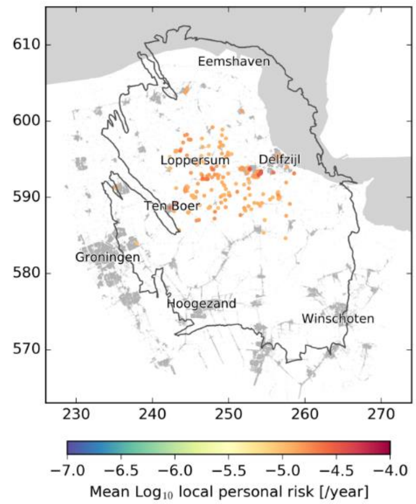
Hazard Map for the period 2023 – 2027.



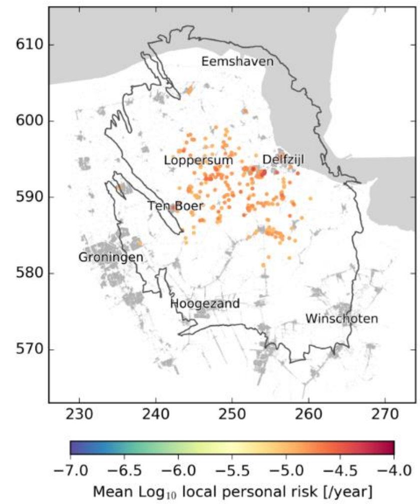
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



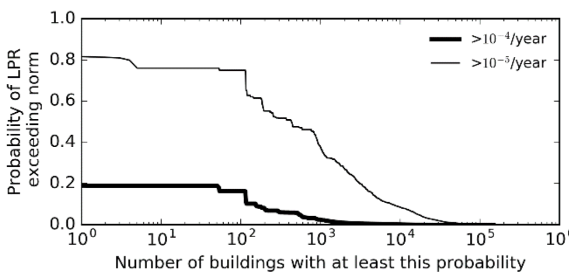
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



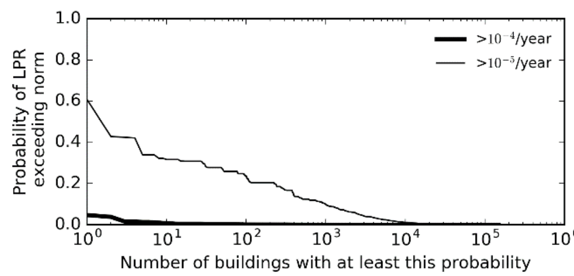
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



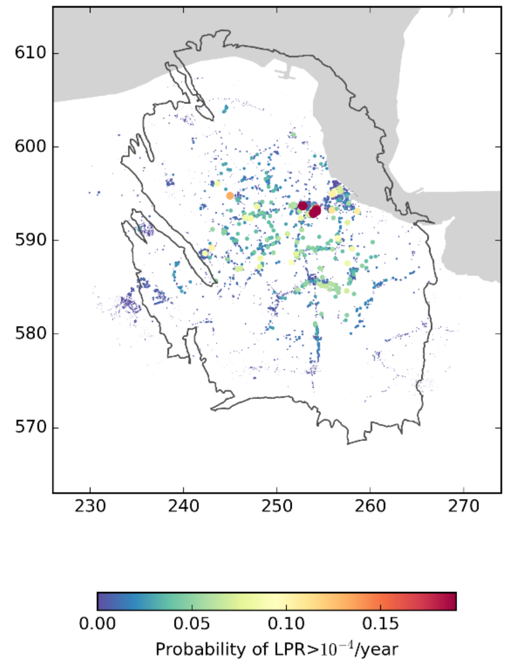
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



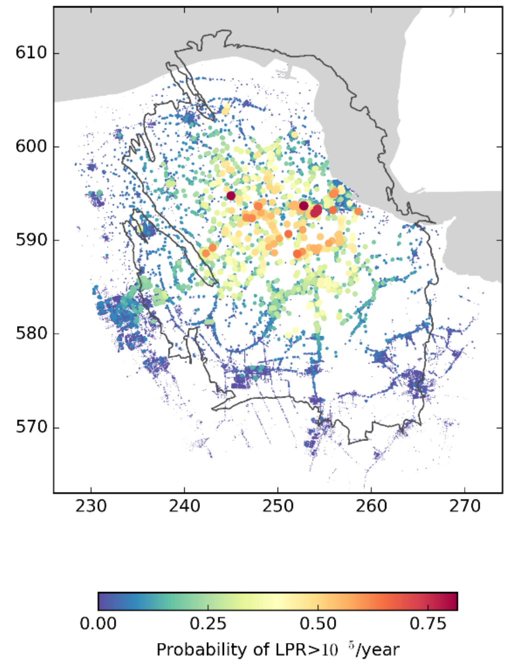
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



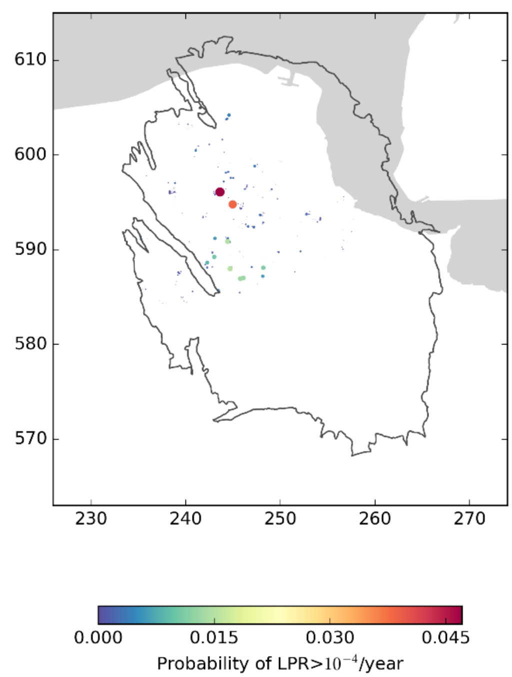
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



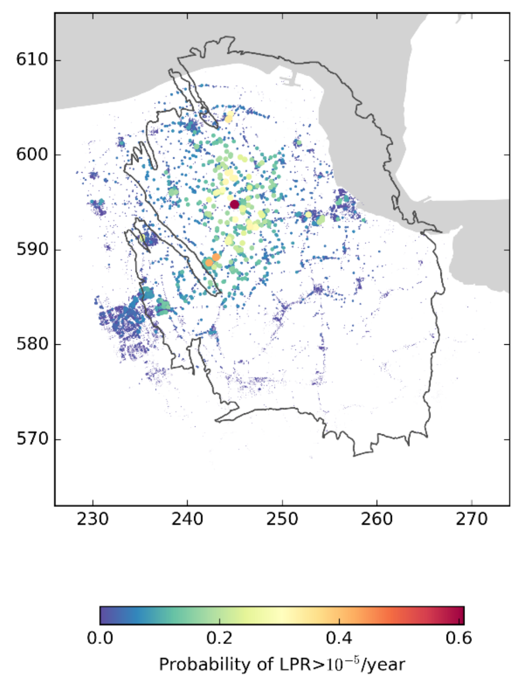
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

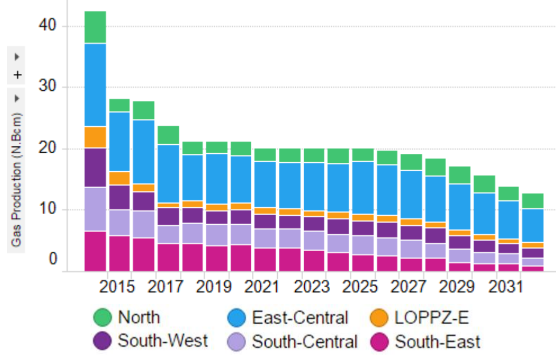


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

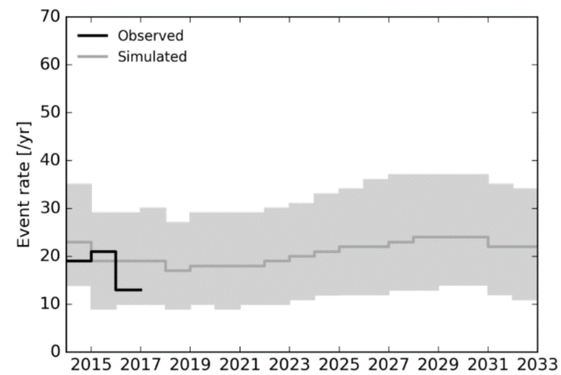


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

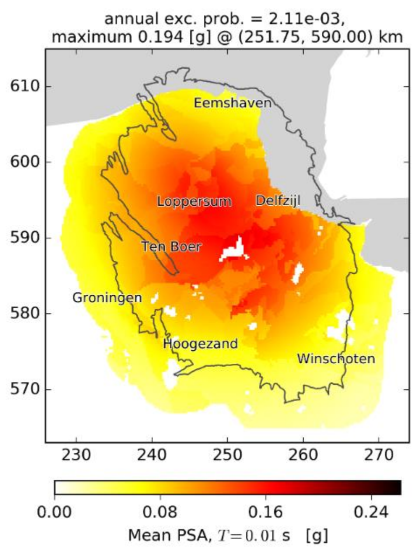
D1a – Production as per Regeerakkoord 2017, imposed production distribution, NFA



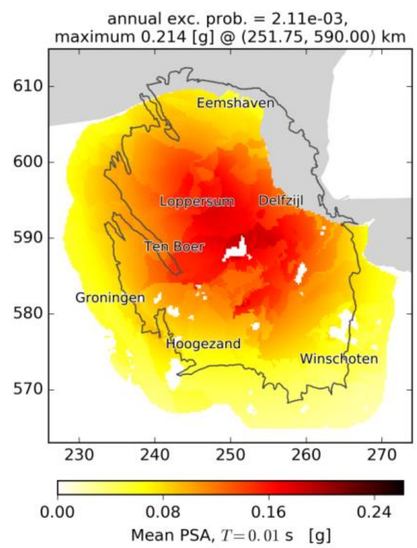
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



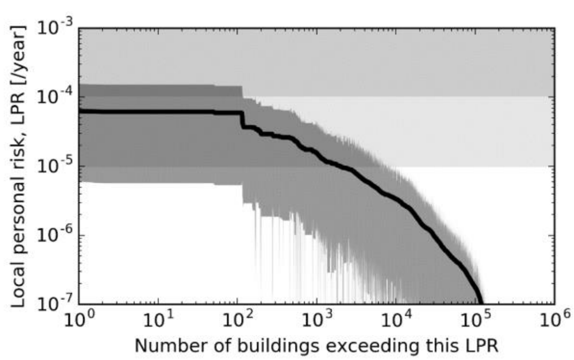
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



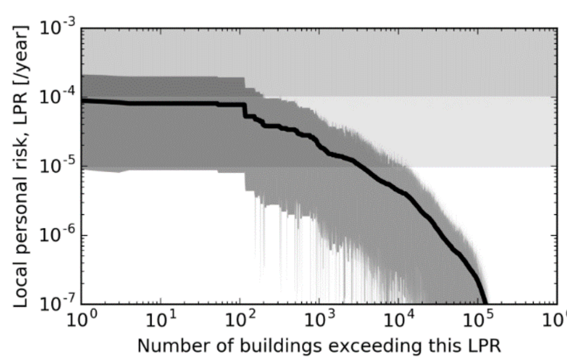
Hazard Map for the period 2018 – 2022.



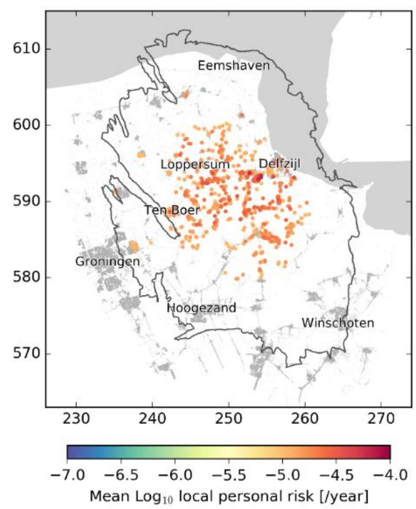
Hazard Map for the period 2023 – 2027.



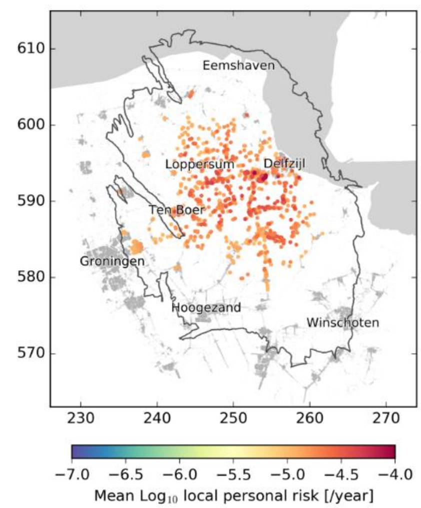
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



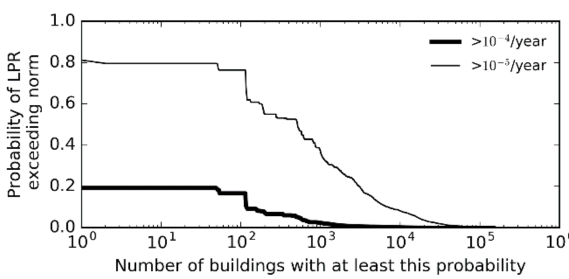
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



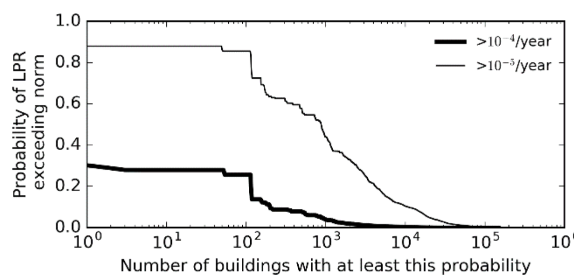
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



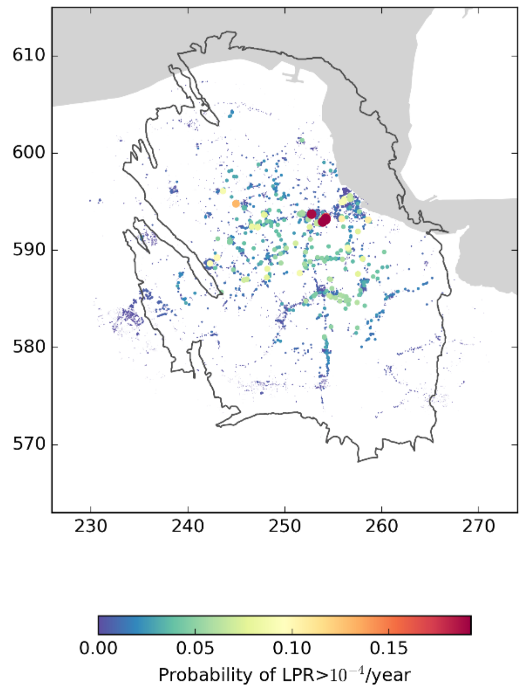
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



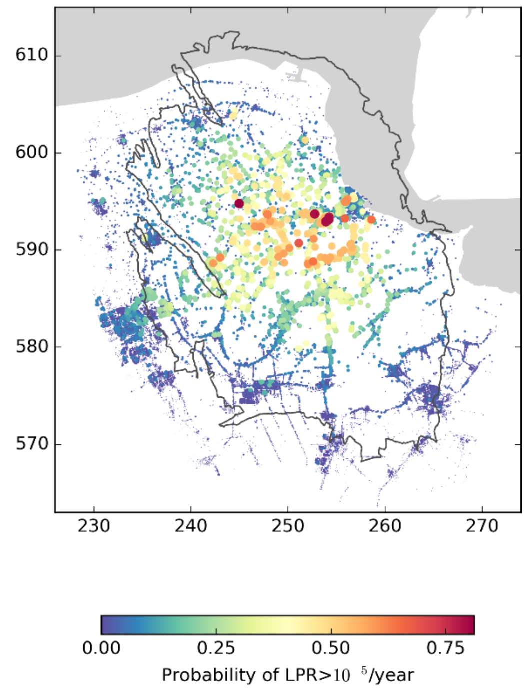
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



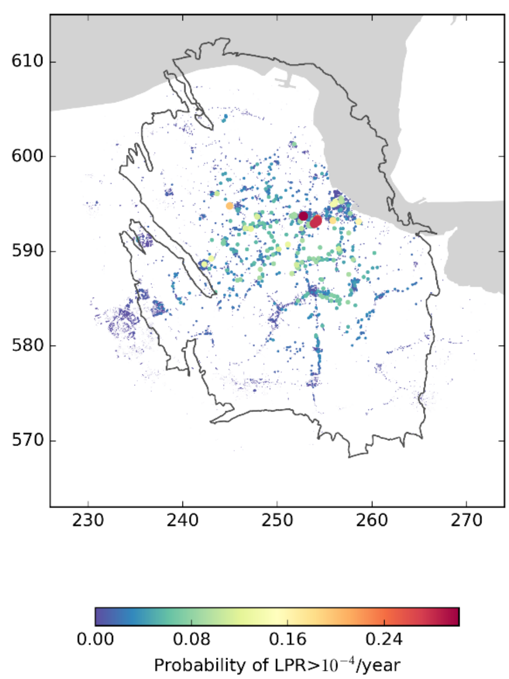
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



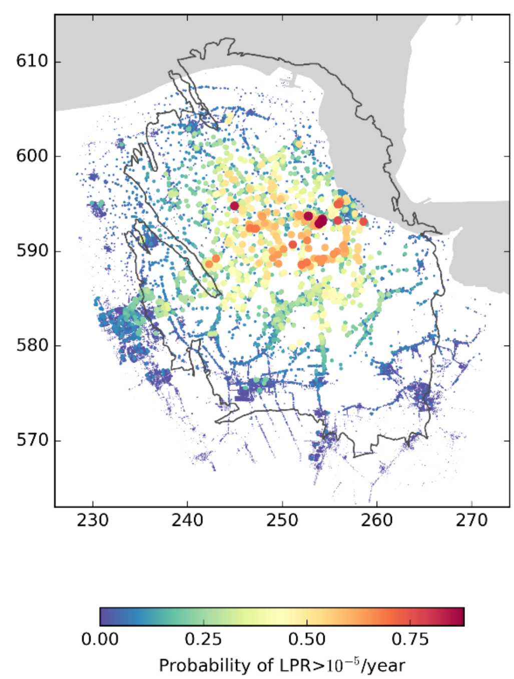
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

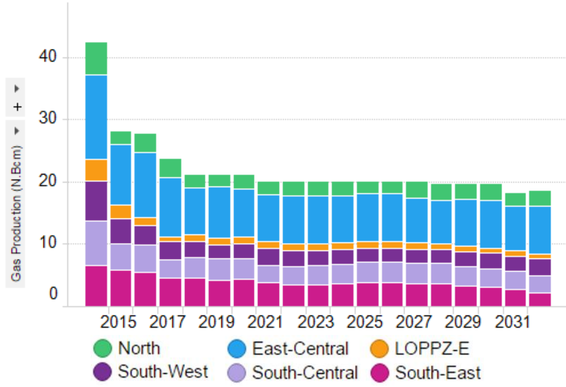


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

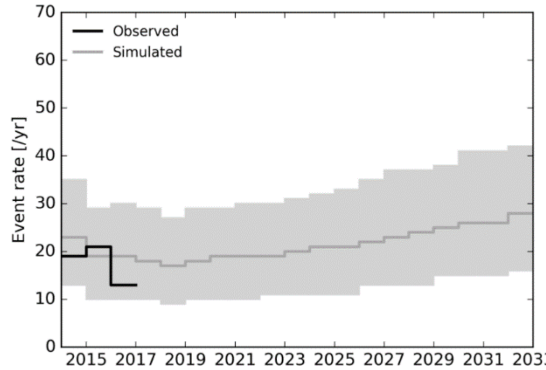


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

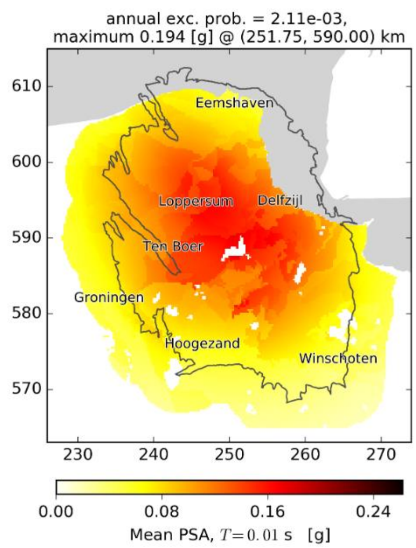
D1b – Production per Regeerakkoord 2017, imposed production distribution, additional compression



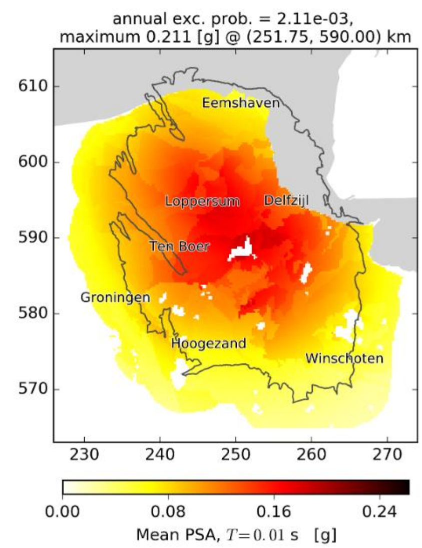
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



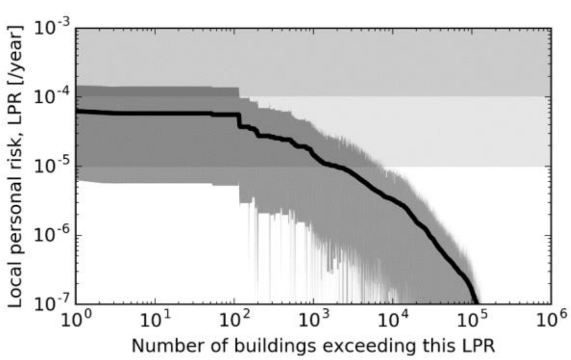
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



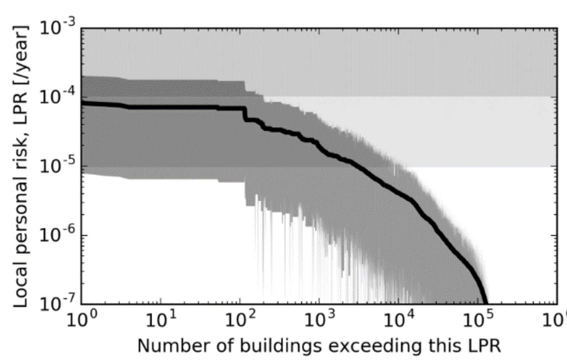
Hazard Map for the period 2018 – 2022.



