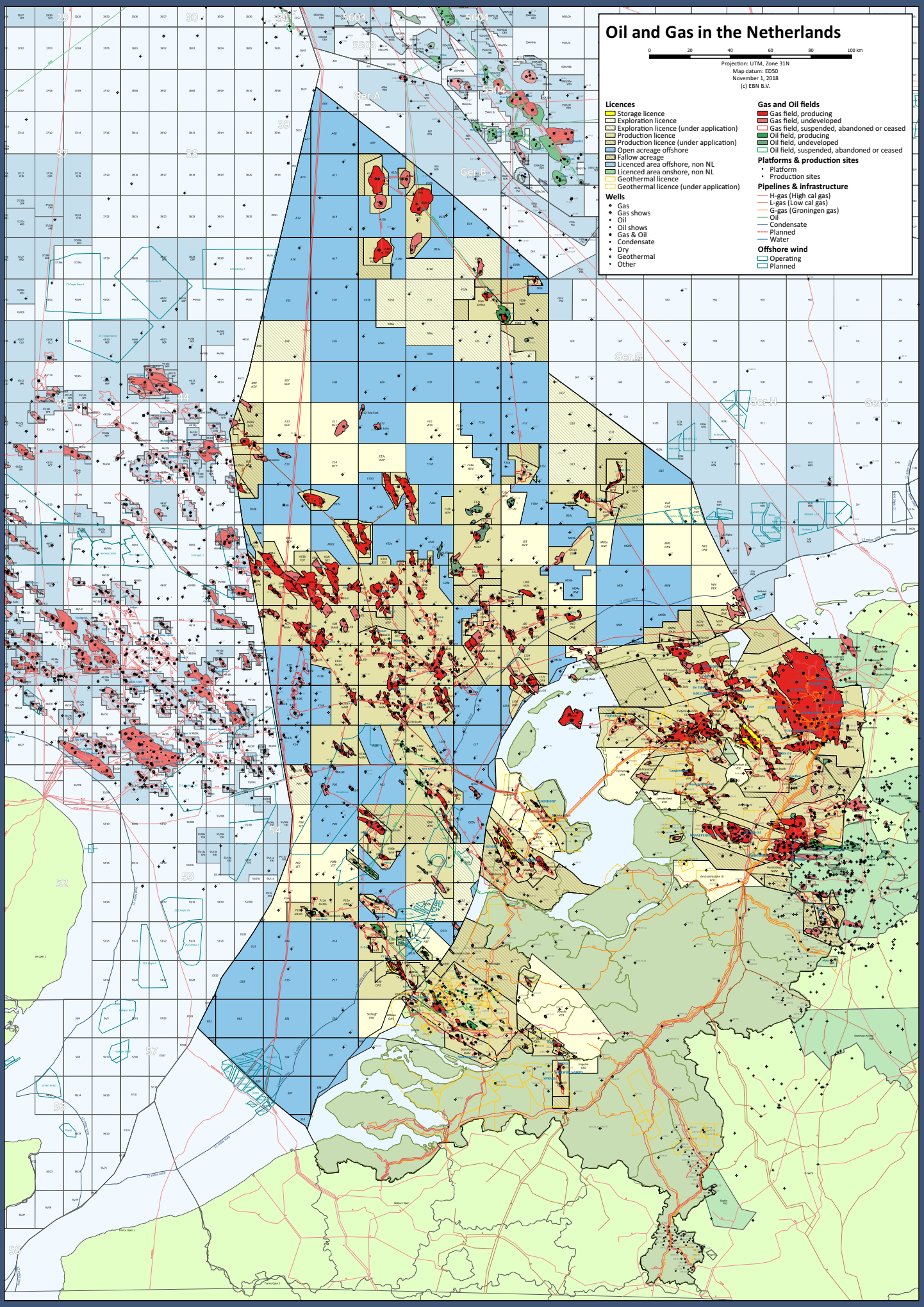
ebn

TNO innovation for life

Ministry of Economic Affairs and Climate Policy

The Netherlands

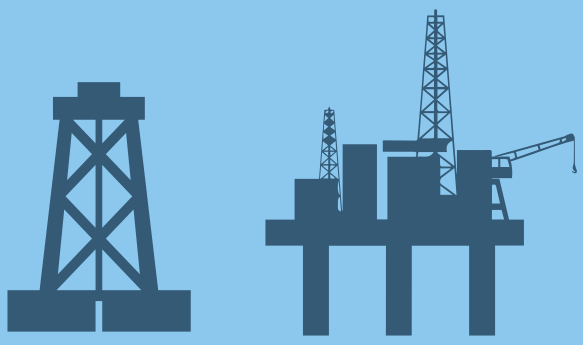
Exploration opportunities


Oil and Gas in the Netherlands
0 20 40 60 80 100 km
Projection: UTM, Zone 31N
Map datum: ED50
November 1, 2018
(c) EBN B.V.
Licences
Storage licence
Exploration licence
Exploration licence (under application)
Production licence
Production licence (under application)
Open acreage offshore
Fallow acreage
Licenced area offshore, non NL
Licenced area onshore, non NL
Geothermal licence
Geothermal licence (under application)
Wells
Gas
Gas shows
Oil
Oil shows
Gas & Oil
Condensate
Dry
Geothermal
Other
Gas and Oil fields
Gas field, producing
Gas field, undeveloped
Gas field, suspended, abandoned or ceased
Oil field, producing
Oil field, undeveloped
Oil field, suspended, abandoned or ceased
Platforms & production sites
Platform
Production sites
Pipelines & infrastructure
H-gas (High cal gas)
L-gas (Low cal gas)
G-gas (Groningen gas)
Oil
Condensate
Planned
Water
Offshore wind
Operating
Planned

Content

Our Dutch Gas

Exploring for new prospects and play concepts



The Netherlands still possesses a considerable potential of oil and gas reserves and resources. Exploration and production in a cost-efficient and safe and sustainable way will continue to provide the necessary energy from hydrocarbons during the energy transition. Whenever sustainable alternatives are insufficient, Dutch gas is the preferred energy source. EBN will continue to encourage the oil and gas industry to innovate and develop new knowledge.

EBN's goal is to create value from geological resources in a safe, sustainable and economically responsible way, by using its unique position as participant in 200+ exploration and production licences and infrastructure. Through this unique position EBN has excellent access to data, knowledge and capital.

EBN encourages exploration activity in underexplored areas by carrying out and funding studies, and by facilitating the sharing of data and knowledge. Creating more value from assets often requires new, innovative ideas. Hence, EBN is participating in research on various topics, covering the full life cycle from exploration to abandonment. A significant part of this research is done collaboratively through joint industry projects. However, EBN also carries out independent studies, partly in-house and partly outsourced to contractors.

In addition, EBN aims at maximizing recovery from existing fields. These include producing fields for which the operators are facing increasing technical and economic challenges. Recent studies by EBN have contributed to optimizing the selection of the most valuable end of field life (EoFL) techniques. Stranded fields are a focus of attention for which development solutions are actively being pursued.