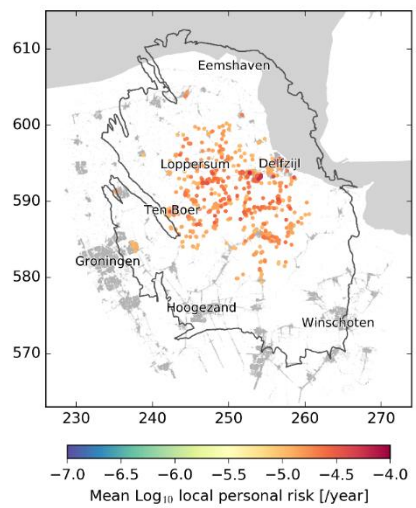
Hazard Map for the period 2023 – 2027.



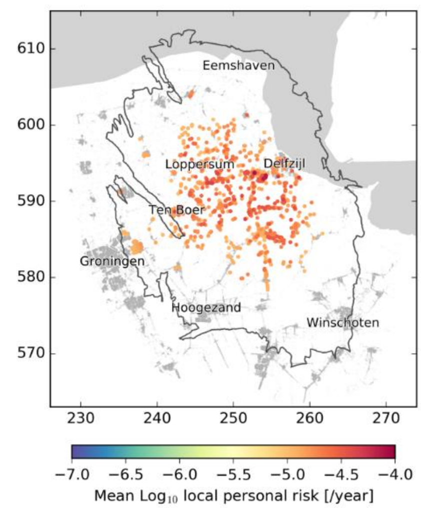
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



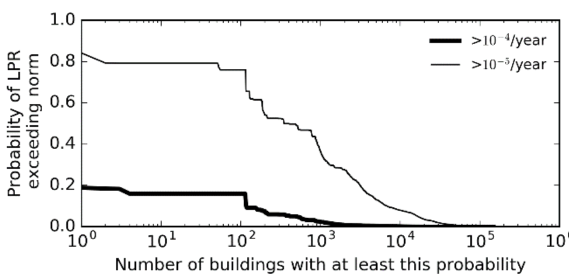
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



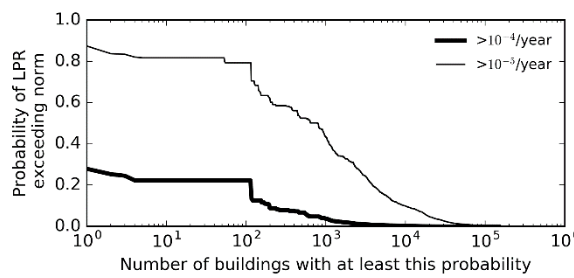
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



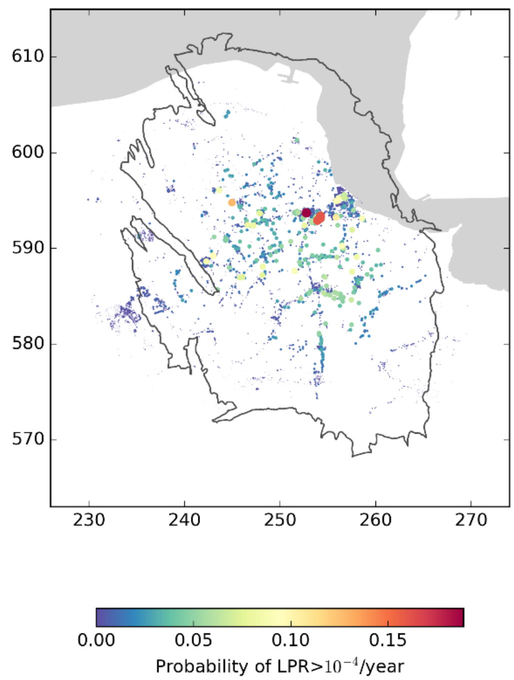
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.

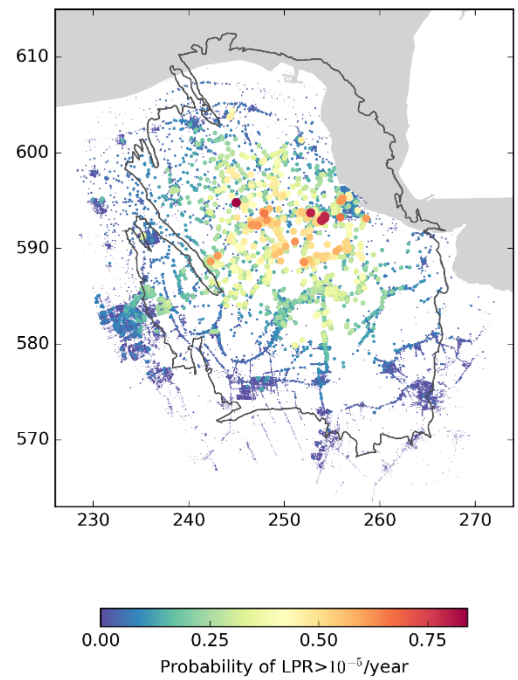


Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



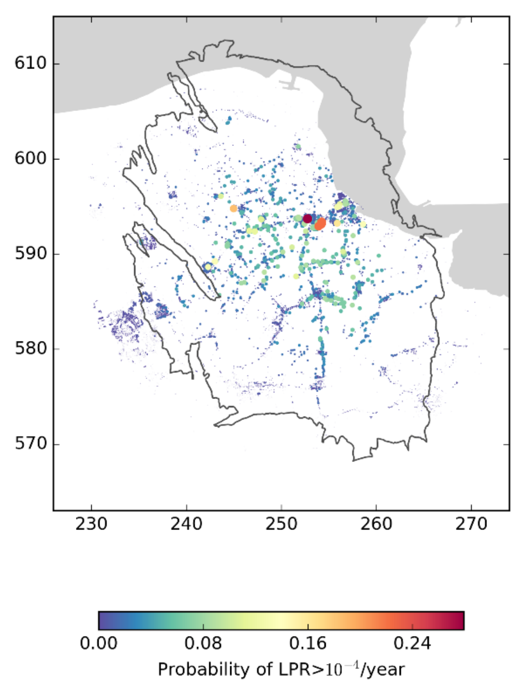
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.

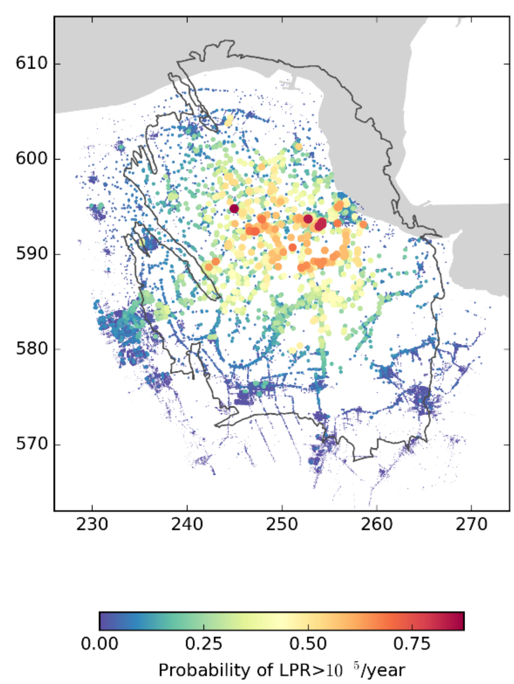




Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

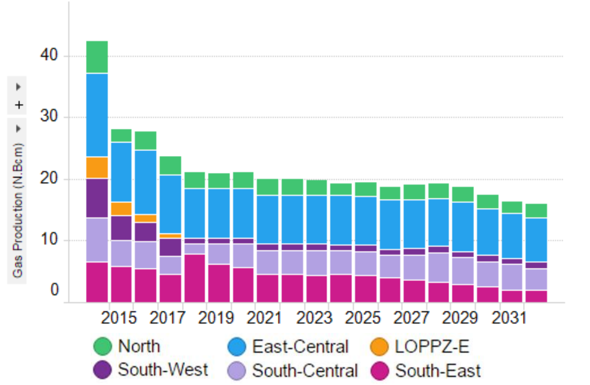




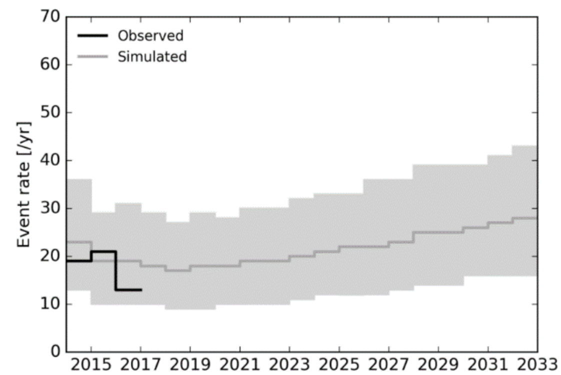
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

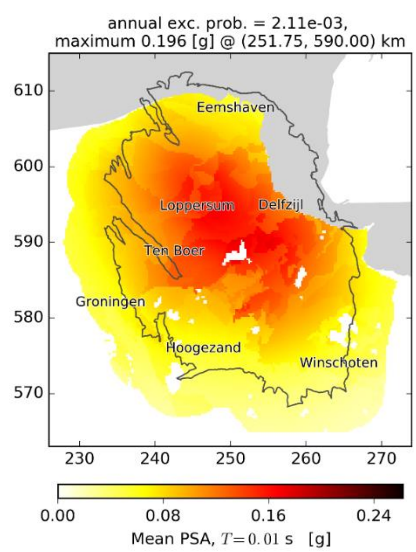
D1c – Production per Regeerakkoord 2017, optimized production distribution, additional compression



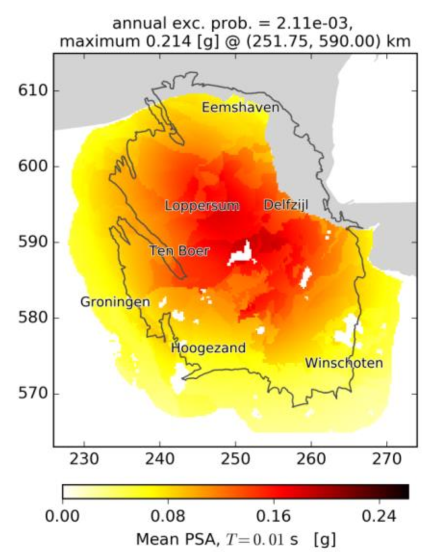
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



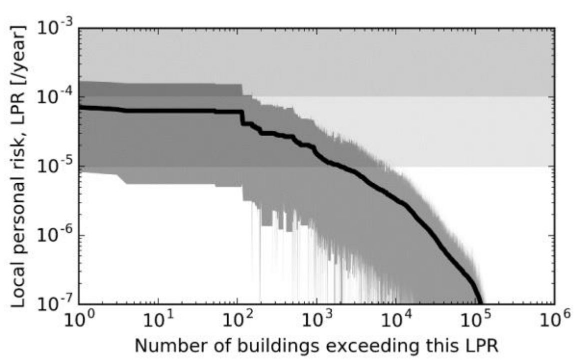
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



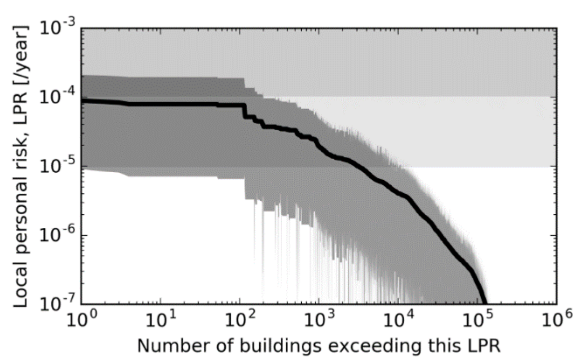
Hazard Map for the period 2018 – 2022.



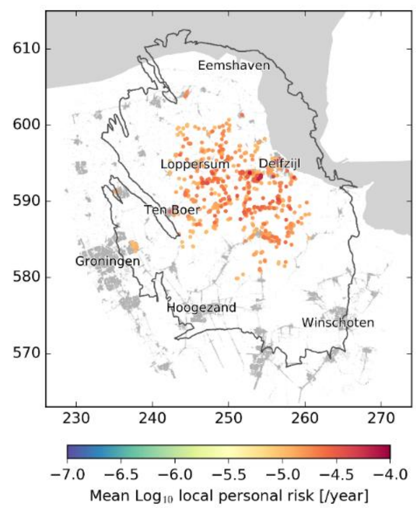
Hazard Map for the period 2023 – 2027.



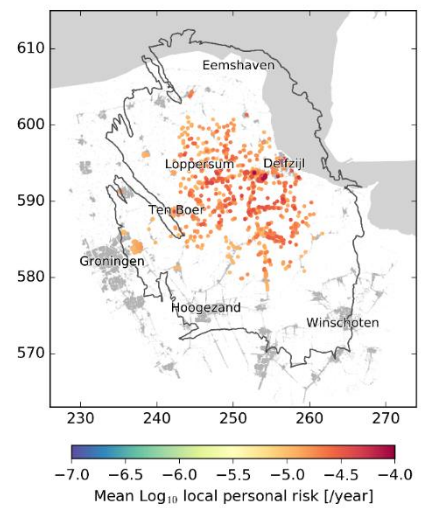
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



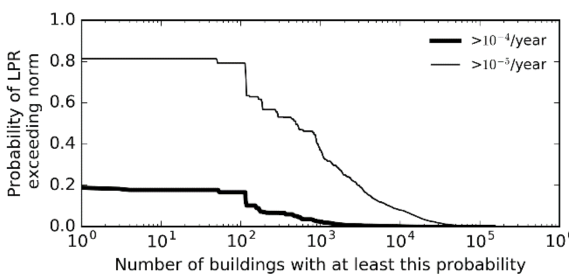
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



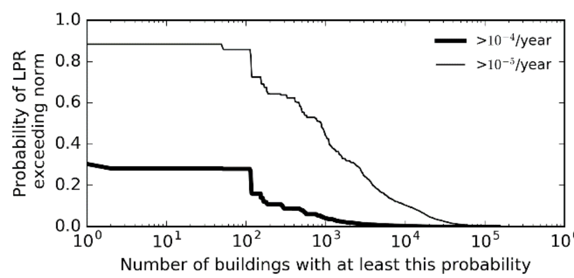
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



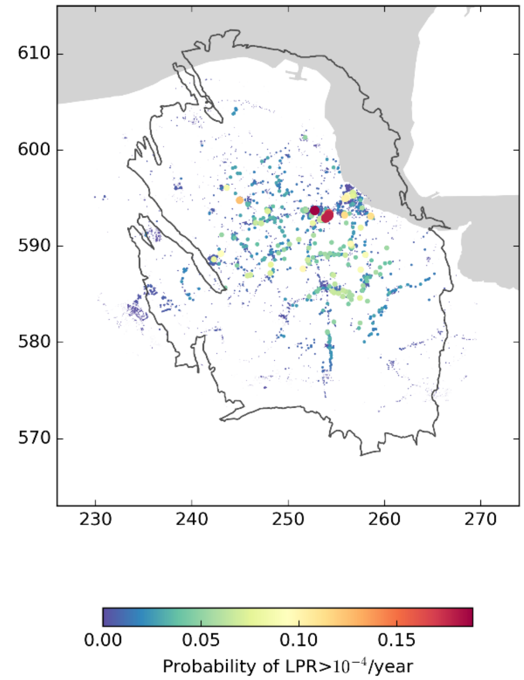
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.

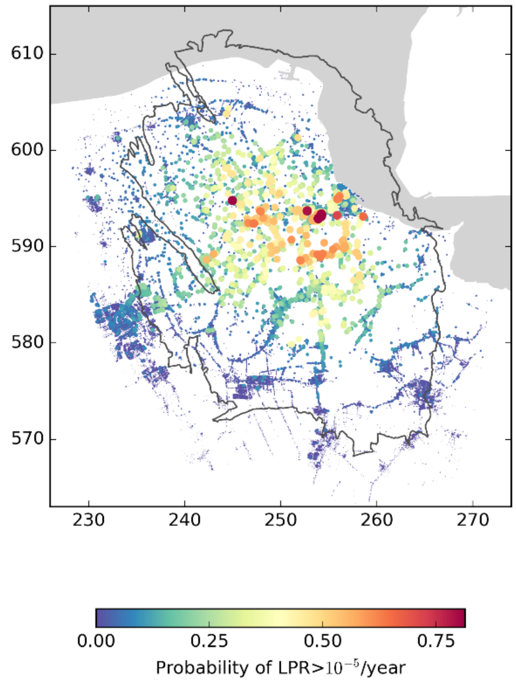


Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.

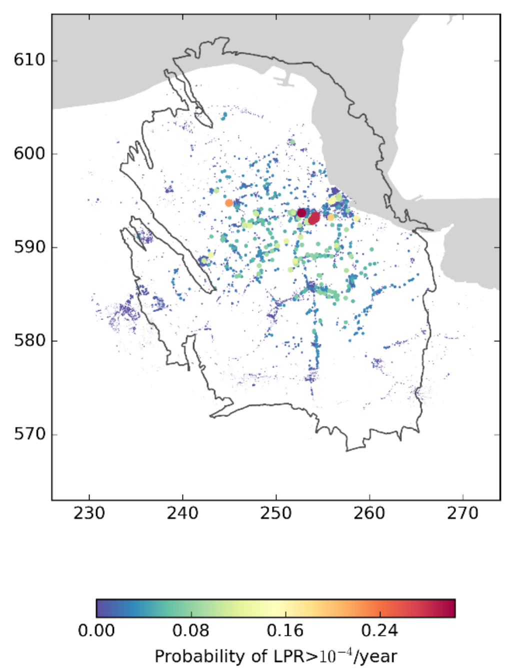


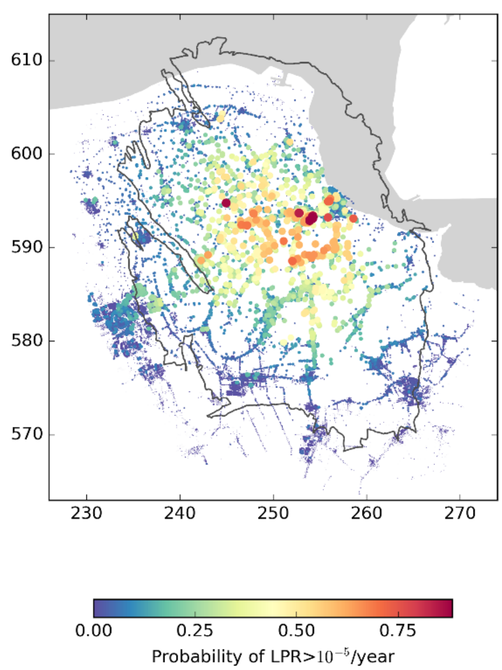
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.





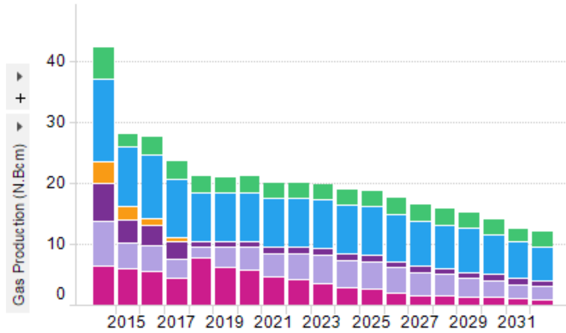
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.	Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



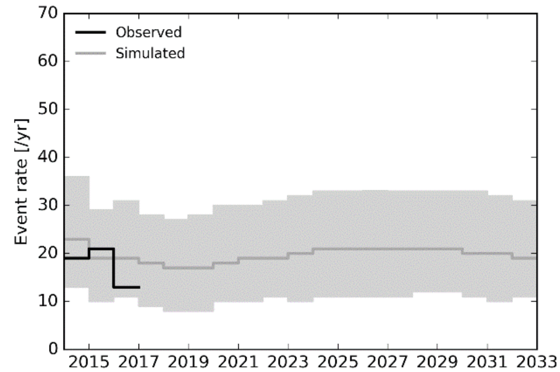


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.	Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

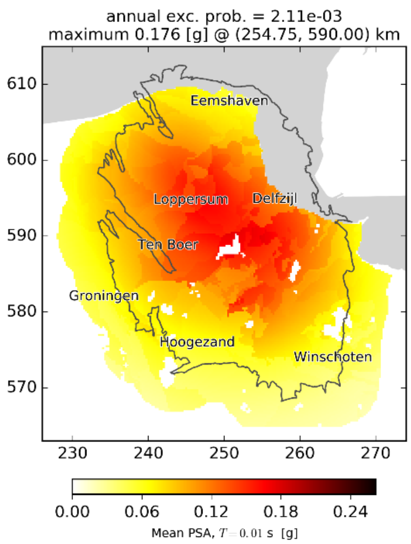
D1d - Regeerakkoord / OP17



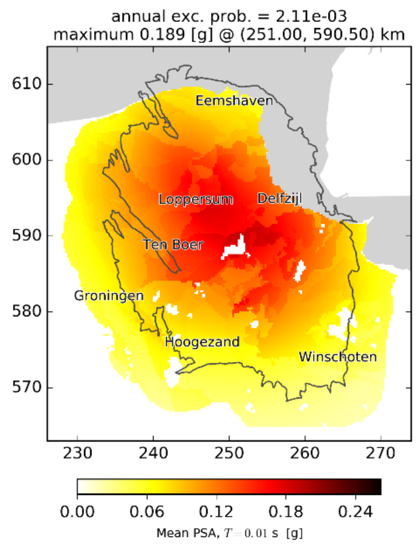
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



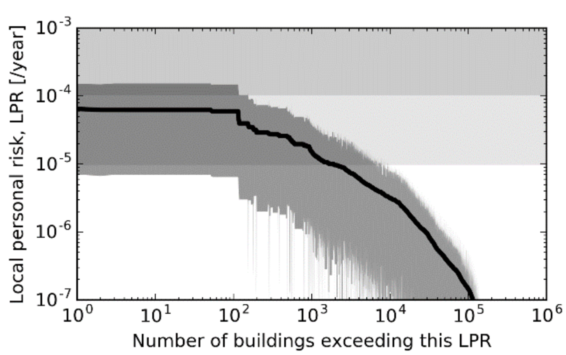
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



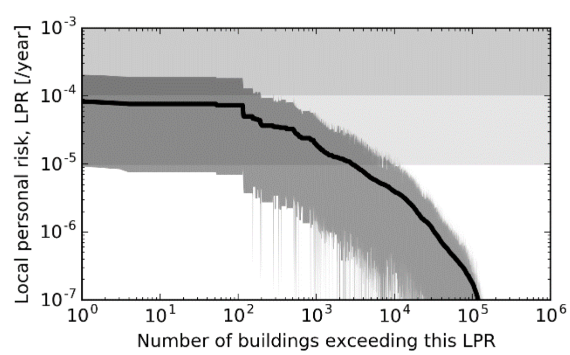
Hazard Map for the period 2018 – 2022.



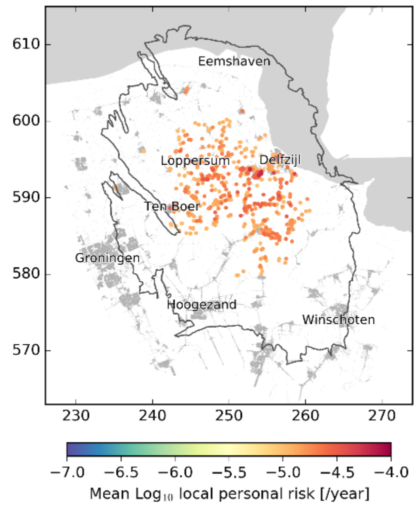
Hazard Map for the period 2023 – 2027.



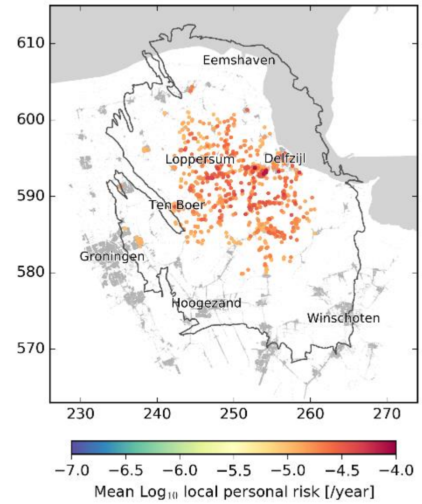
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



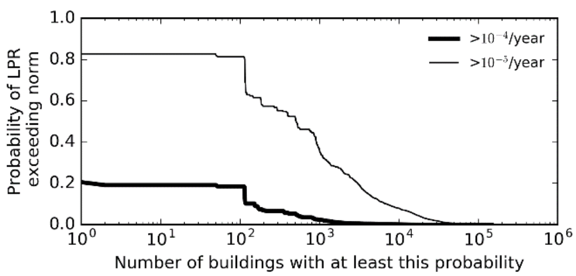
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



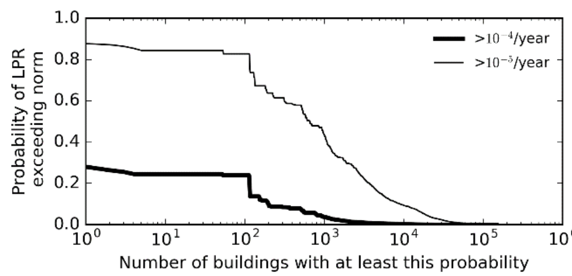
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



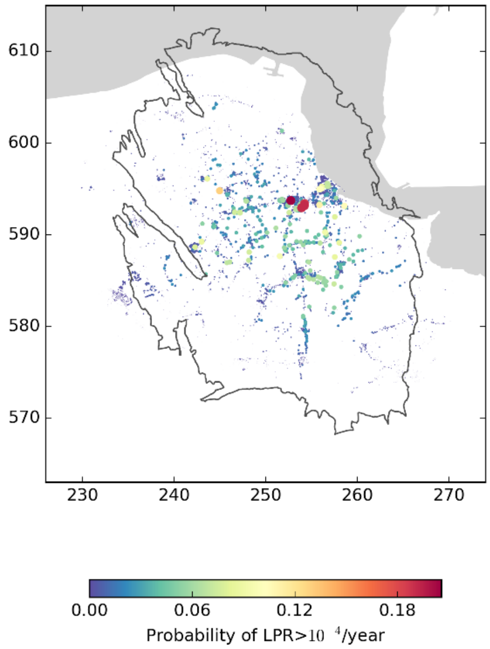
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



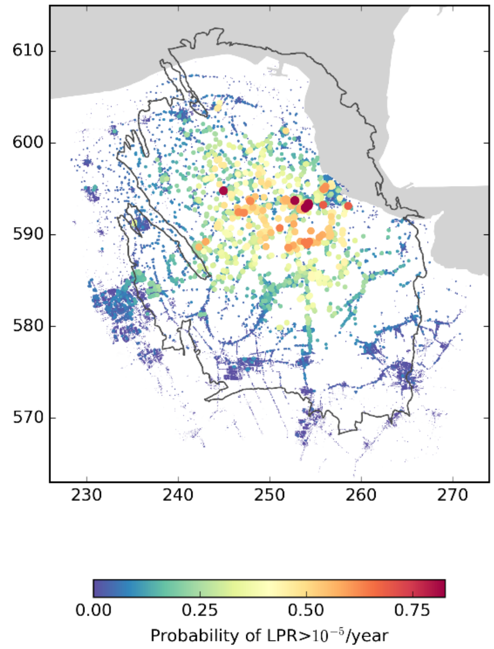
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



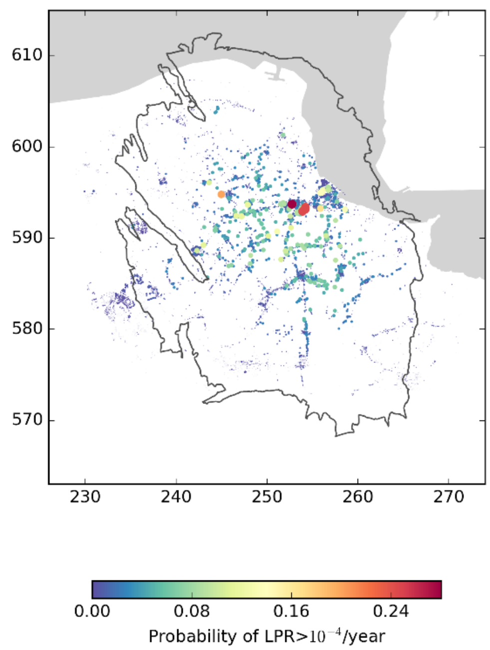
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



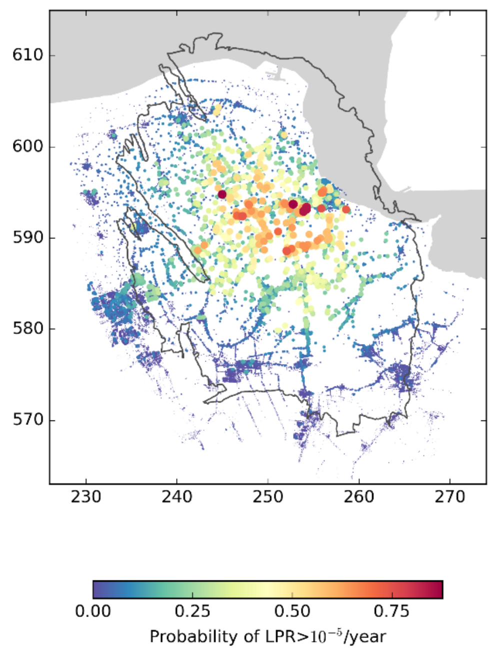
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

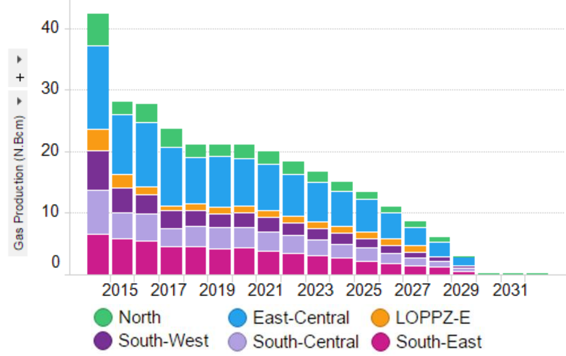


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

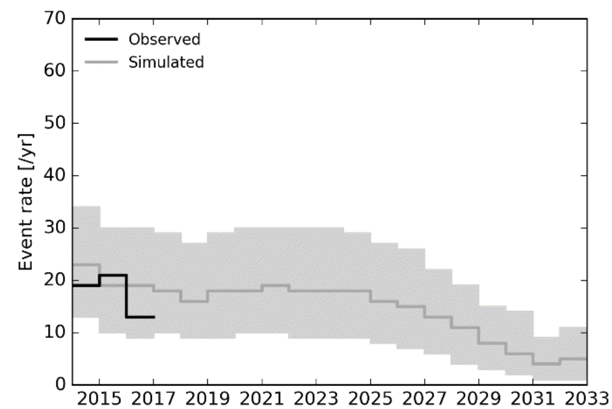


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

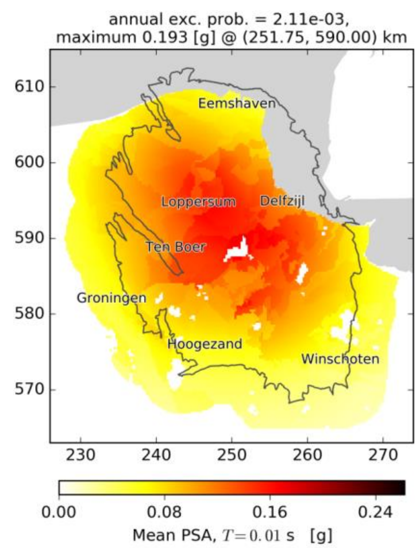
D2a – Max Import scenario at 85% N2 utilization, imposed production distribution



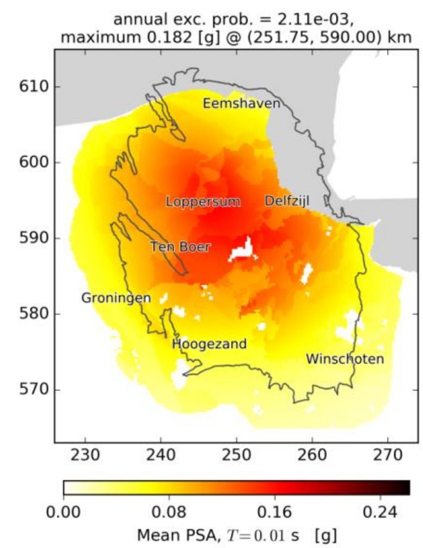
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



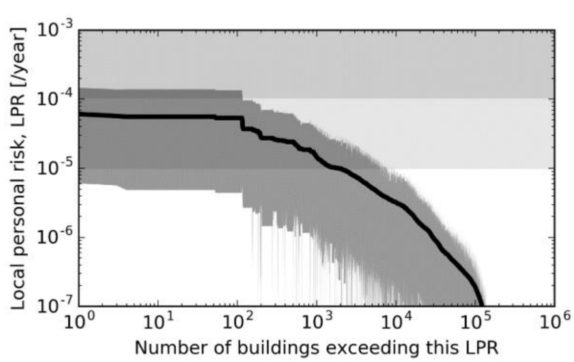
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



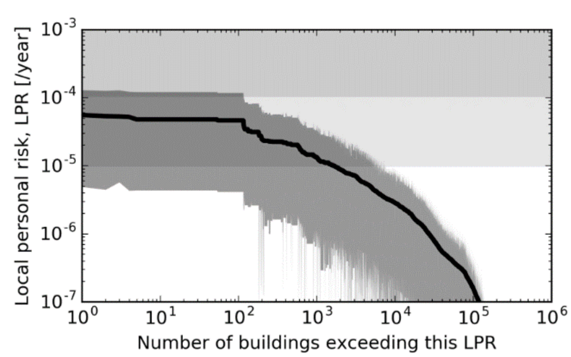
Hazard Map for the period 2018 – 2022.



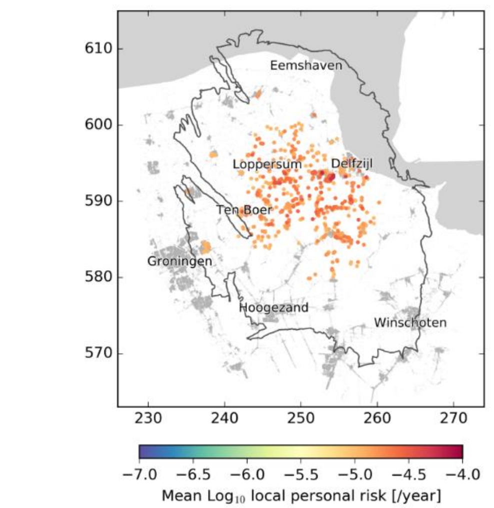
Hazard Map for the period 2023 – 2027.



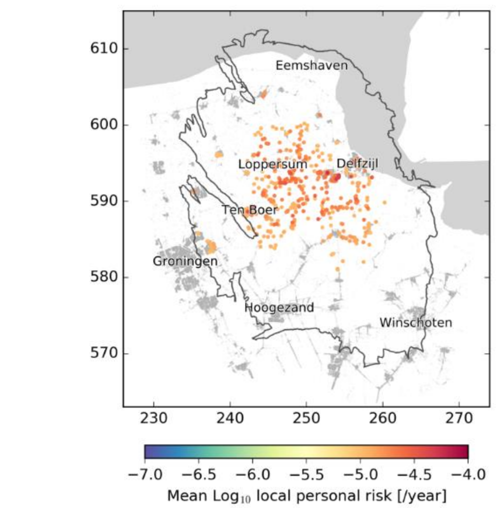
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



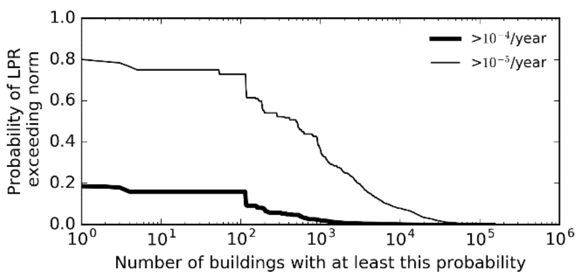
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



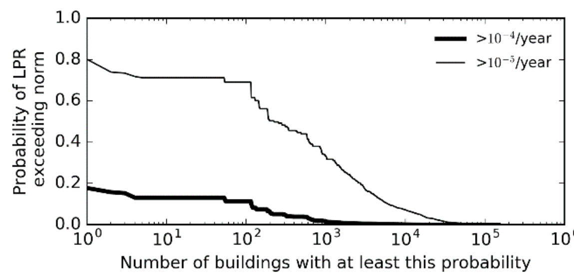
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



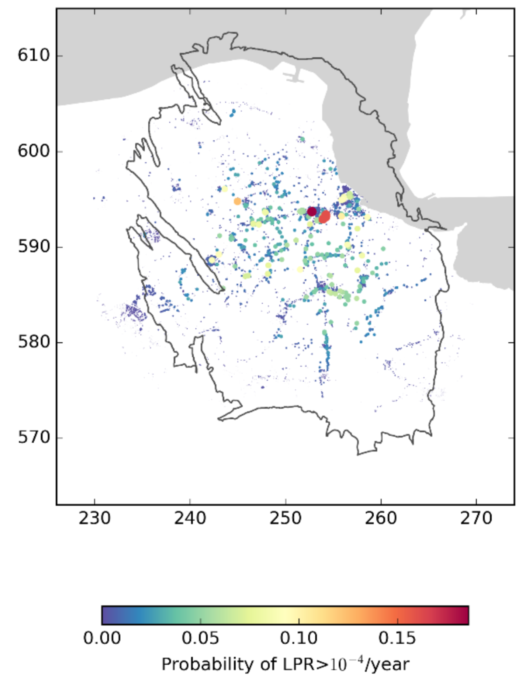
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



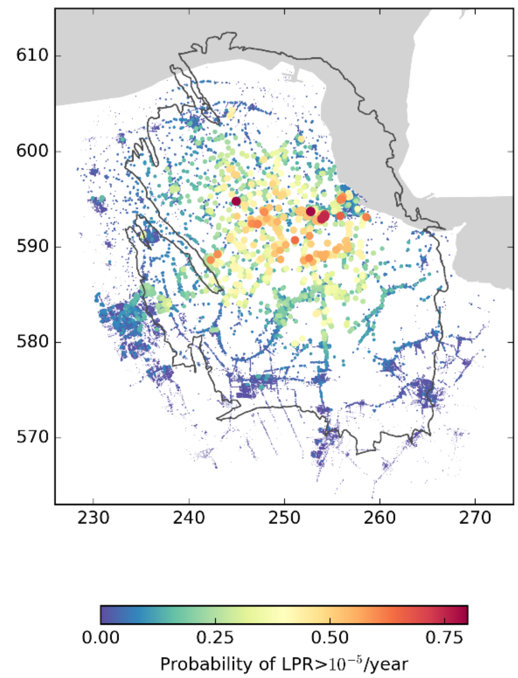
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