For more information visit www.ebn.nl

Ministry of Economic Affairs
and Climate Policy

EBN

EBN is the Dutch state participant with the Ministry of Economic Affairs and Climate Policy as its shareholder. EBN invests, facilitates, shares knowledge and is active in exploration, production, storage and trading of natural gas and oil from the Dutch subsurface. The usual interest in these activities ranges between 40% and 50%. EBN also has interests in offshore gas pipelines, onshore underground gas storage and a 40% interest in gas trading company GasTerra B.V. EBN's mission is to realise economic and societal value from geological energy sources in the Dutch subsurface.

Furthermore, EBN advises the Dutch government on the mining climate and on new opportunities for using the Dutch subsurface as a source for energy, such as geothermal energy and Carbon Capture Utilisation and Storage. By building on a long history in gas and oil projects and an expertise of the subsurface, EBN explores these opportunities which contribute to a carbon-neutral energy future. In addition, EBN has taken the lead in re-use and decommissioning of ageing oil and gas infrastructure by establishing a National Platform (Nexstep) in collaboration with all current operators in the Netherlands.

State Supervision of Mines (SSM)

On behalf of the Minister of economic Affairs and Climate Policy, SSM supervises the exploration, production, transportation and storage of mineral resources such as oil, gas and salt, as well as geothermal energy. The supervision contributes to the safe production of mineral resources and energy for society, employees in the energy sector and the environment. SSM's responsibilities are set out in the Mining Act and the Gas Act. In addition, on behalf of the Minister of Social Affairs and Employment, SSM monitors compliance with legislation on working conditions, working hours at mining facilities and offshore wind farms. On behalf of the Minister of Infrastructure and Water Management, SSM monitors compliance with environmental and building legislation at mining installations.

In addition to its supervisory role, SSM can advise the Minister of Economic Affairs and Climate Policy, either upon request or on its own initiative. SSM proactively fulfils this reflective role, feeding back to policymakers and the Minister, as set out in the 'Guidance on government inspections' that came into effect on 1 January 2016.

TNO-AGE

TNO-AGE is the advisor to the Ministry of Economic Affairs and Climate Policy on use of the deep subsurface. The role of TNO-AGE is to support the ministry and other stakeholders in the public domain (such as State Supervision of the Mines) on policy by providing technical analyses. TNO-AGE focuses on the exploration and production of minerals (oil, gas and salt), geothermal heat, subsurface storage and mining effects.

The task of TNO-AGE comprises among others the collection and quality control of data on Dutch oil and gas fields, drafting annual forecasts on production, research related to licence applications and monitoring new activities of the E&P industry. Important frameworks are the Mining Act and the act BRO. TNO-AGE manages the information portal www.nlog.nl and the underlying data such as seismic surveys and borehole data. This information is made available online where possible after the (usually) 5-year period.

Why the Netherlands?

A businesscase for Dutch exploration & production

Strategic pillars EBN

Return to Nature (Safe)

Our Dutch Gas (Economical)

New Energy (Sustainable)

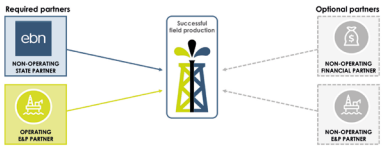
Business climate

- **Stable** and beneficial internationally oriented **investment climate**
- **Stable regulatory regime**
- Extensive and international E&P industry present
- Clear distinction between on- and offshore investment policy
- **Open door policy** allows you to apply for **licences** at any time

- Macro stability
- Ease of doing business
- Supporting infrastructure
- Skilled labor

EBN as your partner

- EBN is your **investment** partner
- 40% **Dutch state participation** via EBN in exploration & production
- **EBN invests, facilitates, participates in R&D and shares knowledge** of the subsurface, facilities and economics



Cost and risk mitigation

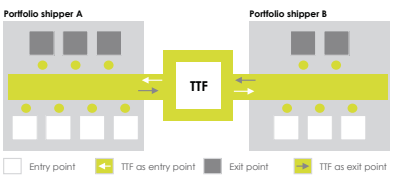
- Marginal field tax allowance: your financial **exposure** on exploration activities is **reduced by 12,5%**
- EBN actively strives to further **improve** the **business climate**
- EBN participation in exploration activities **reduces financial exposure by** another **40%**

40%

reduced financial exposure

Infrastructure

- **Efficient and extensive infrastructure** for hydrocarbon transport and processing
- Reasonable transportation fees
- Strong local demand and **guaranteed offtake** by GasTerra



TTF virtual market place

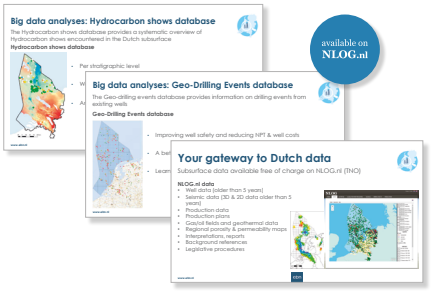
Prospectivity

- Relatively low investment capital required
- Well maintained offshore assets
- Well developed and competitive oil field services
- Downstream access to Northern & Central European markets
- **High** economical exploration **success rate: 58%**

58%

success rate

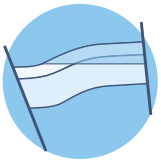
Free access to exploration data and analyses



All posters are downloadable at kennisbank.ebn.nl

Your Gateway to Dutch Data

Data available free of charge on NLOG.nl



Available data

- **Well data:** well log data, well tests, production data, final well reports, stratigraphy, core data
- **Seismic data:** 2D and 3D seismic data is available to download, larger volumes on request
- **Gas/oil fields and geothermal data:** monthly production figures and production plans of all fields
- **And more:** salt production, underground gas storage, underground storage of CO_2, seismicity and subsidence, spatial planning, stranded fields described in fact sheets

Interpretation

- **Maps and digital datasets:** oil and gas fields, thematic maps, key regional horizons in time and depth, regional velocity models for time-depth conversion, gas composition
- **Papers and presentations:** annual review: Natural resources and geothermal energy in the Netherlands, bibliography, key publications on (petroleum) geology, reserves and production reports

Most data is available free of charge, after the legal confidentiality term.
Only large scale seismic volumes are subject to minor handling costs.

Legislation

- **Easy online access** to the Dutch mining legislation (also available in English)
- Explanation and **guidelines for reporting** requirements
- Information on **fees, tax benefits and state participation**

Examples of data availability

Large scale regional velocity model

The Velmod 3.1. regional velocity model has been developed for:

- Large scale time–depth conversion
- Seismic interpretation
- Mapping

The new version includes updates of data and methods, higher data density and more detail of the lithostratigraphic units.
This model is based on:

- Velocity data from sonic logs
- Checkshot data

With this data a layer cake velocity model is constructed based on V_0k parameterization.