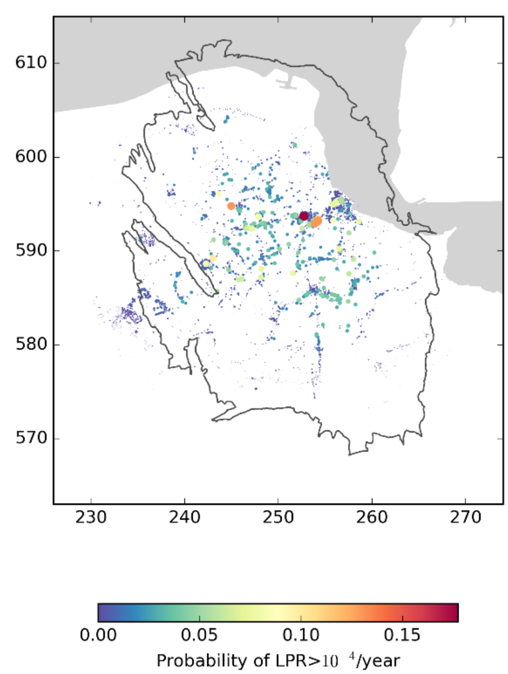
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



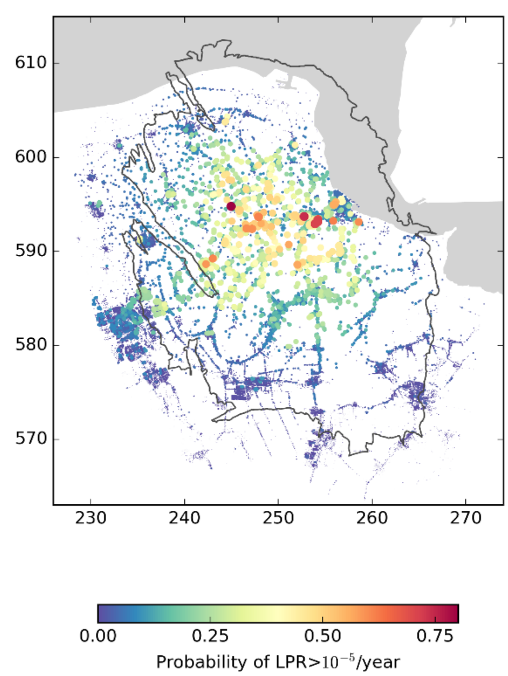
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

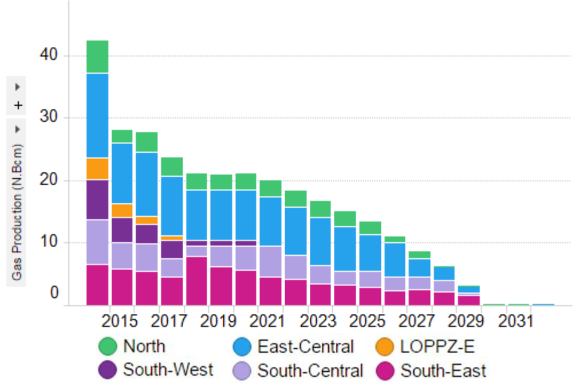


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

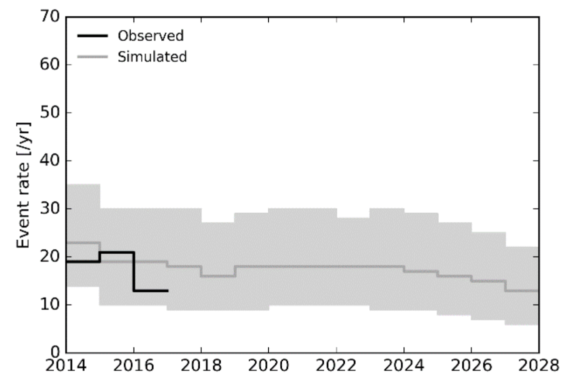


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

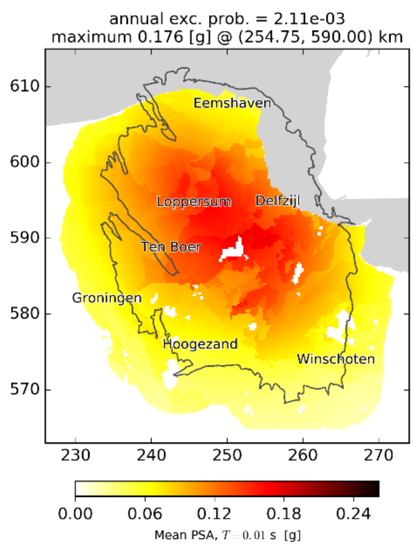
D2b – Max Import scenario at 85% N2 utilization, imposed production distribution



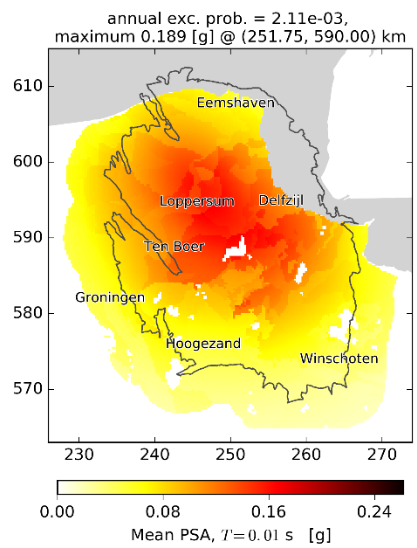
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



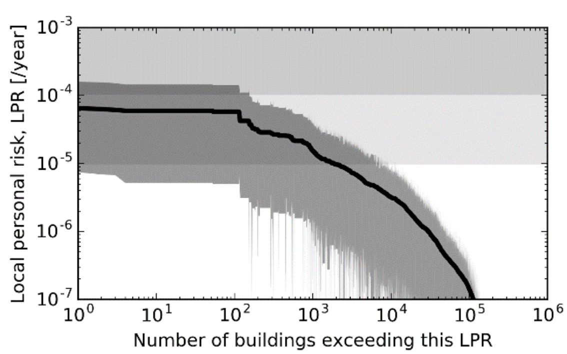
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



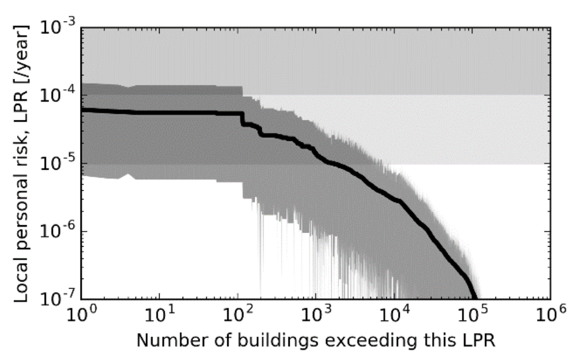
Hazard Map for the period 2018 – 2022.



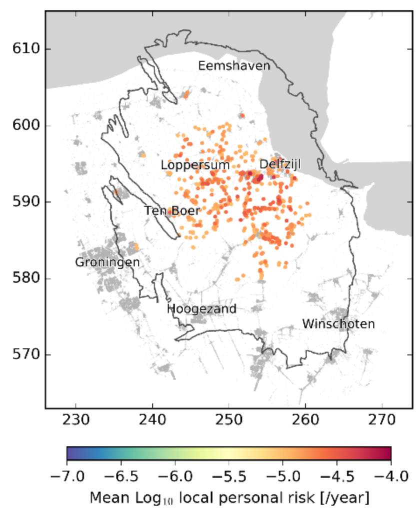
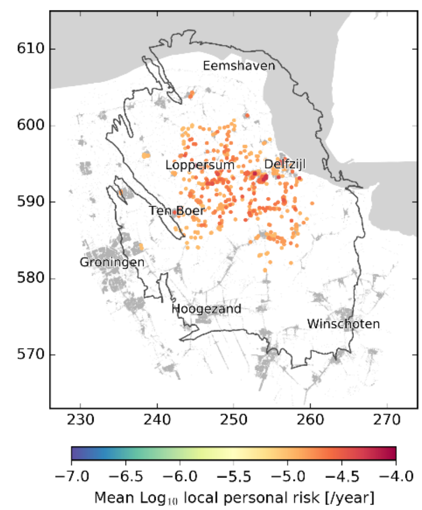
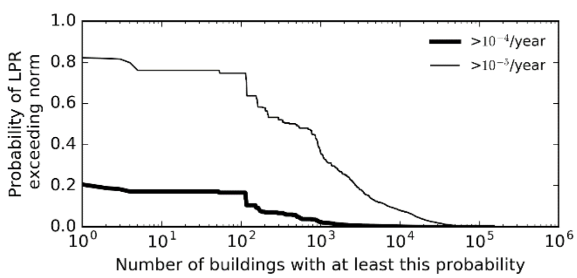
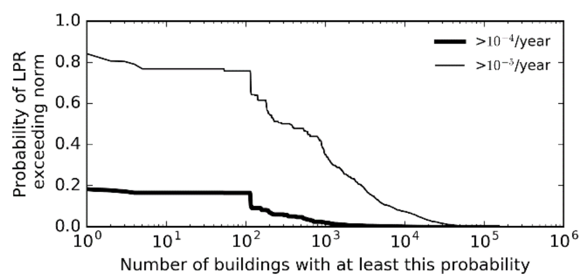
Hazard Map for the period 2023 – 2027.

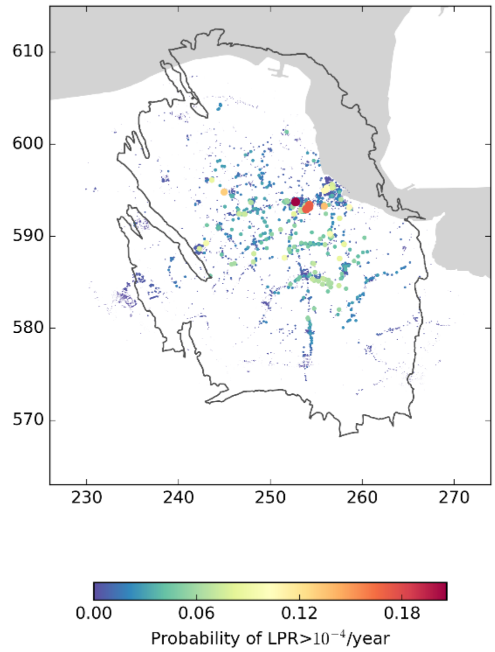


Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.

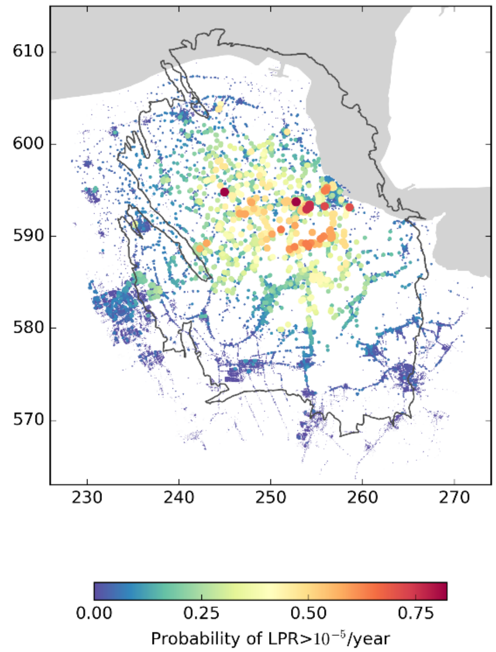


Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.

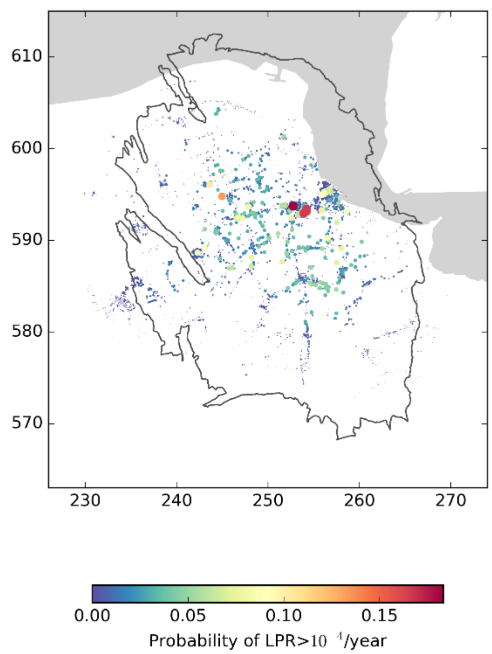
	
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.	Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.
	
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.	Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



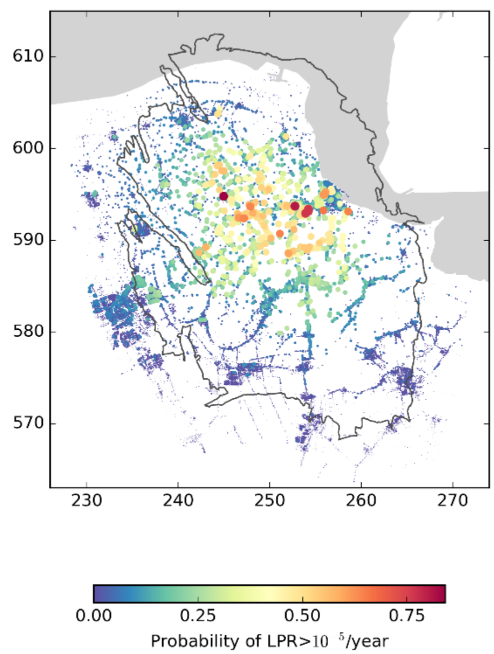
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

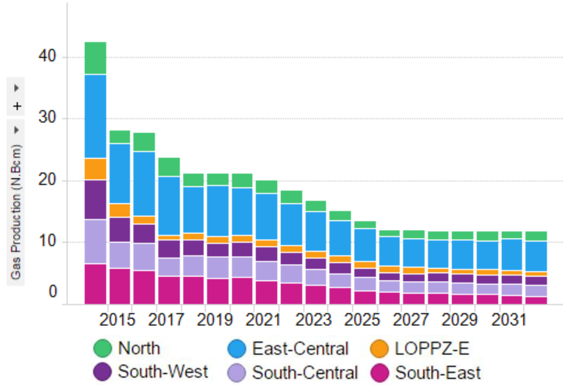


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

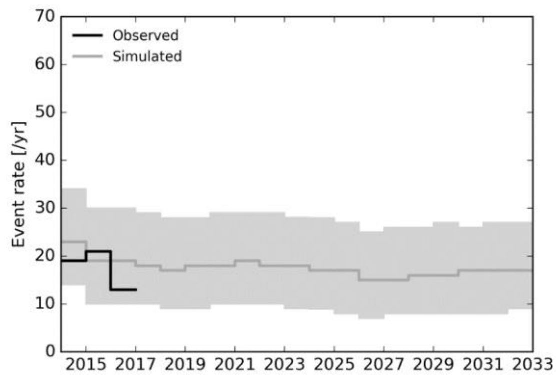


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

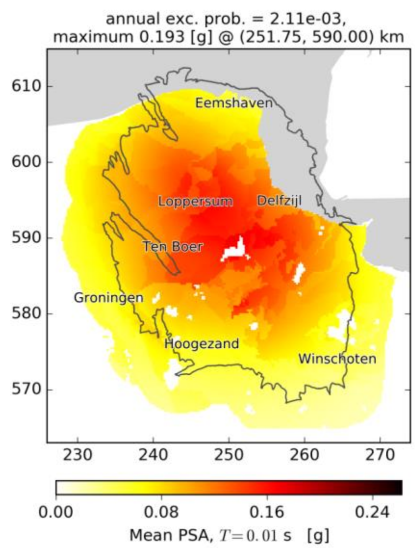
D3a – Max Import scenario with 12 N.Bcm plateau at 85% N2 utilization, imposed production distribution, NFA



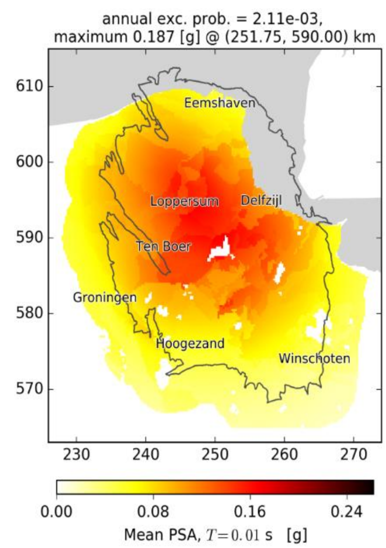
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



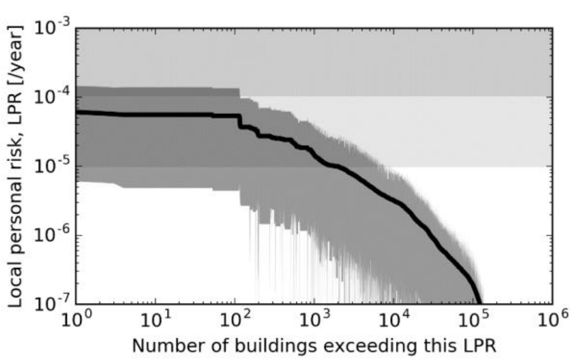
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



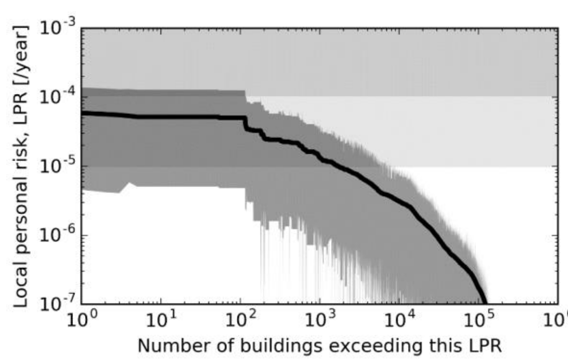
Hazard Map for the period 2018 – 2022.



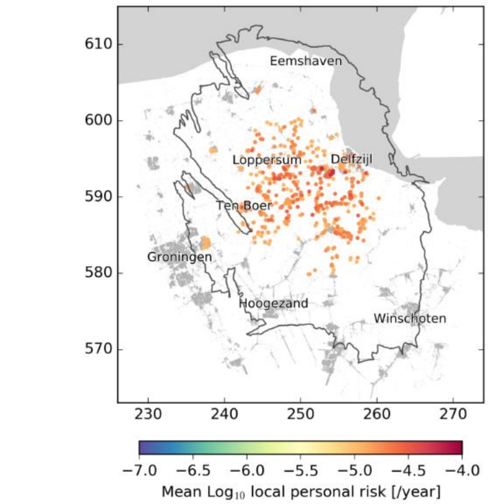
Hazard Map for the period 2023 – 2027.