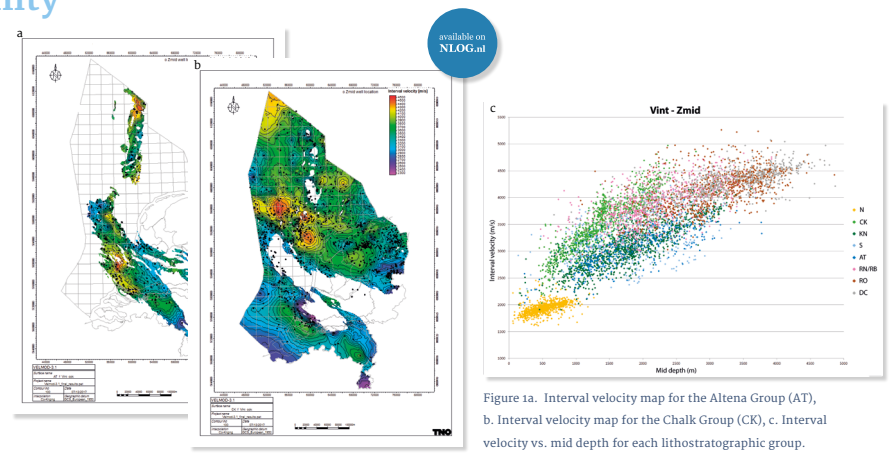


Figure 1a. Interval velocity map for the Altena Group (AT), b. Interval velocity map for the Chalk Group (CK), c. Interval velocity vs. mid depth for each lithostratographic group.

Southern Permian Basin atlas

A comprehensive overview based on data of more than 150 years of petroleum exploration and research. The atlas covers the entire Southern Permian Basin and addresses, among others, the:

- Geological evolution of hydrocarbon potential per stratigraphic interval
- Paleogeographic and tectonic evolution: framework of the principal stratigraphic intervals
- Petroleum generation, migration, trapping and production
- History of exploration and licensing
- Summary of resource assessments
- Other potential for the use and reuse of the deep subsurface such as gas storage and geothermal energy

The atlas was published in 2010 by TNO and is publicly available on www.NLOG.nl.

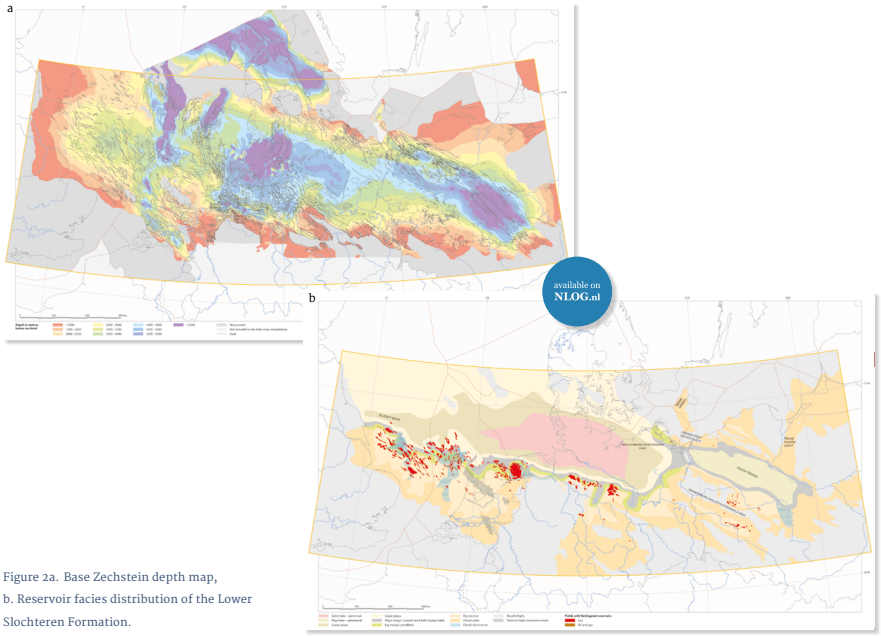


Figure 2a. Base Zechstein depth map, b. Reservoir facies distribution of the Lower Slochteren Formation.

All posters are downloadable at kennisbank.ebn.nl

From Data to Information

Learnings from data analysis by EBN

Geo-Drilling Events database

Webportal hosted by EBN

Planning new wells requires careful screening of the trajectory for possible geodrilling hazards. This database provides a better understanding of Geo-Drilling Events (GDE) and hazards in the Dutch subsurface. GDEs' are those events for which a significant geological component contributed to the cause of the incident. The GDE database contains information on drilling events from existing wells. This database is freely accessible for operators active in the Dutch subsurface.

Information in the database

Around **1100** GDEs' have been analysed in approximately **930** on- and offshore wells. The database consists of 3 parts:

- Generic well data
- Geo-drilling events (observations)
- Geo-drilling hazards (interpretations)

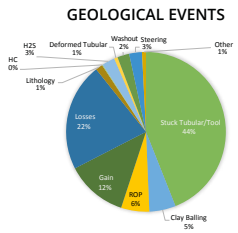


Figure 1a. Distribution of observed geological events while drilling in the Netherlands.

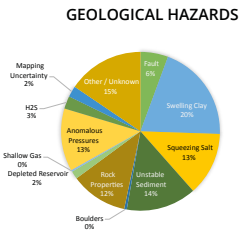


Figure 1b. Distribution of interpreted geological hazards while drilling in the Netherlands.

Hydrocarbon Show database

Webportal hosted by EBN (available in 2019)

The Hydrocarbon Show (HCS) database provides a systematic overview of hydrocarbon shows based on: mudlog data, well test data and (sidewall-)core data. This information is compiled per stratigraphic interval in key wells drilled in the Dutch subsurface. The analysis uses a detailed classification scheme to describe all types of oil and gas shows and includes estimates of the confidence level of interpretation. This information is used for exploration purposes and to assist in well planning, including geothermal wells.

Information in the database

The database currently contains **2200** wells of which approximately **700** on- and offshore wells have been analyzed in a detailed manner.

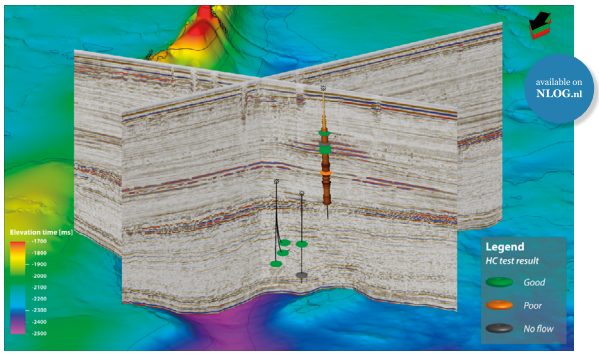


Figure 3. Integrated visualization of HC show test data with seismic- and well log data (gamma ray). Displayed surface is the Base North Sea Group.

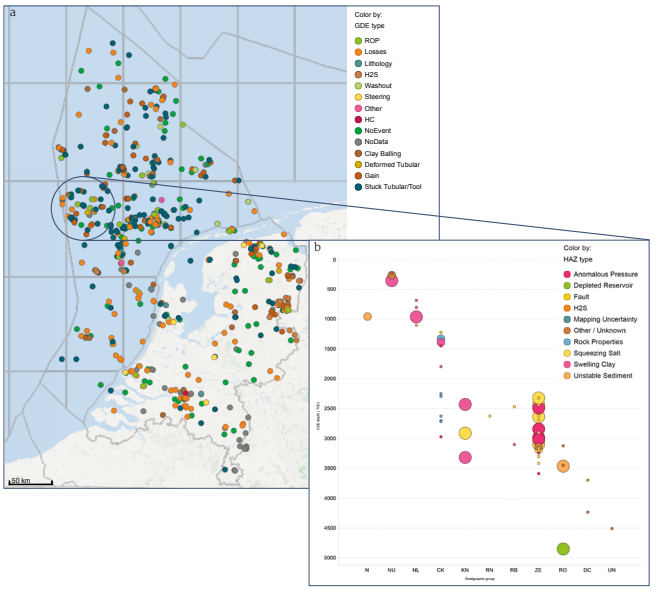


Figure 2a. Map view of the GDE database in the spotfire analysis tool. The observed GDE types are indicated as coloured spheres for which additional information is available, b. Regional selection of GDEs' plotted by their interpreted hazard type. The size of the spheres is indicative of the severity of the GDE, whereas ordering by stratigraphic interval allows the user to link certain hazard types to particular stratigraphic intervals.

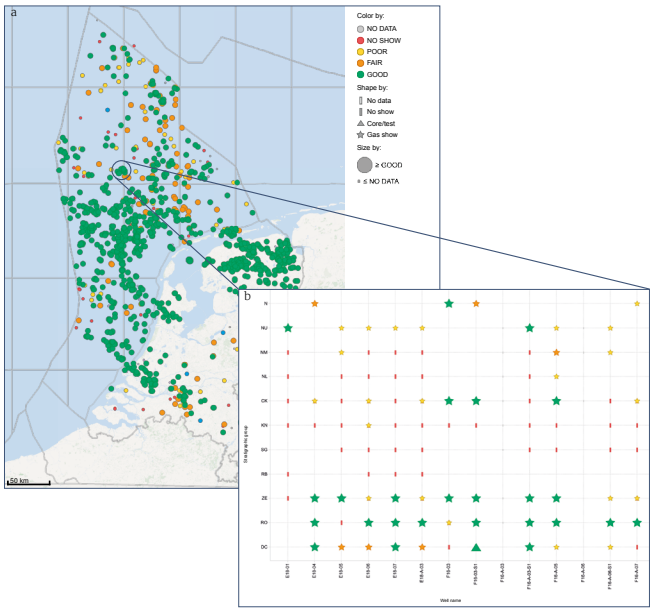


Figure 4a. Map view of the HCS database in the analysis tool. Each stratigraphic interval is classified and the quality of obtained HC shows is indicated by the coloured spheres, b. Regional selection of wells with encountered HC shows per stratigraphic group.

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Hydrocarbons in the Netherlands

Diversity as the key to successful exploration

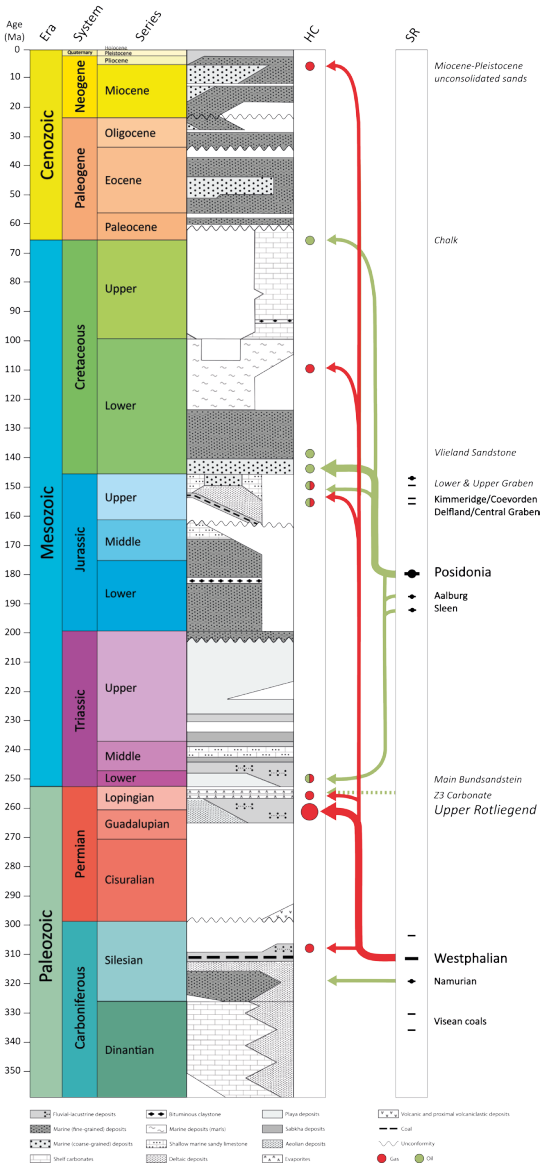

Figure 1. Hydrocarbon systems in the Dutch subsurface. The arrows show hydrocarbon migration into the main reservoir units (modified after de Jager & Geluk, 2007; Adrichem Boogaert & Kouwe, 1993–1997 and the Southern Permian Basin Atlas by Doornenbal and Stevenson, 2007).

Tertiary

- **Bright spots** are indicative of shallow gas presence
- High production rates

More information on the "Shallow Gas" poster

Upper Cretaceous – Chalk

- A proven but underexplored play
- **Most important oil reservoir** (production since 2001 (F2-Hanze field))
- Challenging but rewarding play e.g. Rembrandt field (NL), Fife field (UK), Halfdan field (DK)
- Potential for intra-Chalk structural or stratigraphic traps
- > 55 untested closures in the northern Dutch offshore, of which > 30 in open acreage. STOIIP from 10 – 300 MMbbls each

Jurassic

- Abundant **oil and gas prospectivity**
- Requiring dedicated geological studies

Triassic

- Volumetrically, **the second largest gas play** in the Netherlands e.g. F15-A field
- Significant hydrocarbon potential

More information on the "Triassic Hydrocarbon Potential" poster

Rotliegend

- Volumetrically, the **most important gas play** in the Netherlands e.g. Groningen gasfield (2800 bcm)
- Still **new concepts** identified and proven e.g. Ruby and Cygnus plays

More information on the "A New Upper Rotliegend Play" poster

Carboniferous

Upper Carboniferous

- The **Westphalian coals** are the principal **source rock for gas** and are present in most of the Dutch subsurface

Lower Carboniferous

- Virtually **untested and underexplored play**

More information on the "Lower Carboniferous" poster

Dinantian Carbonates

- Underexplored play: the **Dinantian Carbonates** have recently become the **target of exploration** for both hydrocarbons and geothermal energy in the Netherlands
- Several prospects and leads identified, currently being pursued

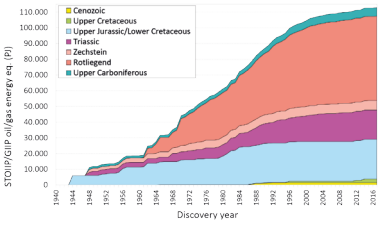

Figure 2. Cumulative energy (PJ) per lithostratigraphic unit in the Netherlands. Pseudo creaming curve (after Doornenbal et al., 2019 (expected publication)).