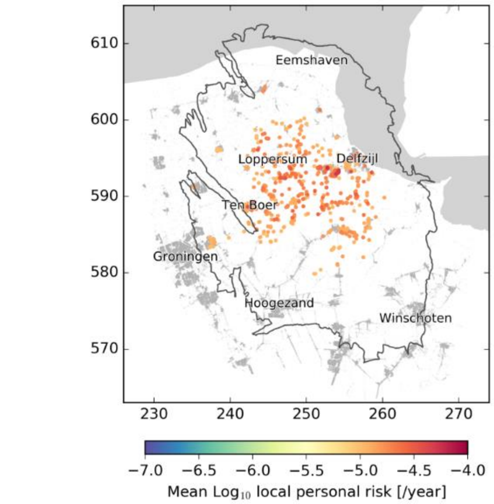
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



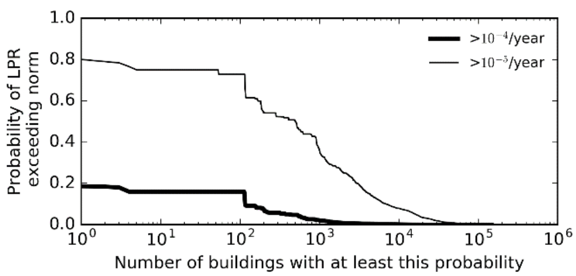
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



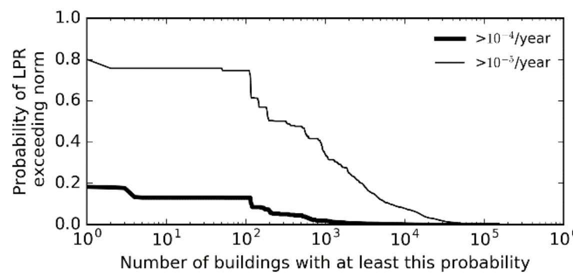
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



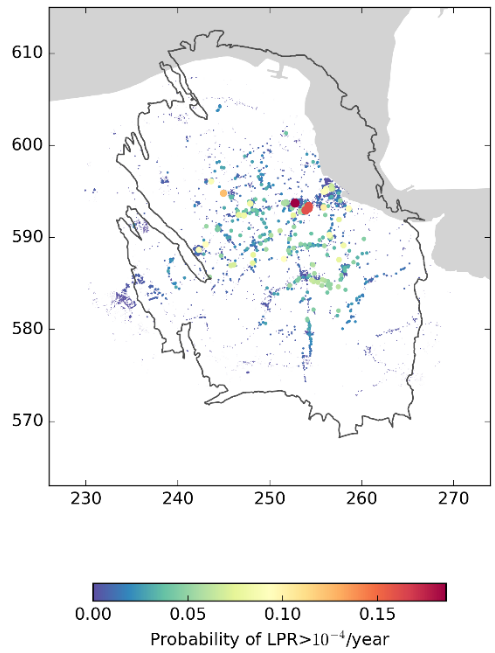
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



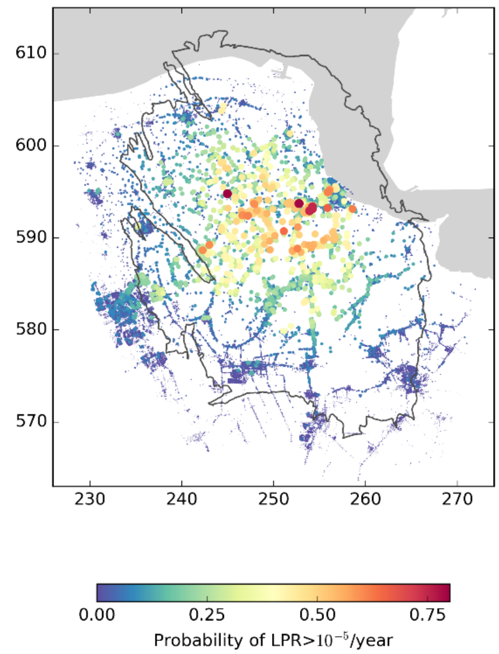
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



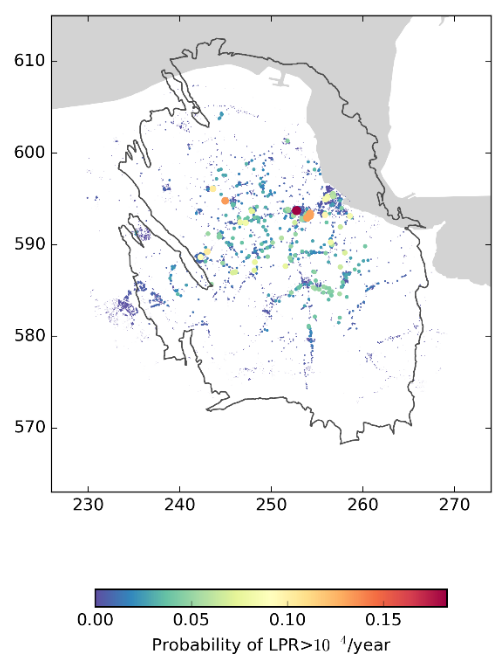
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



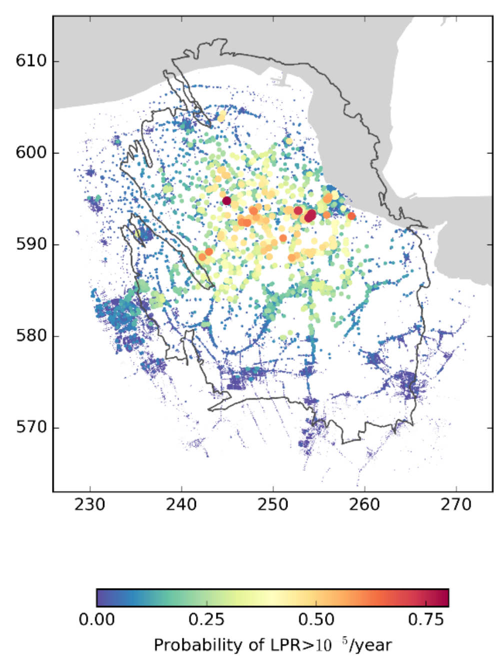
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

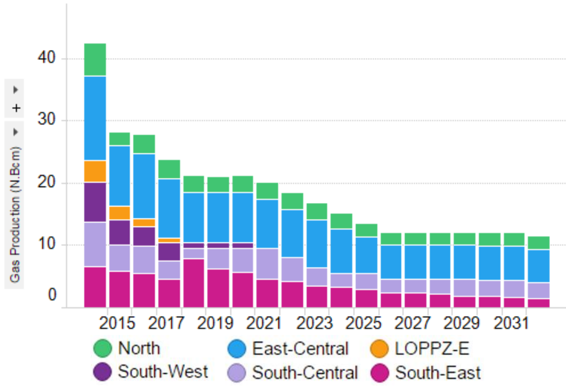


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

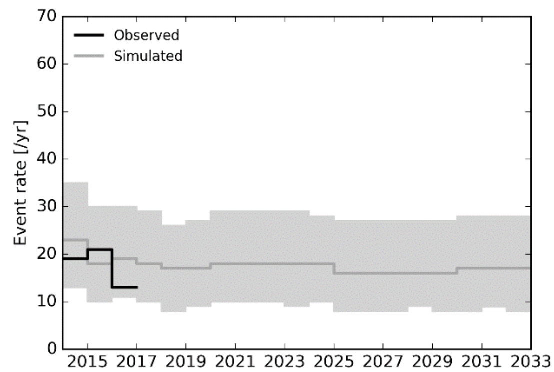


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

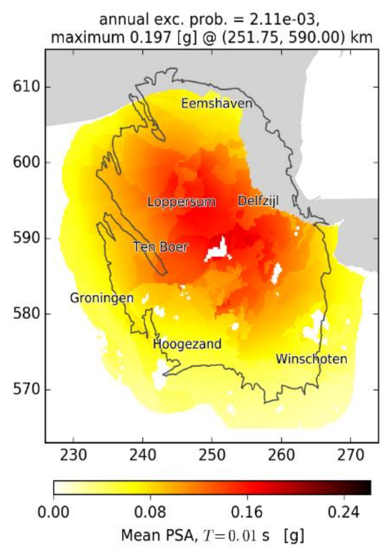
D3b – Max Import scenario with 12 N.Bcm plateau at 85% N2 utilization, optimized production distribution, NFA



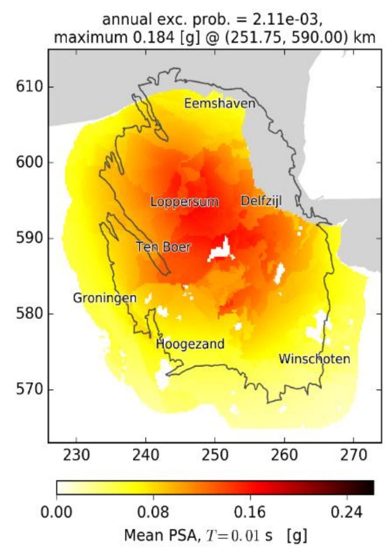
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



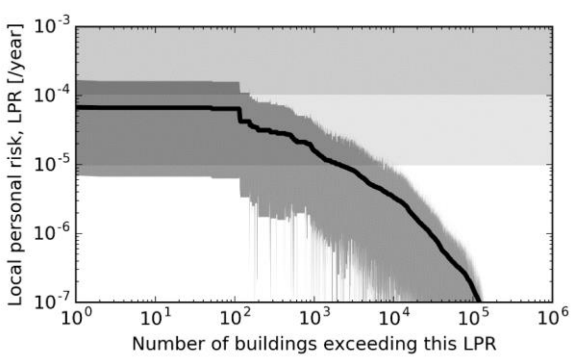
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



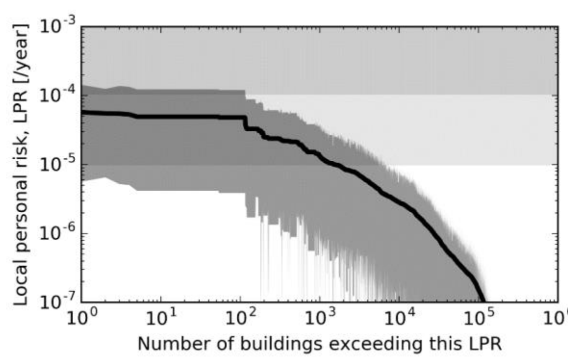
Hazard Map for the period 2018 – 2022.



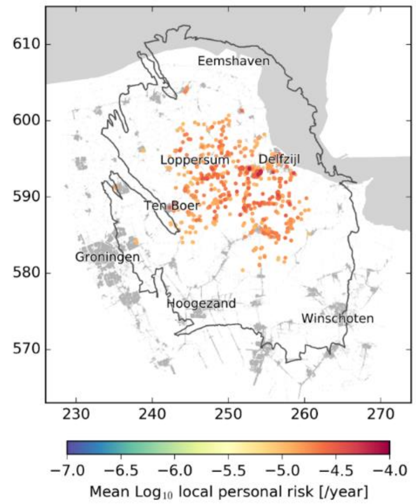
Hazard Map for the period 2023 – 2027.



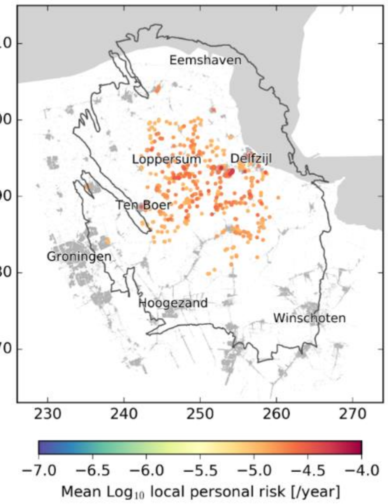
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



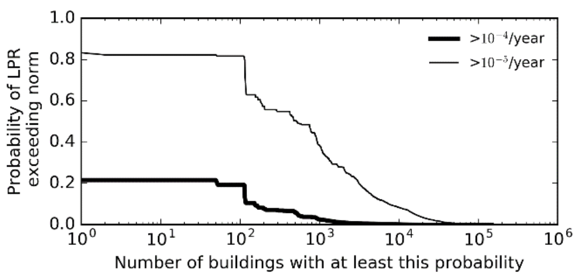
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



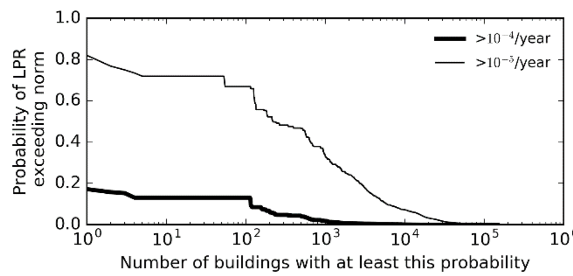
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



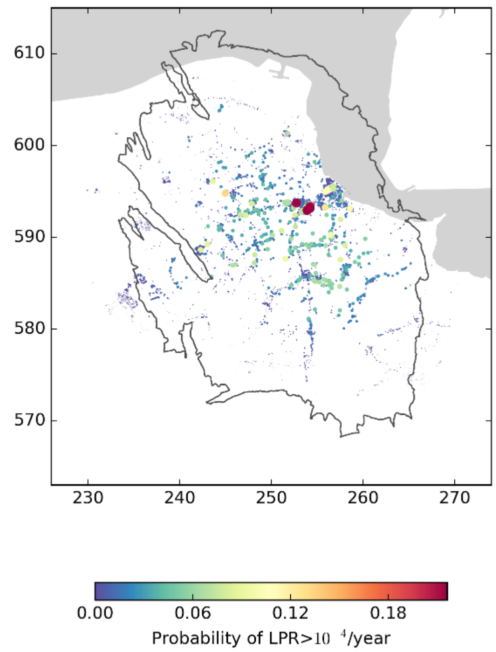
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



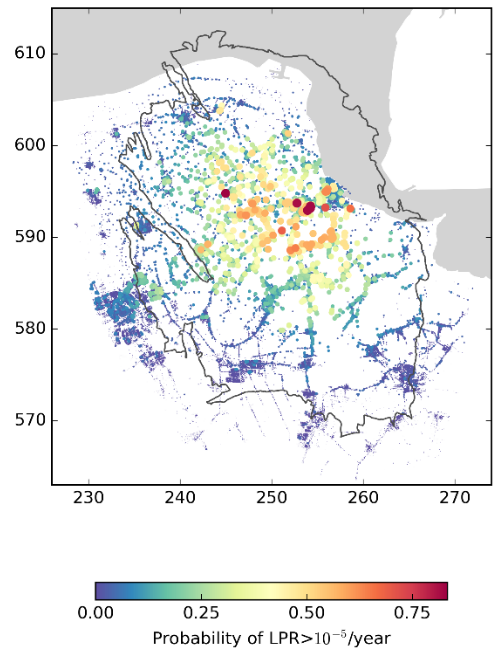
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



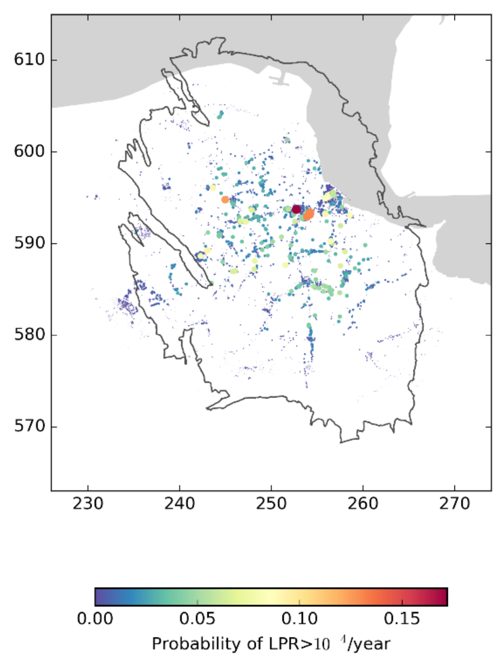
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



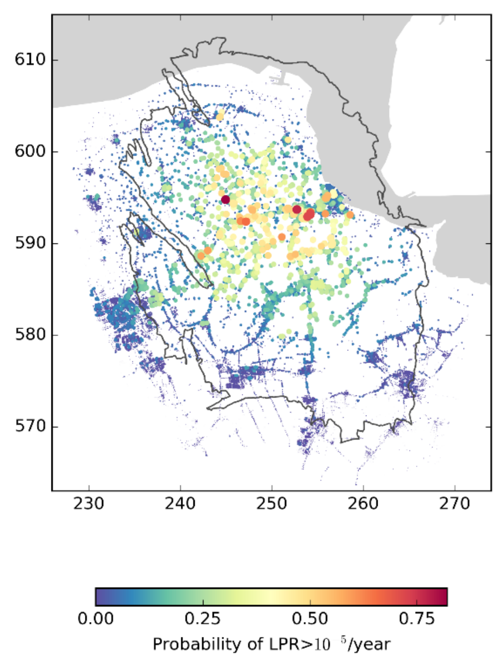
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

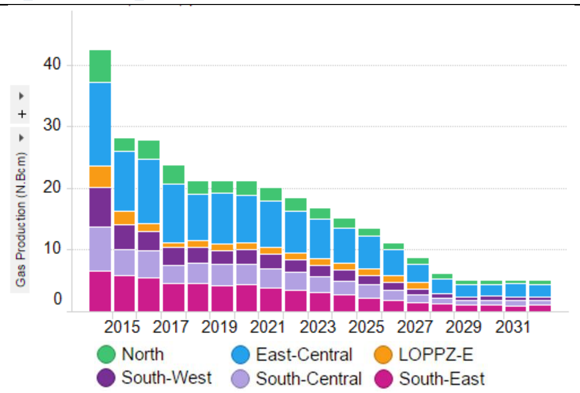


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

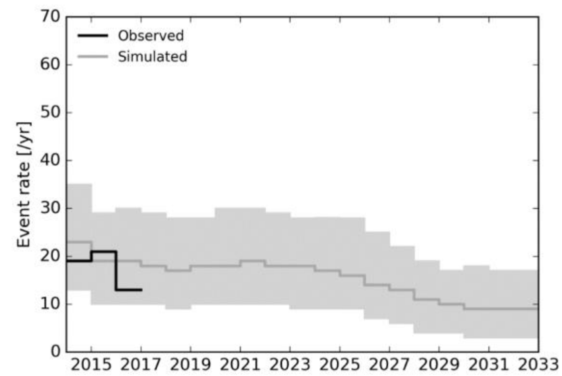


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

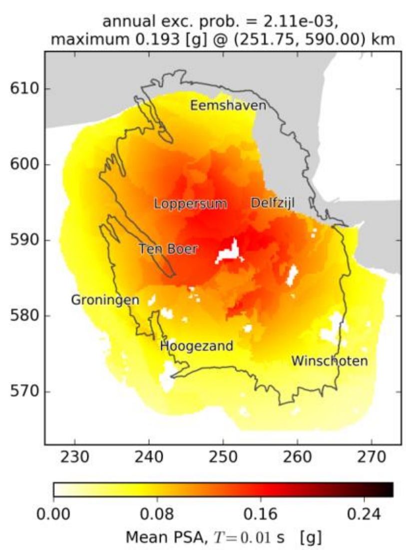
D4a – Max Import scenario with 5 N.Bcm plateau at 85% N2 utilization, imposed production distribution, NFA



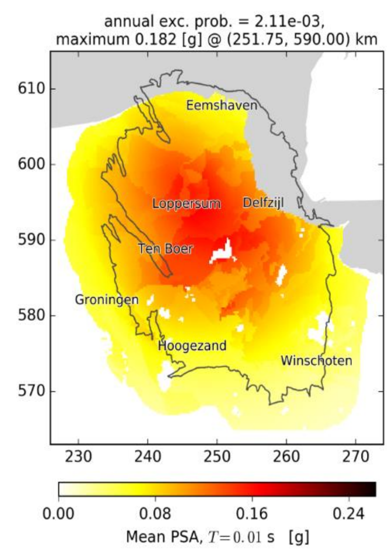
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



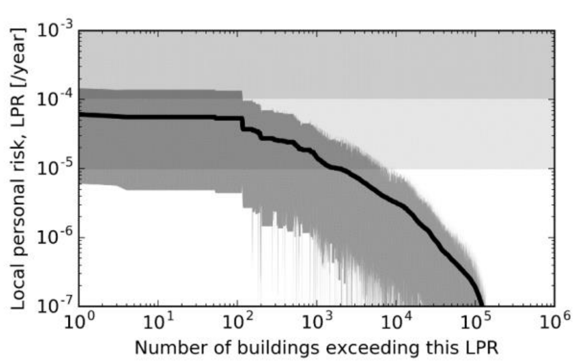
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



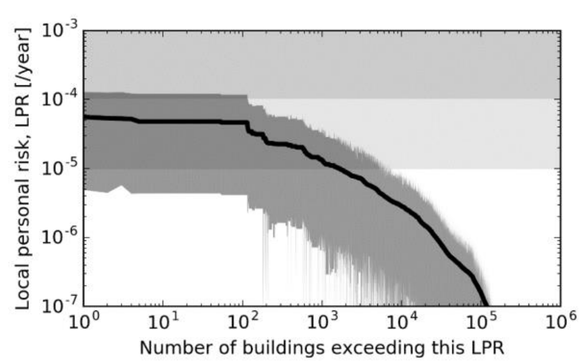
Hazard Map for the period 2018 – 2022.



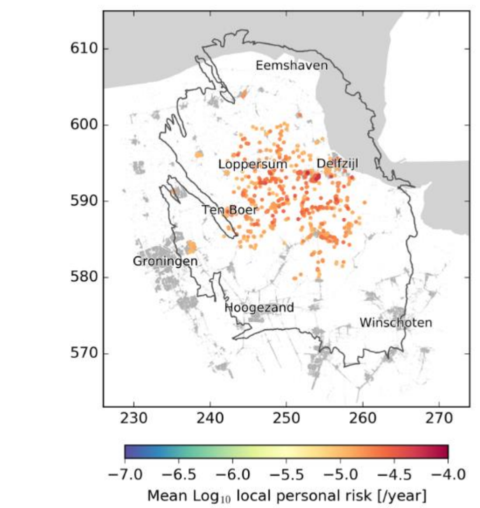
Hazard Map for the period 2023 – 2027.



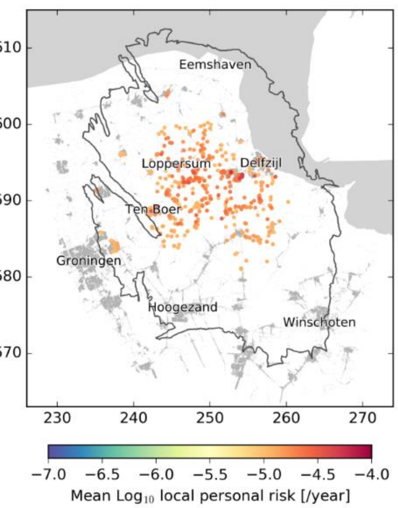
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



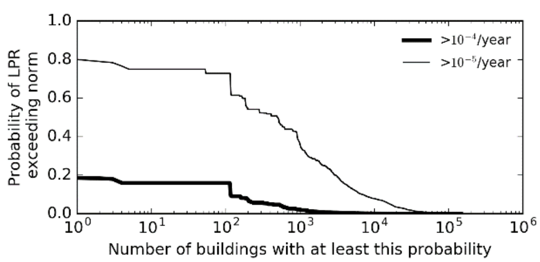
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



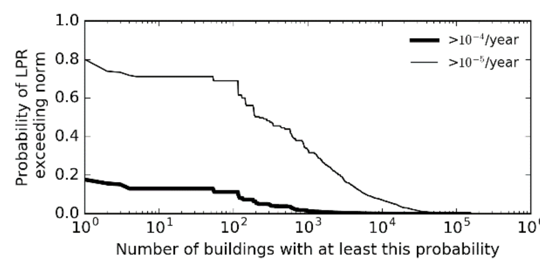
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



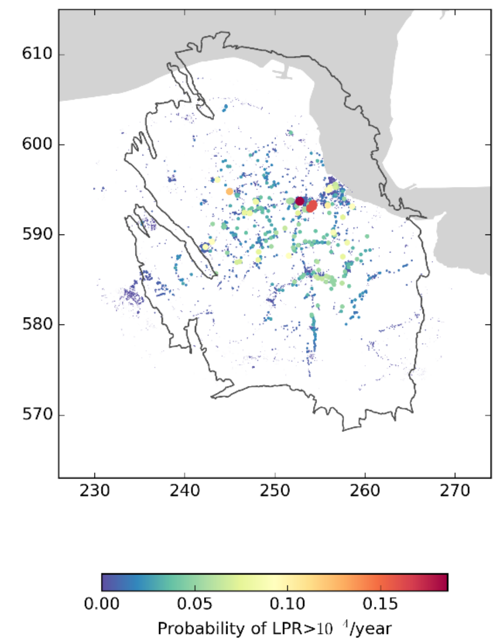
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



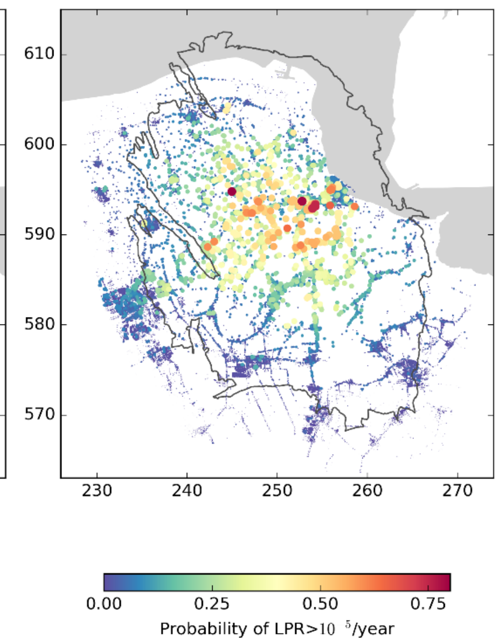
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



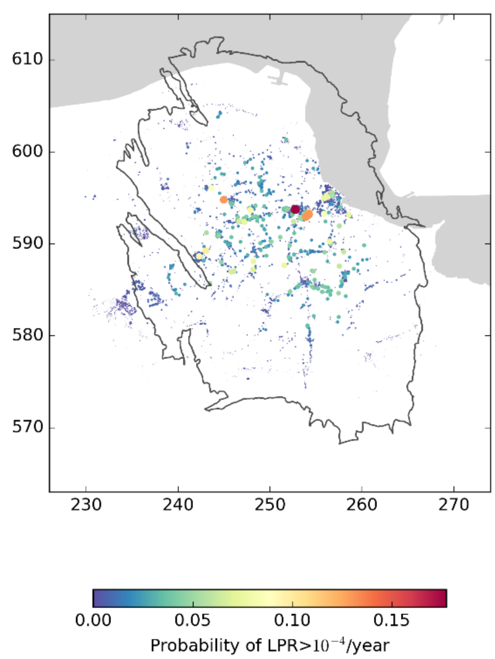
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



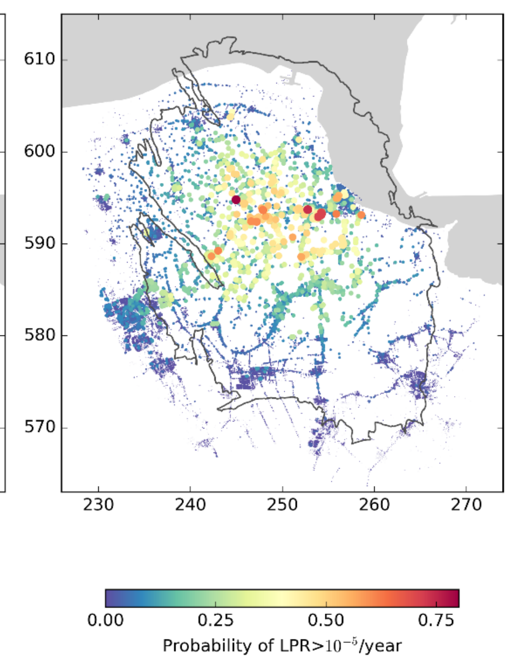
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

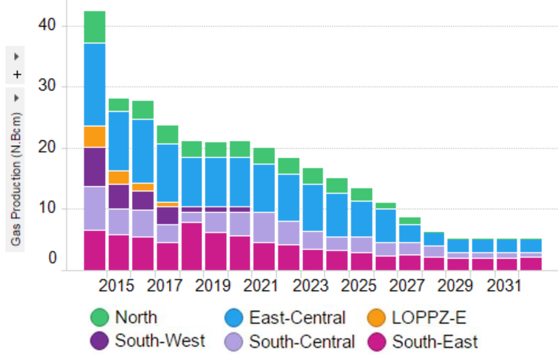


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

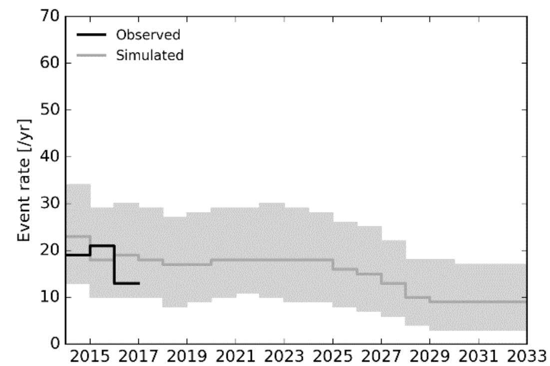


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

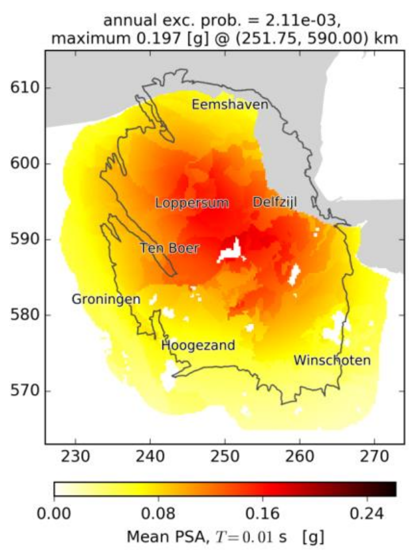
D4b – Max Import scenario with 5 N.Bcm plateau at 85% N2 utilization, optimized production distribution, NFA



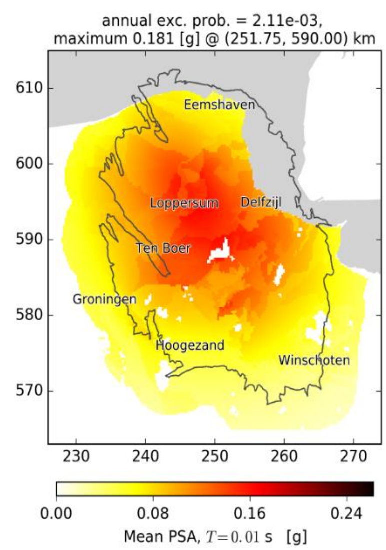
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



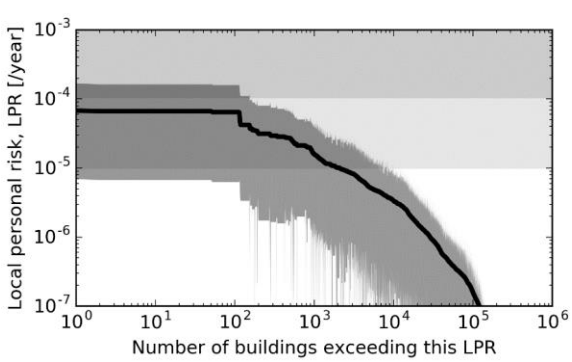
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



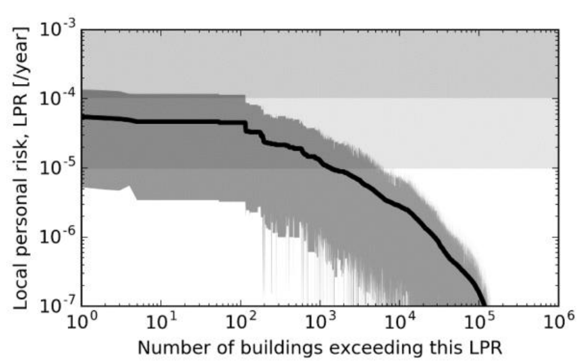
Hazard Map for the period 2018 – 2022.



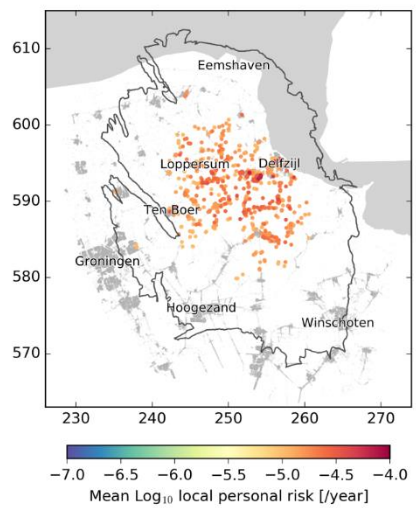
Hazard Map for the period 2023 – 2027.



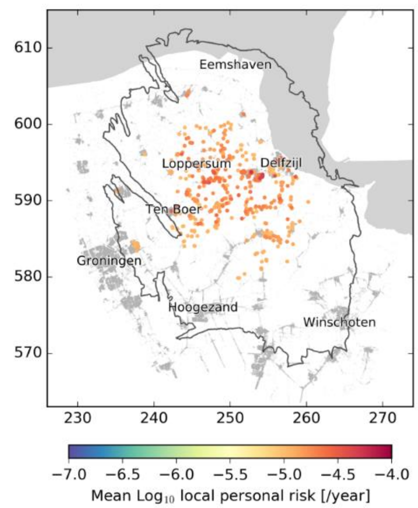
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



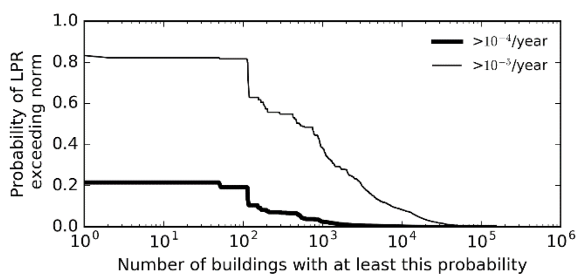
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



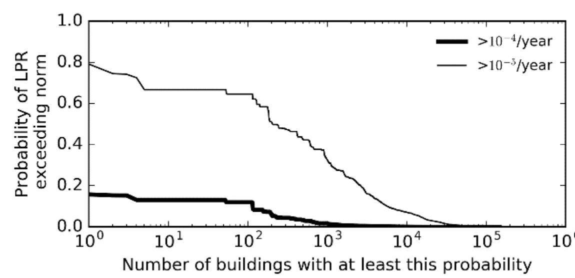
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



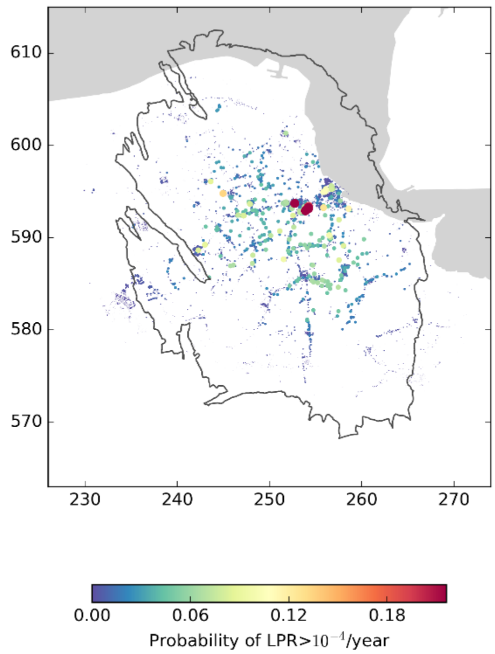
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



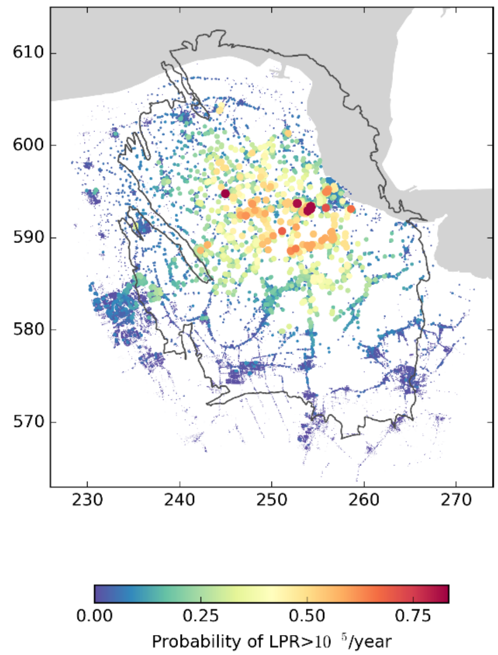
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



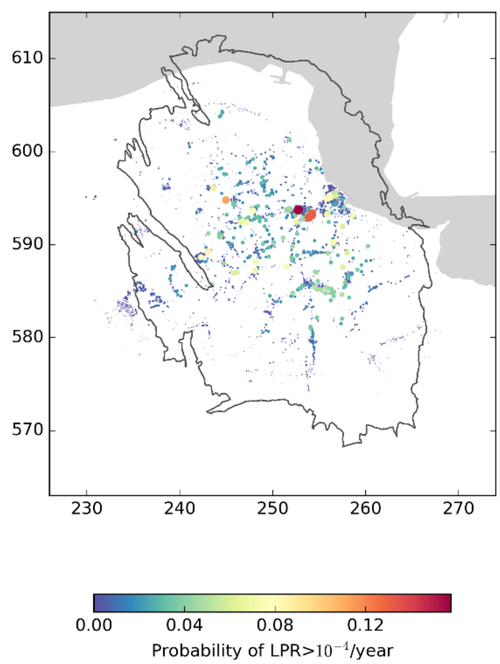
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



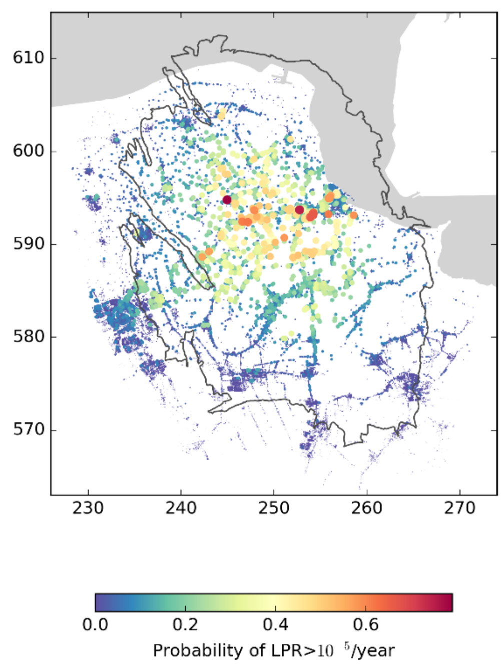
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

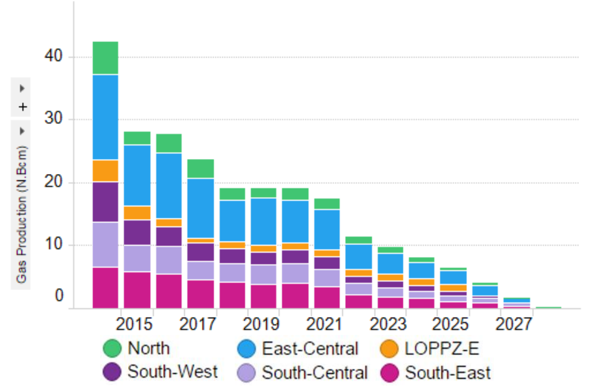


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

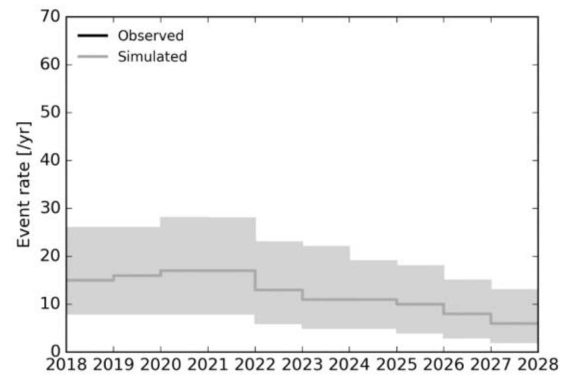


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

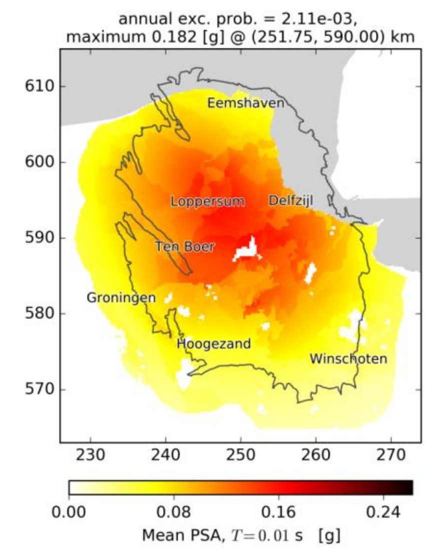
D5a – Max Import scenario at 100% N2 utilization including a new N2 plant as per 2022, imposed production distribution, NFA



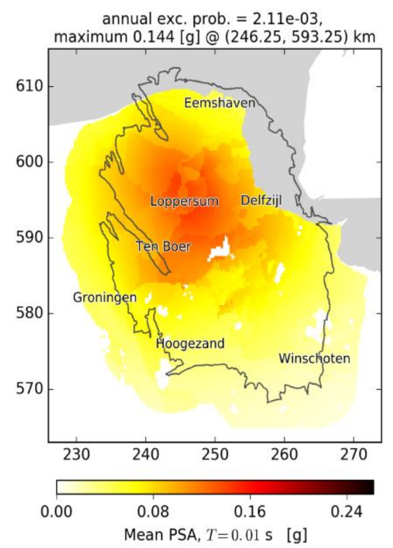
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



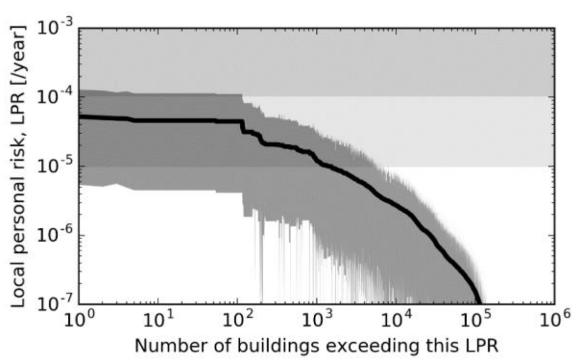
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



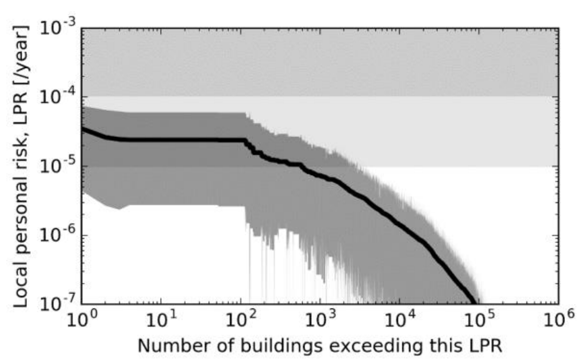
Hazard Map for the period 2018 – 2022.