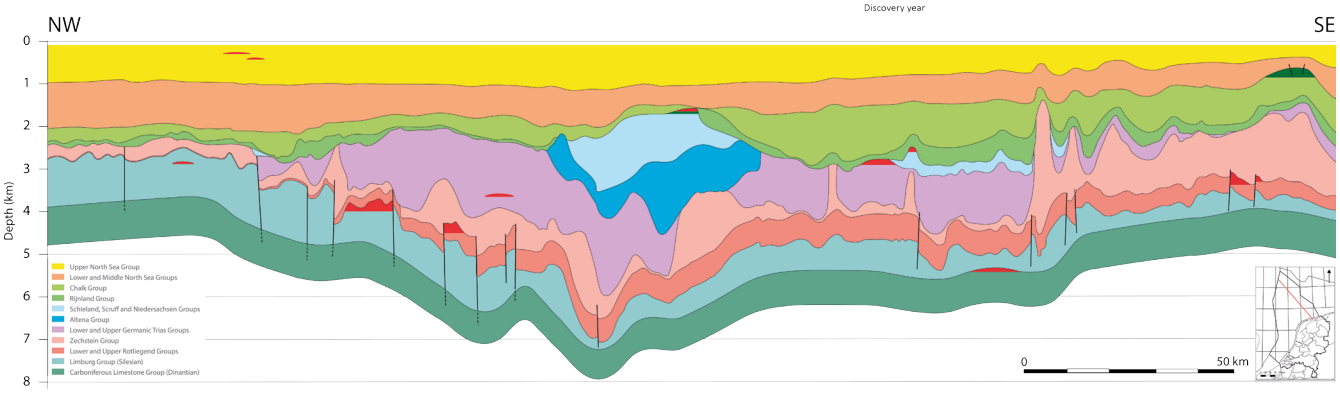

Figure 3. Schematic cross section through the northern Dutch offshore (modified after Duin et al., 2006).

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Opportunities in the Netherlands

Scope for exploration in a mature hydrocarbon province

Prospectivity per structural element
currently known resources

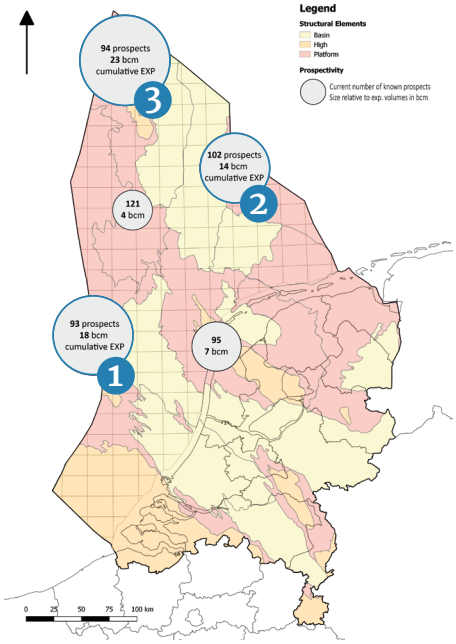

Figure 1. Prospectivity per structural element based on currently known resources.

Examples in carbonate plays

1 Dinantian Carbonates

New insights in the Dinantian Carbonates petroleum play, allowing for prospectivity:

- Wells and seismic data show potential for fractured and/or karstified (producing) reservoir
- Combined with Namurian clastics as secondary targets
- Exploration targets identified in the P-Quad (offshore)

Prospective targets

- The conceptual diagram in figure 3 shows the different scenarios for karstification and/or fracturing of Dinantian carbonate reservoir – to be explored for
- The indicated prospective structures are recognizable on seismic data

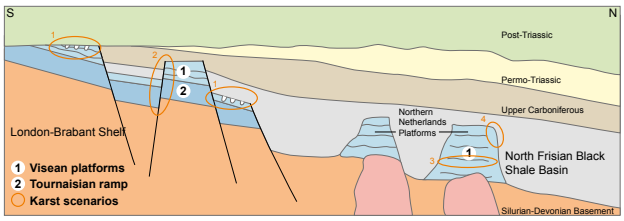

Figure 3. Locations with a higher chance of karstification are indicated by orange ellipsoids.

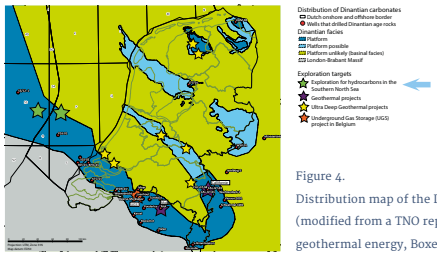

Figure 4.
Distribution map of the Dinantian carbonates (modified from a TNO report on ultra-deep geothermal energy, Boxem et al., 2016).

Simulated exploration gas volume

Simulated prediction of the **volumetric resources** expected to be found in the Netherlands up to the year 2050. This prediction is based on known prospects and leads (PMRS resource classes 8 and 9).

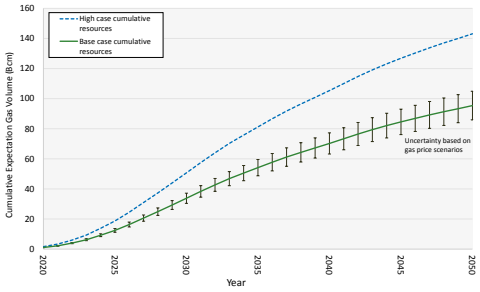

Figure 2.
Gas volumes derived from an exploration simulation using all Dutch prospects and leads known to EBN.

2 Zechstein Carbonates build-ups

- **Zechstein Carbonates**: established petroleum play in the Netherlands
- Several undrilled **build-ups** with potential
- A new **Zechstein-2 carbonate distribution and facies map** for the northern Dutch offshore
- Diverse play including sands and carbonates

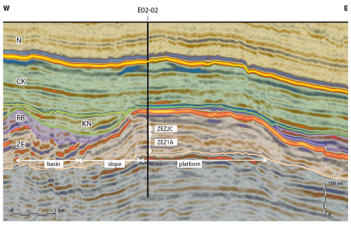

Figure 5. Seismic line across the E02-02 buildup. Illustrating the presence of carbonate build-ups in the DEFAB area.

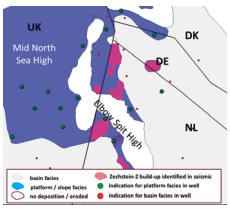

Figure 6. Zechstein-2 Carbonates distribution.

3 Chalk plays

There are several play types at Chalk level within the North Sea Basin with various trapping types and reservoir facies distribution patterns:

- Structural traps associated with salt domes e.g. Hanze (NL)
- Combined structural/dip closure traps e.g. Adda, Kraka (DK)
- Stratigraphic and/or migration traps e.g. Halfdan (DK), Rembrandt (NL)

Chalk fields

Recently, two Chalk oil fields (Rembrandt and Vermeer) have been discovered.

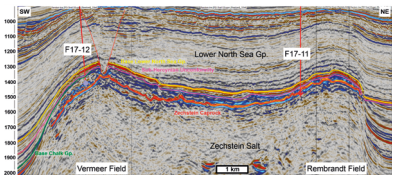

Figure 7. Seismic section across the Vermeer and Rembrandt fields (Van Lochem, 2017).

Lead: B16-Amethyst

The B16-Amethyst prospect is an example of a structural trap which has been formed due to tectonic activity associated with the underlying Zechstein salt dome. This opportunity lies in open acreage.