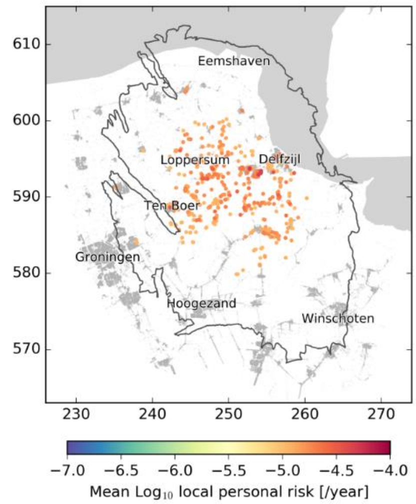
Hazard Map for the period 2023 – 2027.



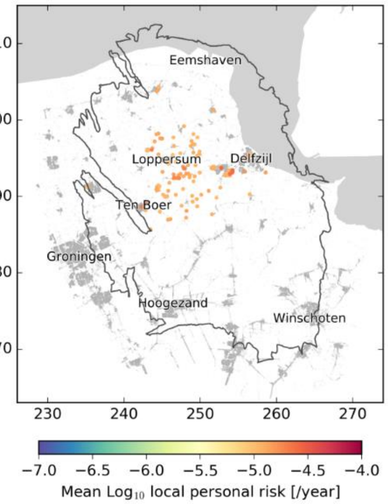
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



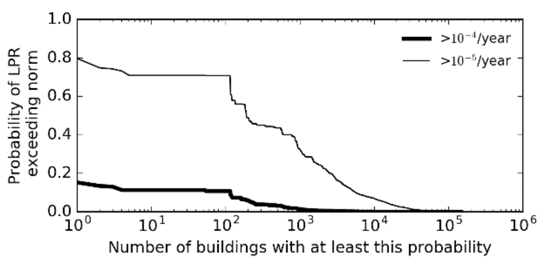
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



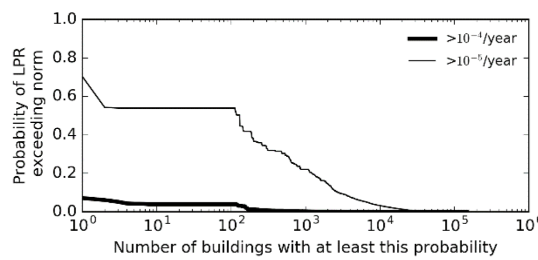
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



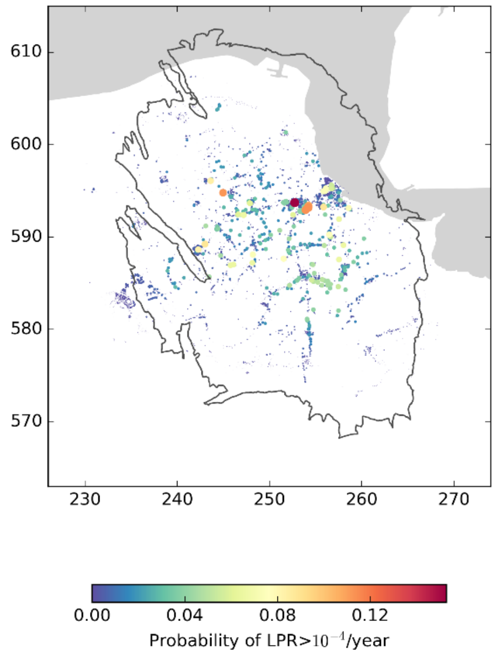
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



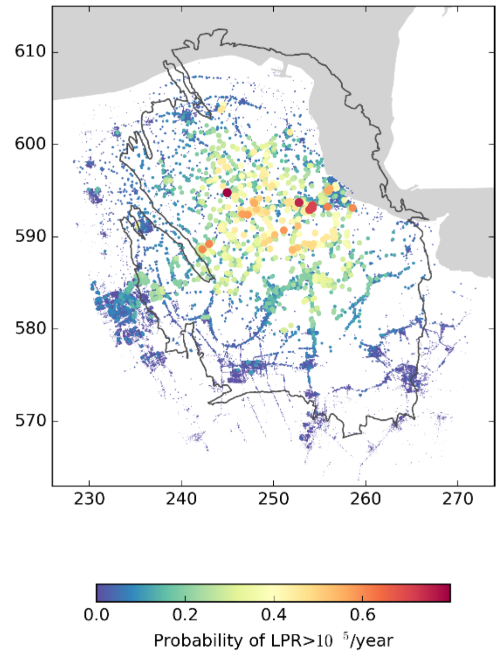
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



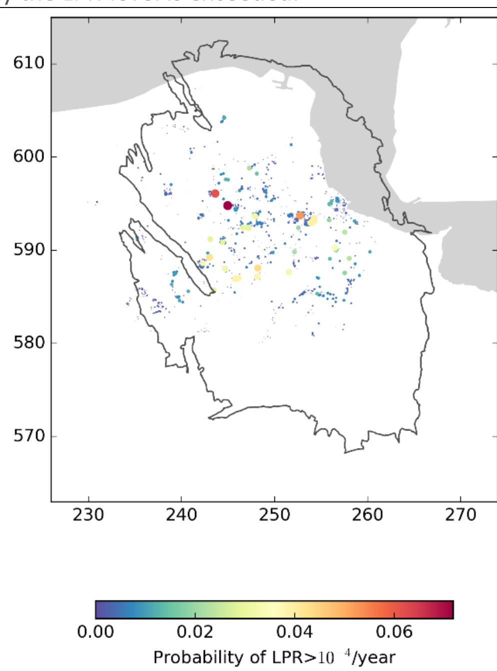
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



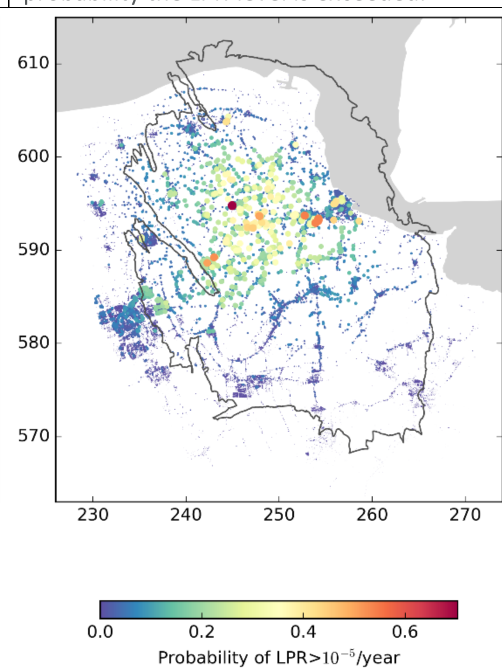
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

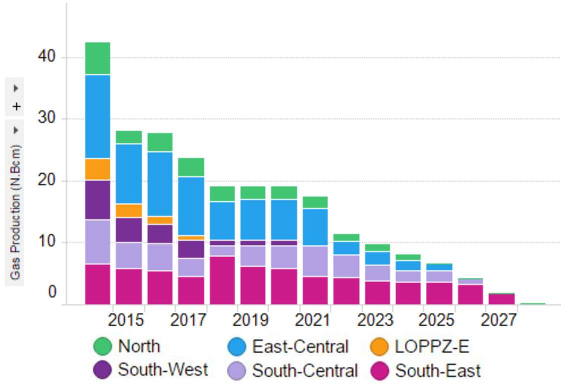


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

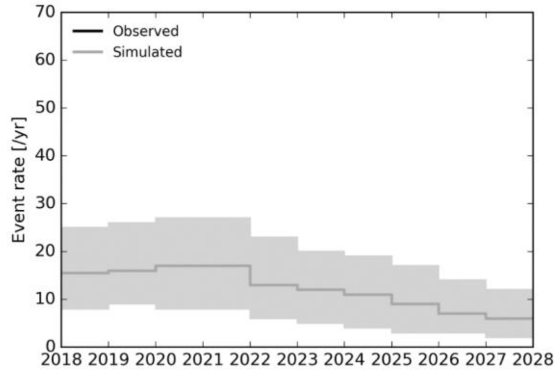


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

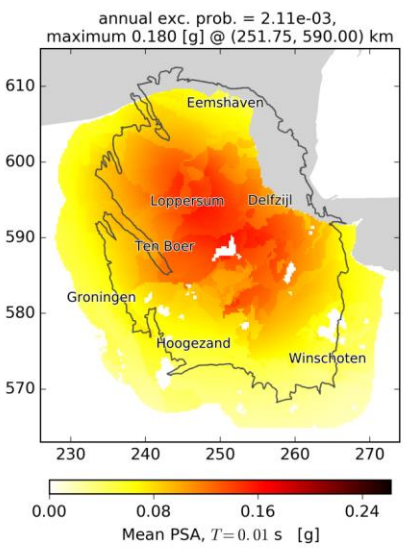
D5b – Max Import scenario at 100% N2 utilization including a new N2 plant as per 2022, optimized production distribution, NFA



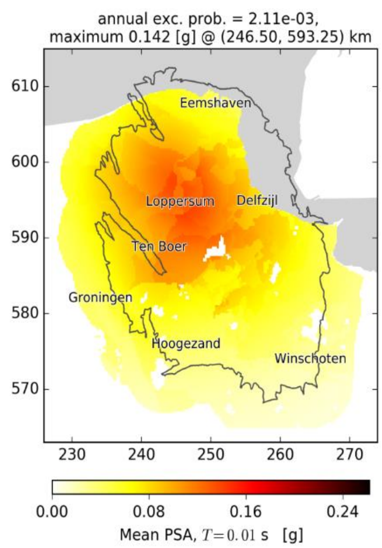
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



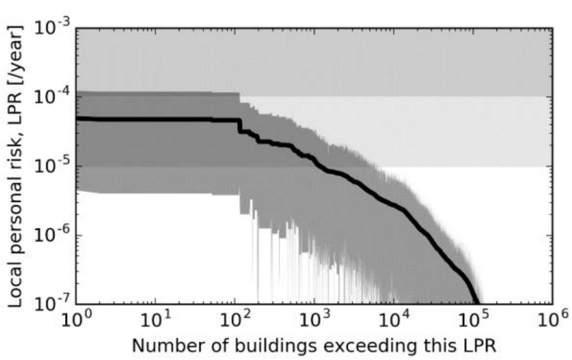
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



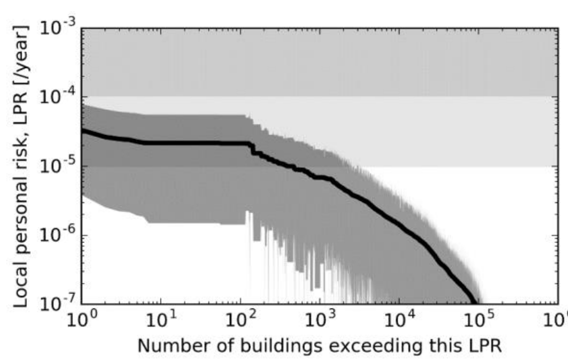
Hazard Map for the period 2018 – 2022.



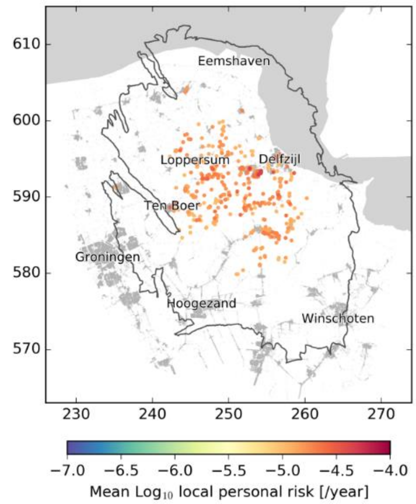
Hazard Map for the period 2023 – 2027.



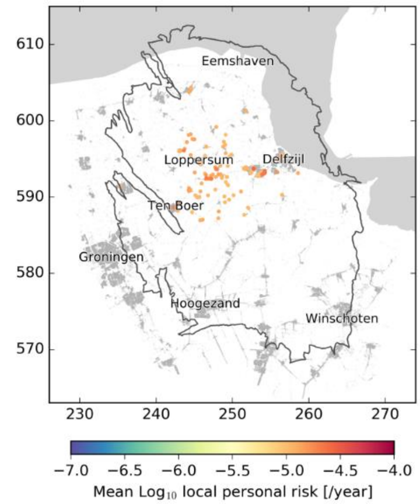
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



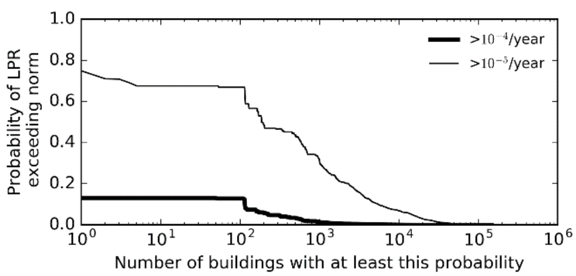
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



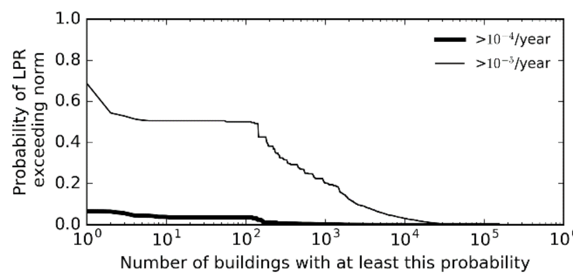
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



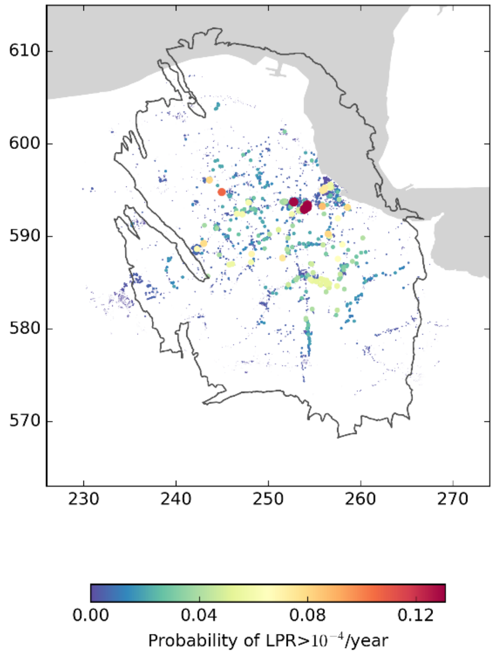
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.

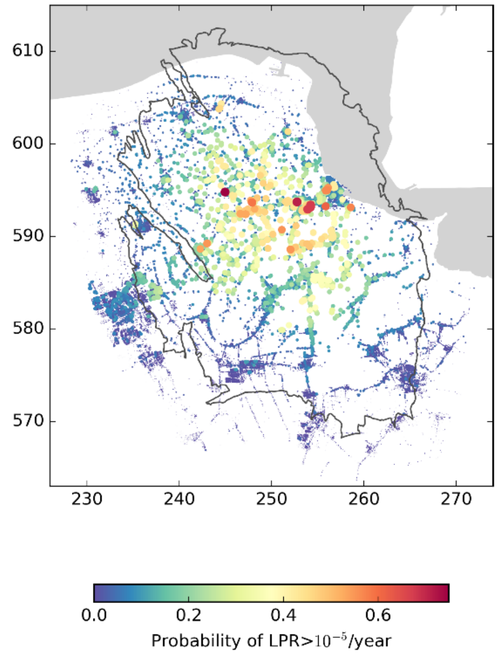


Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.

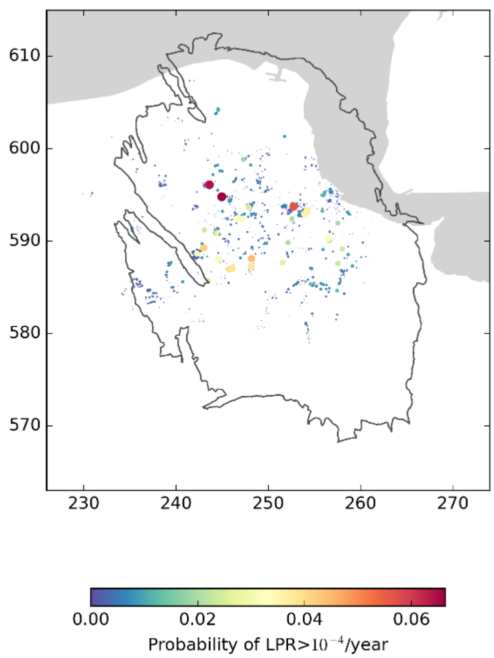


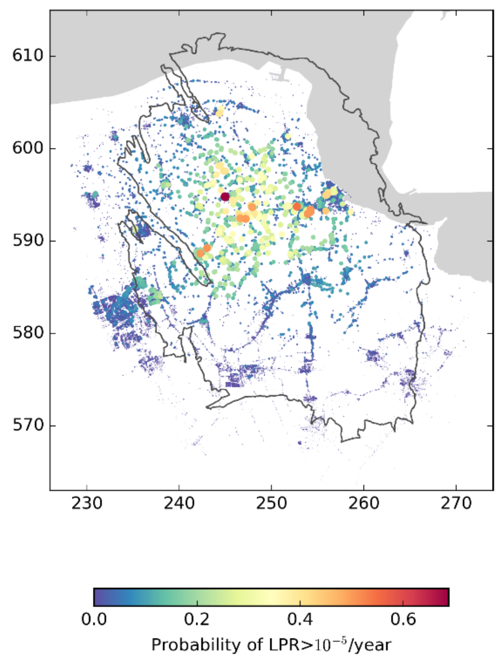
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.





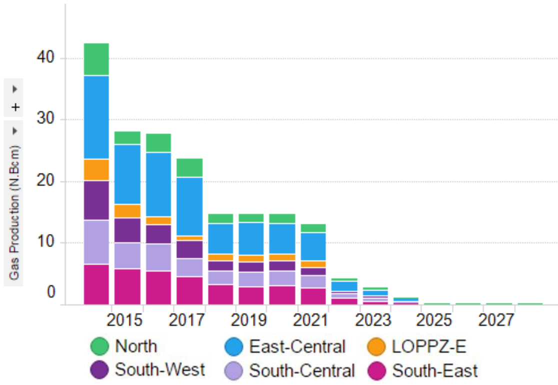
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.	Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



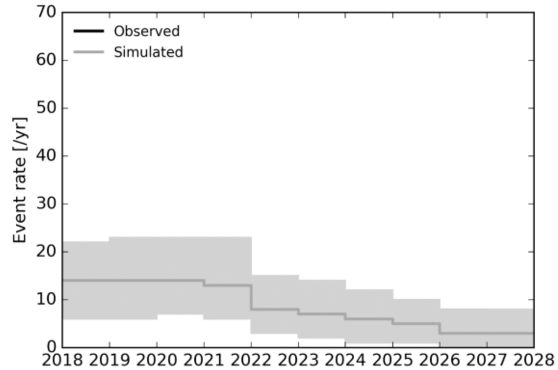


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.	Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

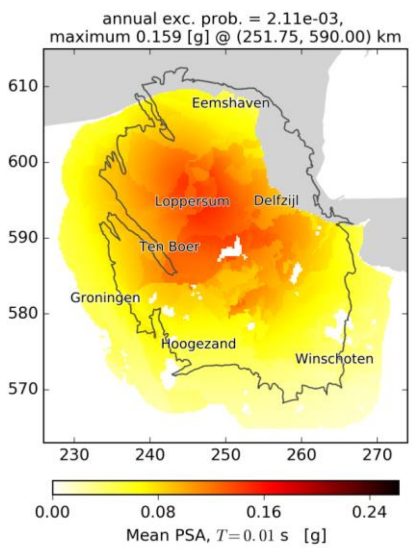
D6a – Max Import scenario at 100% N2 utilization including a new N2 plant as per 2022 for a warm year, imposed production distribution, NFA



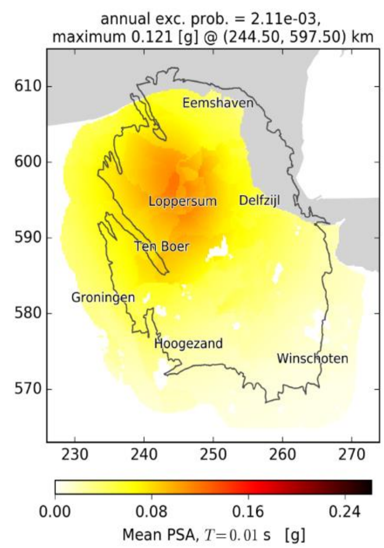
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



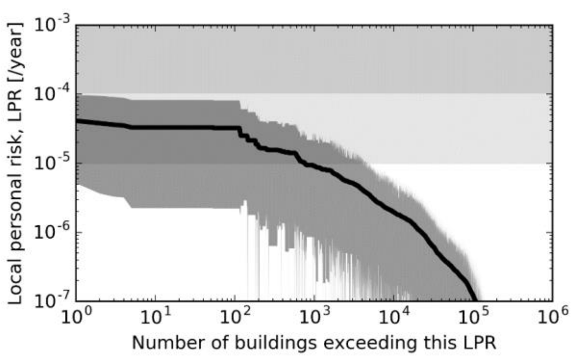
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



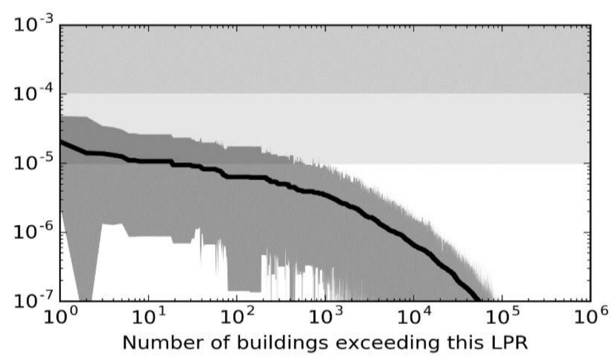
Hazard Map for the period 2018 – 2022.