Trap	Large faulted / divided salt diapir closure with multiple stacked targets, shallow gas above
Reservoir	Danian and/or Maastrichtian Chalk
Seal	Tertiary shales
Source	Jurassic Kimmeridge Clay, Westphalien, Namurian, Dinantian coals/shales

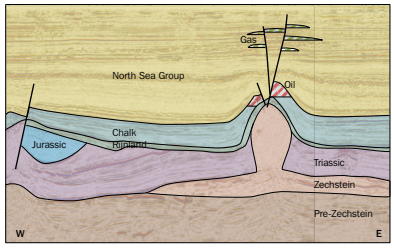

Figure 8. The structural configuration of the B16-Amethyst prospect.

All posters are downloadable at kennisbank.ebn.nl

Shallow Gas

Bright opportunities in the northern Dutch offshore

Explore for shallow gas

Cenozoic sediments in the northern Dutch offshore host abundant seismic amplitude anomalies or **bright spots** at the interval of 300–800 m depth, of which several are proven to be related to the presence of hydrocarbons. **Traps** are generally provided by low relief **4-way dip anticlines** formed by underlying salt diapirs, whereas **intercalating clays** provide the necessary **sealing** capacity. Currently, **4 shallow gas fields** are successfully **producing**, and more fields will come on stream in the coming years.

The shallow gas play has proven to be a valuable resource and with several tens of undrilled shallow leads, largely covered by 3D seismic data, it is worthwhile to further evaluate the development potential of this play.

Key factors for a **successful development** of shallow gas accumulations are:

- Distance to existing infrastructure
- Gas saturation
- Flow and storage capacity

A **challenge** remains in the presence of mobile gas and estimating gas saturation prior to drilling. Seismic attributes do not distinguish between high and low saturation or even lithological effects.

Reservoir properties

Based on fields currently in production

- Gas saturation: ~50–80%
- Expected recovery factor: ~70%
- Porosity: 20–25%
- Permeability: good to excellent (100–500 mD)

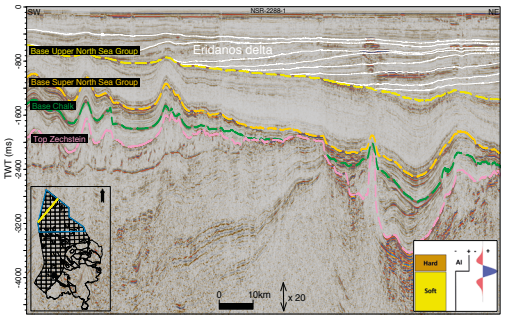

Figure 2. Seismic section through the study area showing the Cenozoic foresets of the Eridanos delta system in white.

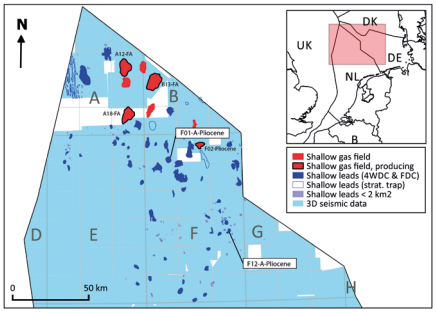

Figure 1.
Shallow gas leads in the northern Dutch offshore identified by bright spots.

High production rates despite modest pressures

The Dutch shallow gas reservoirs produce quicker than initially expected. The **A12-FA field** ranked amongst the best producing gas fields in the Netherlands with production rates around **3 million Nm³/day** from six producers.

The positive effect of production-induced reservoir compaction (rock compressibility)

- The recovery from shallow gas reservoirs is potentially enhanced by production-induced compaction of the unconsolidated sediment reservoir
- The reduction of pore volume as a result of reservoir compaction has a positive impact on the reservoir pressure and therefore the recovery. The potentially negative effect of compaction (reduction in permeability) is negligible

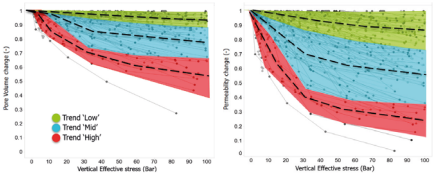

Figure 3.
Representation of rock behaviour during compaction of weakly consolidated to unconsolidated sandstone based on literature.
a. Variation in pore volume (~ porosity),
b. Variation in permeability (based on the Carman-Kozeny equation).
Three different levels of compaction are defined (low-mid-high).

Under-estimation of compaction leads to an initial underprediction of the ultimate recovery.

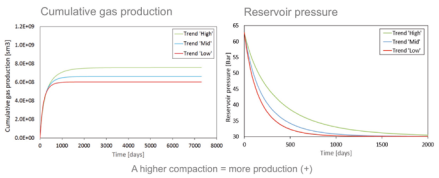

Figure 4.
Results from the reservoir simulation done on a block model with the defined compaction trends. With a higher rock compressibility, more gas is produced.

Lead F12-A-Pliocene

Licence	Open acreage
Seismic data	3D coverage, seismic data in public domain
Seismic response	Amplitude anomaly conformable to structure, flat-spot, push-down effect and attenuation
Structure	4-way dip closure
Thickness	~50 m (net-to-gross: 85%)
Porosity	> 25%
Gas saturation	± 60%
GIIP	0.5 – 0.8 – 1.1 bcm (P90 – P50 – P10)

Considering the presence of several other shallow gas leads in close proximity and the opportunity to explore for deeper targets, this lead ranks high for further detailed analysis.

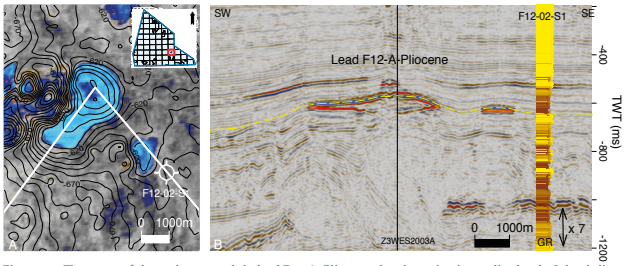

Figure 5a. Time map of the main reservoir in lead F12-A-Pliocene showing seismic amplitudes, b. Seismic line through this faulted dip closure. The top of the main reservoir is indicated by the yellow dotted line.

Lead F01-A-Pliocene

Licence	Exploration (under application)
Seismic data	High quality 3D seismic spec survey (2011)
Seismic response	Several stacked bright spots of which one single sand is considered the main reservoir. Velocity push-down, attenuation and a gas chimney can be observed.
Structure	4-way dip closure with crestal faulting

GIIP calculated by means of Monte Carlo simulation using net-to-gross, porosity and saturation ranges similar to those in the producing shallow gas fields.

GIIP	0.8 – 1.5 – 3.0 bcm (P90 – P50 – P10) Excluding the upside potential of the other sands in the stacked amplitude anomalies.

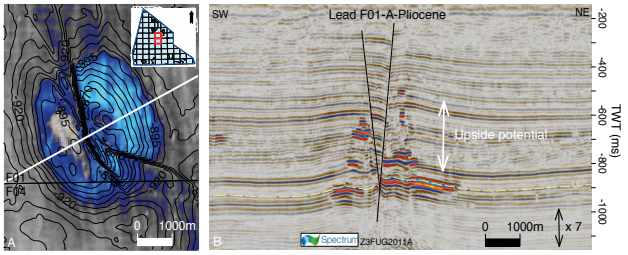

Figure 6a. Time map of the main F01-A-Pliocene lead showing seismic amplitudes, b. Seismic line through this faulted dip closure. The top of the main reservoir is indicated by the yellow dotted line.

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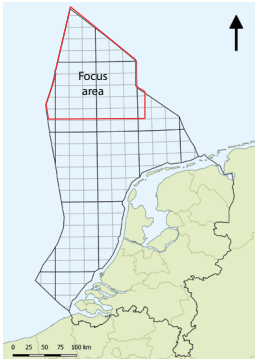
The Triassic Hydrocarbon Potential

Overlooked upside of the northern Dutch offshore

The Triassic play in the Netherlands



The Triassic is a well studied stratigraphic interval in the Dutch subsurface and represents, volumetrically, the second largest gas play.

However, this play is often **overlooked** in the **northern Dutch offshore** and presents high upside potential.

Figure 1.
Study area for the Triassic hydrocarbon potential in the northern Dutch offshore.

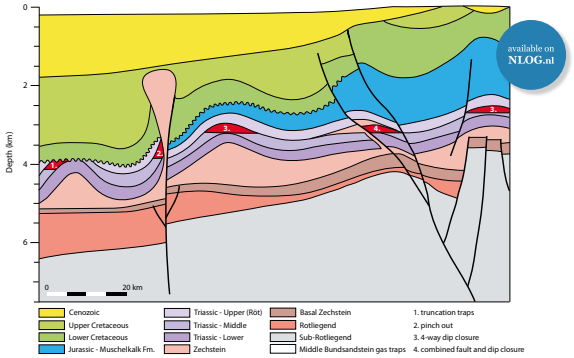


Figure 2. Schematic overview of the Triassic play concepts in the Netherlands (Petroleum Geological Atlas of the Southern Permian Basin Area, 2010).

Reservoir

The present study focused on the **Volpriehausen Sst Member** as the main reservoir:

- In general, this member has a southern provenance and shales out towards the north
- Recent studies show additional reservoir potential in the form of **fluvial sands** deposited in **local depocentres**, and **local sourcing** of sediment from the north

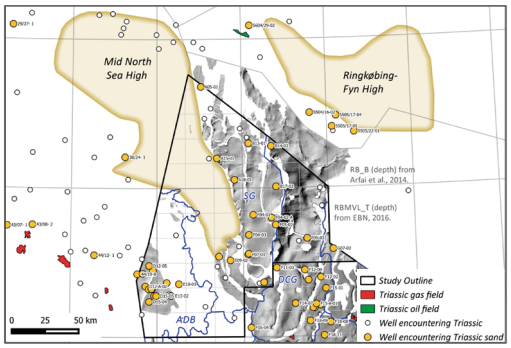


Figure 3. Top Lower Volpriehausen Sst Member depth map in the study area. Structural elements in blue (SG: Step Graben, DCG: Dutch Central Graben, ADB: Anglo-Dutch Basin) (Kombrink et al., 2012).

Source and charge

Recent studies show **potential presence and maturity** of several **source rock** intervals:

- **Coals**:
  - The **Elleboog Formation** shows a northward increase in coal content
  - Furthermore, the **Yoredale Formation** and **Namurian (Epen Formation)** contain coal; up to 7.5 m thick encountered in wells
- **Additional source rock potential** present through:
  - Migration from Westphalian coals
  - Migration from downthrown Posidonia shale
  - Charge from Namurian marine shales, present as a potential source rock in the southern region
  - Charge from bituminous Yoredale limestones

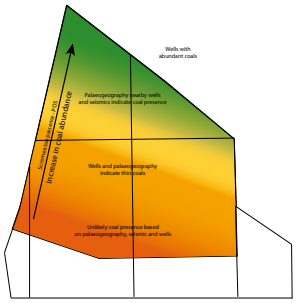


Figure 4. Source rock potential of the Elleboog Formation based on the coal content (Ter Borgh et al., 2018).

Hydrocarbon charge and migration

Two different migration pathway mechanisms are identified:

- **'Classical' vertical migration** through Zechstein windows or along major faults
- Hydrocarbon migration via **Tertiary dykes**, where:
  - Charge bypasses the thick Zechstein via volcanic dykes
  - Significant lateral hydrocarbon migration is possible

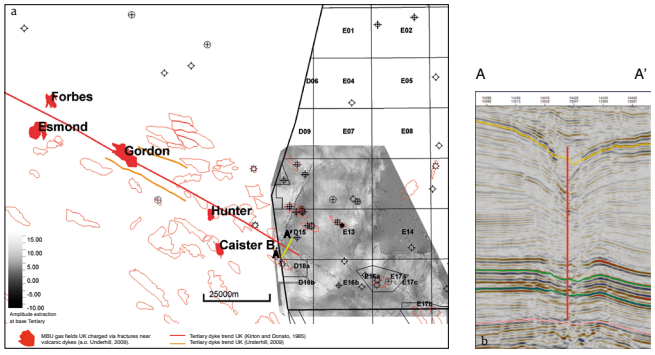


Figure 5a. Hydrocarbon migration via Tertiary dykes, b. Seismic section A-A' through Tertiary dyke. Location indicated in figure 5a.

Seal and overpressure

The Upper Triassic **Röt evaporites** are present across a large part in the area of interest and are a potential high quality seal.
Overpressures may restrict gas column height and potentially cause seal breach, however, they also **offer an opportunity** due to:

- Significantly higher reservoir pressures — **more GIIP**
- Arrest of (early burial) compaction and therefore better porosity — **more GIIP**

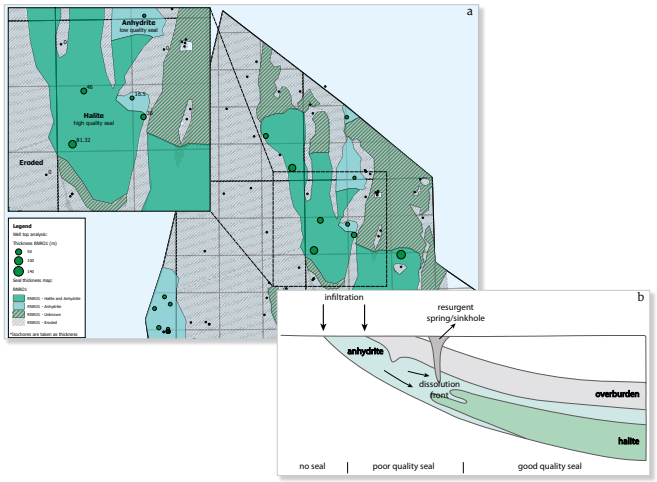


Figure 6a. Areal distribution of the Röt evaporites based on thickness found in wells, b. Schematic overview of the process of conversion of halite to anhydrite in relation to sealing quality.

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A New Upper Rotliegend Play
Opportunities in the Dutch offshore

Unlocked potential

The presence of a Lower Slochteren ('Lower Leman') reservoir equivalent on the northern feather-edge of the Southern Permian Basin is expected. The recent Cygnus discovery in the UK is a very significant play-opener as it confirms the presence of a viable Slochteren sandstone play fairway. This northerly-sourced Rotliegend play fairway is expected to extend into the Dutch offshore as well.