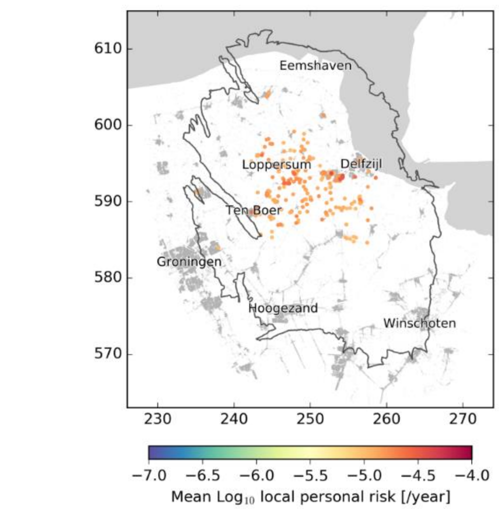
Hazard Map for the period 2023 – 2027.



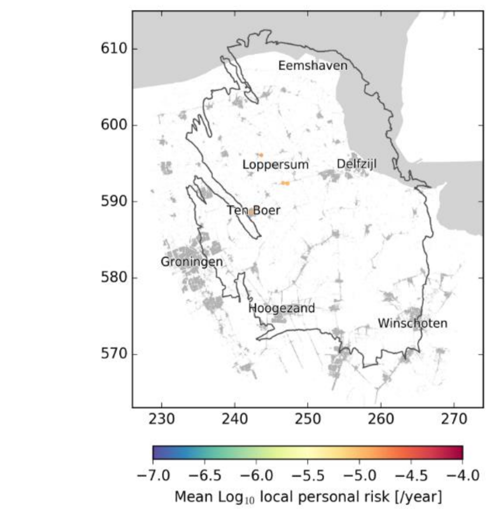
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



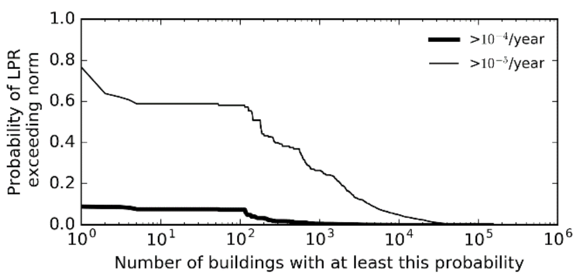
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



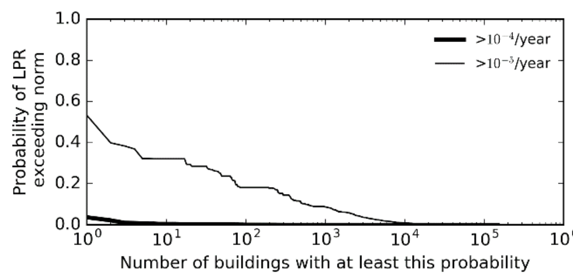
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



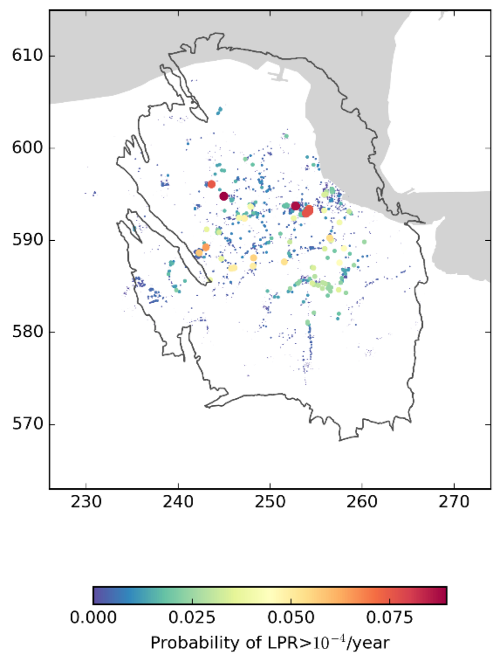
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



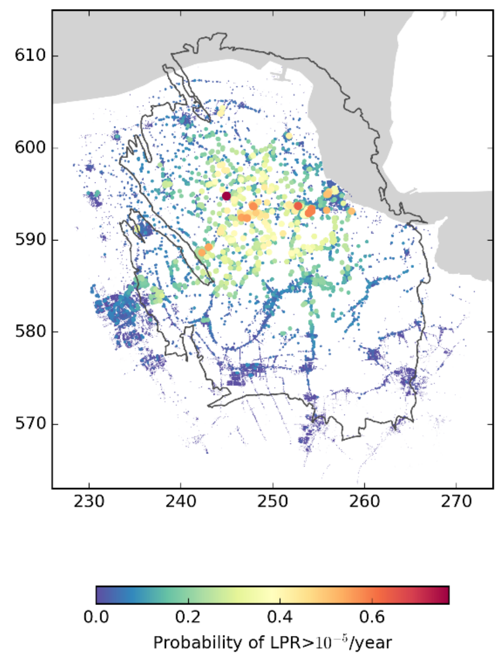
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



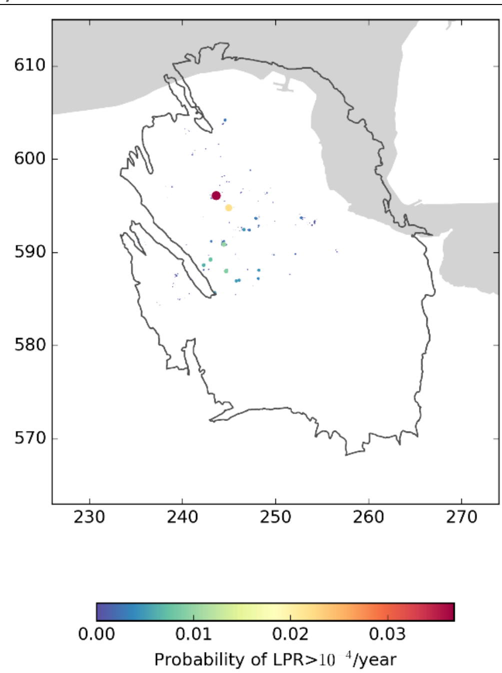
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



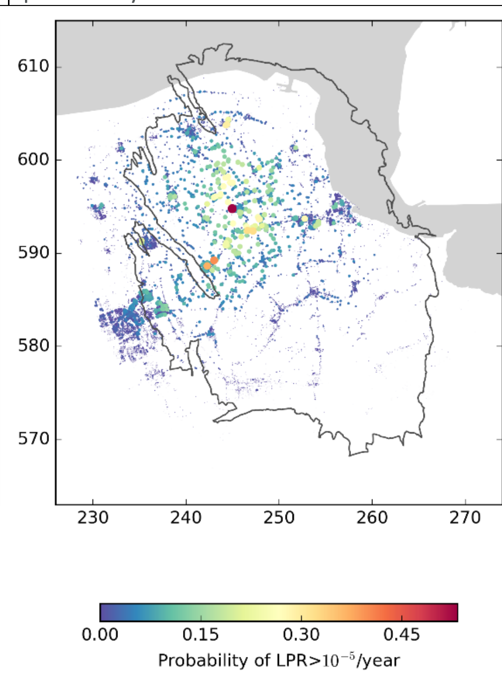
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.

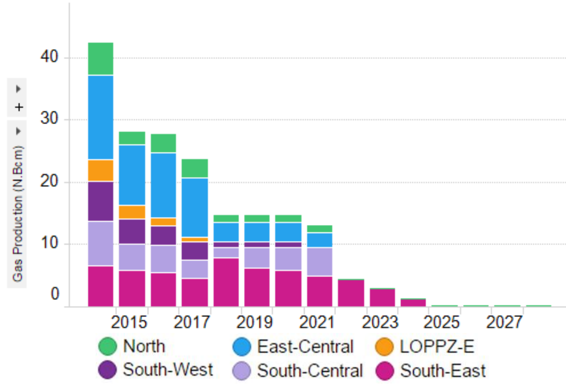


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

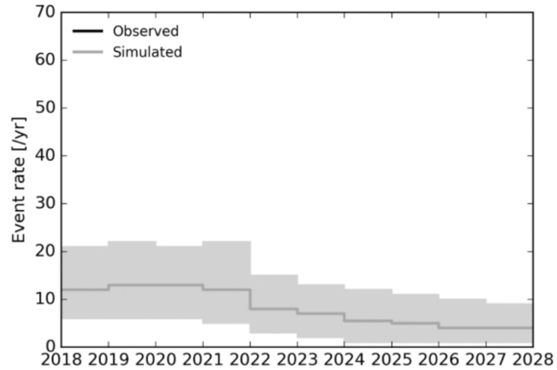


Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.

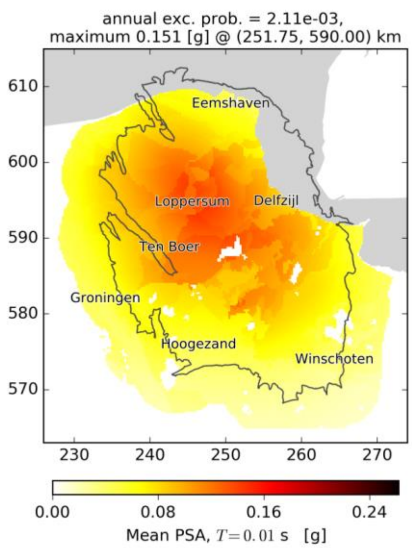
D6b – Max Import scenario at 100% N2 utilization including a new N2 plant as per 2022 for a warm year, optimized production distribution, NFA



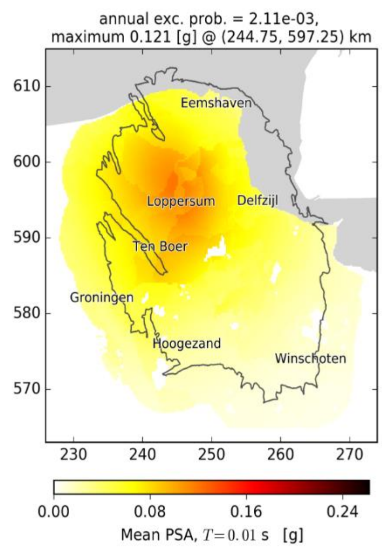
Gas Production, split out by production area (LOPPZ clusters shut-in from 2018 onwards)



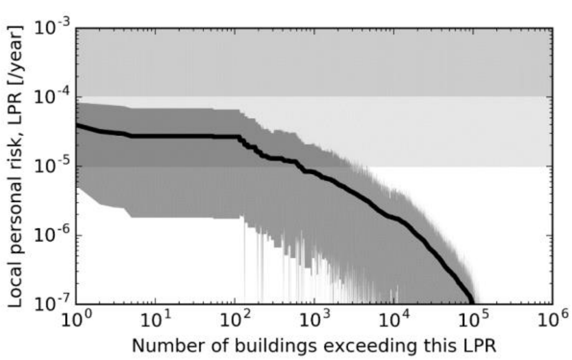
Seismicity observed and predicted. Black is observed seismicity. Grey line and grey band are simulated seismicity with uncertainty band.



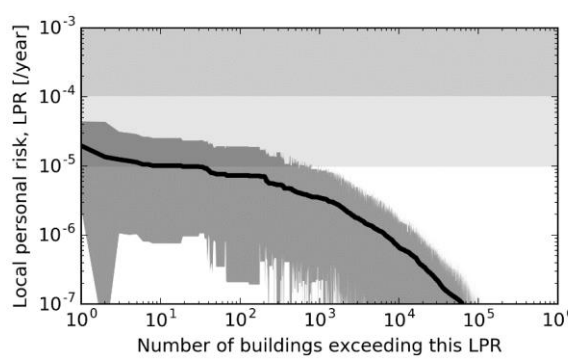
Hazard Map for the period 2018 – 2022.



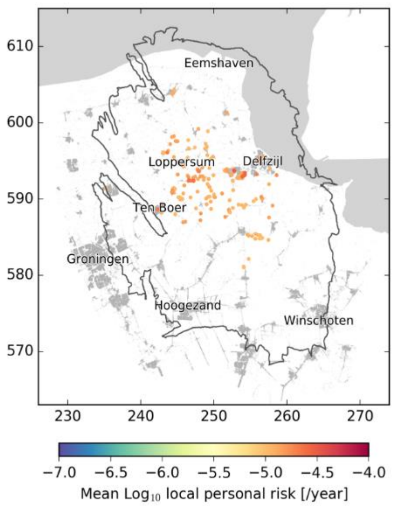
Hazard Map for the period 2023 – 2027.



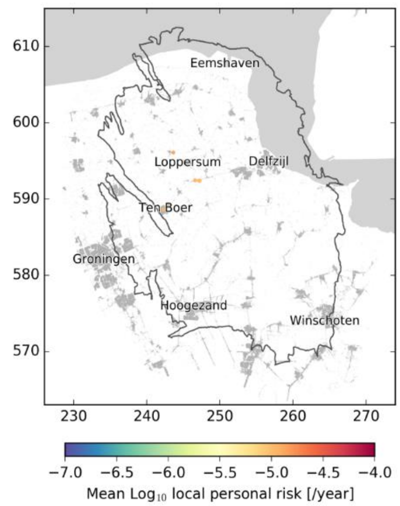
Number of buildings exceeding Local Personal Risk (LPR) for the period 2018 – 2022.



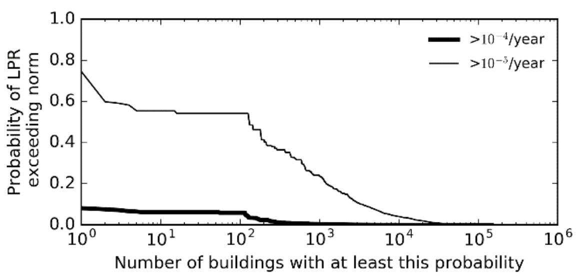
Number of buildings exceeding Local Personal Risk (LPR) for the period 2023 – 2027.



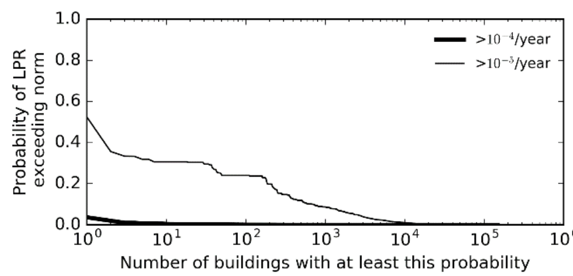
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2017 - 2022.



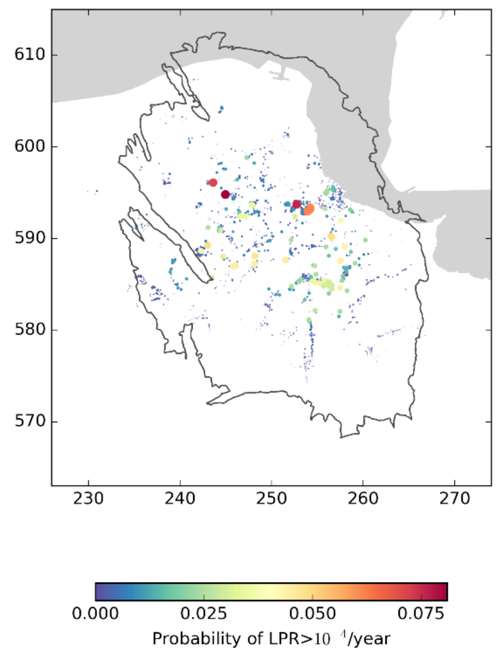
Map of the location of buildings with LPR exceeding 10^{-5}/year for the period 2023 - 2027.



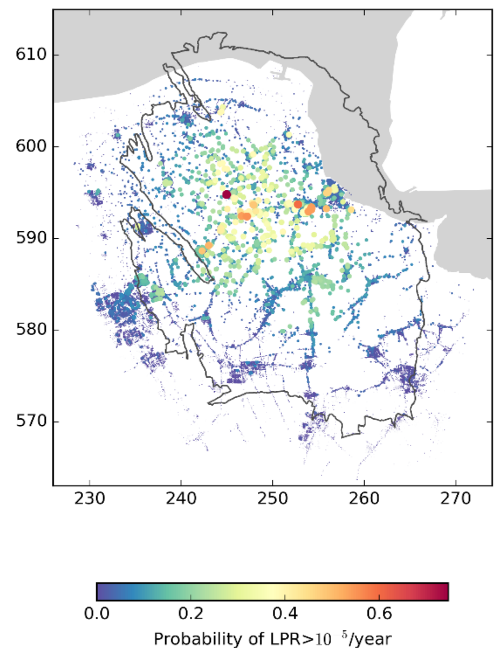
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2018 to 2022.



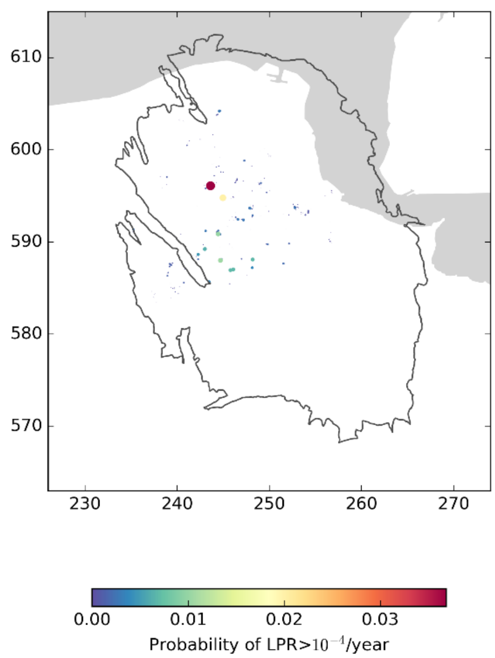
Number of buildings that with a probability exceed a set LPR level (10^{-4} /year and 10^{-5} /year) for the period 2023 to 2027.



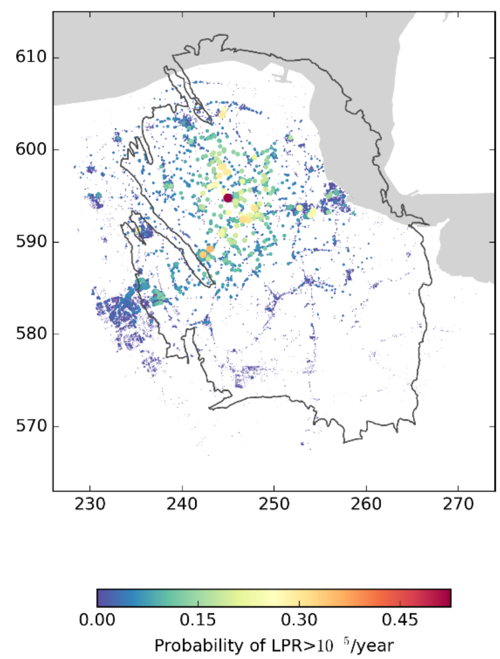
Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2018 to 2022. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-4} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.



Map of buildings indicating for each building the probability of exceeding a LPR of 10^{-5} /year, during the period 2023 to 2027. The colour indicates the probability the LPR-level is exceeded.