- The northern Dutch offshore is an underexplored area
- Presence of **Rotliegend sandstones** on the northern edge of the Southern Permian Basin is proven by a TNO study (2015)
- Rotliegend reservoir potential present in the northern offshore is waiting to be unlocked

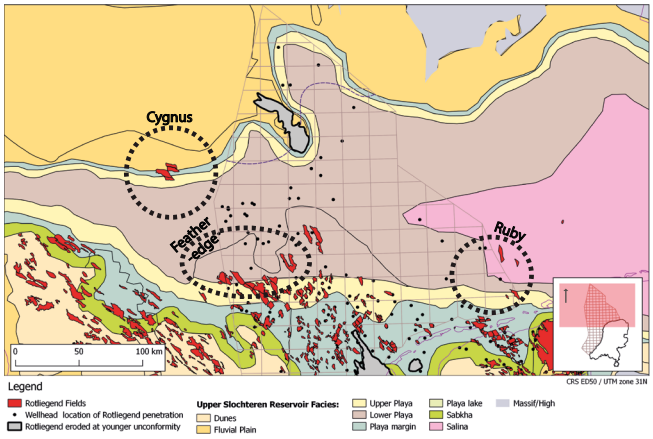

Figure 1. Facies distribution in the Upper Slochteren (modified after Doornenbal & Stevenson (SPBA), 2010).

Cygnus field

- **21 Bcm** (760 bcf) ultimate recoverable volume (forecast)
- Reservoir comprises **stacked sandstones of the Permian Leman Sandstone Formation** (Lower Slochteren Member) and **Carboniferous Ketch Formation**
- Northern-sourced play fairway at Upper Rotliegend times
- Top seal provided by shales of the Silverpit Formation
- Closure: **broad 4-way dip anticlines**

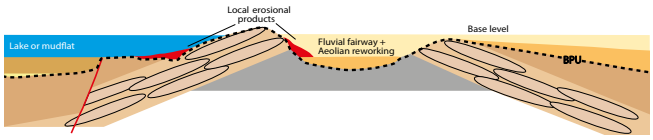

Figure 2. Cuesta model applied to the Feather-edge area (modified after Mijnlieff & Pezatti, 2009).

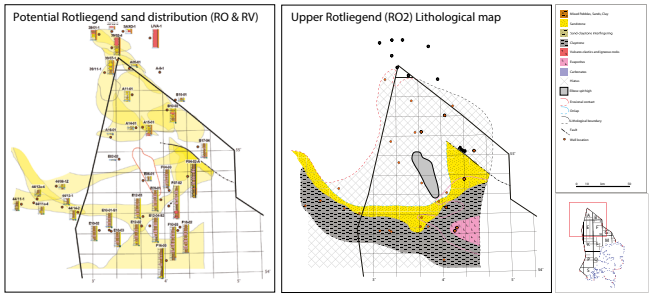

Figure 3a. Facies distribution of the basal sequence of the Lower Rotliegend Group, b. Cycle 2 (of 5) of the Upper Rotliegend Group (constrained by well data and limited 2D seismic data) (TNO, 2015).

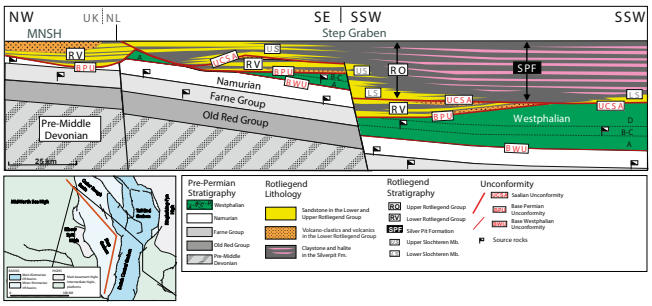

Figure 4. NE-SW trending cross section through the Step Graben and Elbow Spit High.

Reservoir

The presence of reservoir sands depends on the transport of sand from the north into local depressions. A varied landscape of depressions and asymmetrical highs ('cuestas') was created as a result of differential erosion after the Variscan orogeny. This cuesta-**type landscape** is interpreted to have controlled the distribution of the Lower Leman Sandstone, this is a **proven concept** elsewhere in the Dutch and UK offshore:

- Feather-edge area (Mijnlieff & Pezatti, 2009)
- Ruby area (Corcoran, 2014)
- Cygnus area (Catto et al., 2018)

Tectonostratigraphic setting

A tectonostratigraphic review has been carried out (TNO, 2015) with the following conclusions:

- Sand-prone Lower Rotliegend strata are proven to be present in the north-eastern part of the study area (fig. 3.)
- Sand-prone Upper Rotliegend reservoir facies are present along the northern margin of the paleo Silver Pit Lake, in an E-W trending belt across the northern Dutch offshore area. This belt likely has migrated northward through time due to the infill of the Southern Permian Basin (fig. 4.)

Prospectivity

Petroleum system modelling has been carried out and provided better insights into the thermal maturity and timing of hydrocarbon generation and expulsion. Combination of the distribution of thermally mature source rock and the presence of Permian-aged reservoir rock has allowed identification of prospective areas, which require further analysis to define and mature a prospect portfolio.

Lower Carboniferous
A virtually untested play

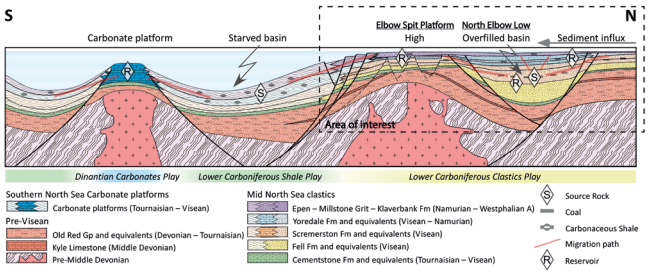

Figure 1. Diagram illustrating the structural geology and play elements of the Visean and Namurian in the Mid North Sea area. The Elbow Spit Platform is an example of a high, while the North Elbow Low is an example of an overfilled basin (Ter Borgh et al., 2018).

Play elements of the Lower Carboniferous plays

The **Visean and Namurian deposits** in the northern Dutch offshore have significant hydrocarbon potential:

- **20 structures** have been identified on the Base Permian Unconformity (BPU) depth map, all **4-way dip or fault dip closures**. Provisional P50 GIIP's add up to ~75 BCM (unrisked)
- The Lower Carboniferous clastics play is established in the UK part of the southern North Sea. The UK fields are producing from Namurian and Visean reservoirs (e.g. Breagh field development)
- From well reviews it is concluded that the play is **virtually untested** in the northern Dutch offshore

Reservoir

- **Visean and Namurian reservoir rocks** are present throughout the study area
- Abundance and thickness of sands with reservoir quality increase from Breagh (well 42/13-2) towards the northeast

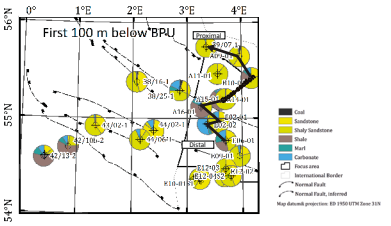

Figure 2. Lithological statistics of the first 100m below BPU. High chances of encountering sandstone in the Visean or Namurian directly below the BPU.

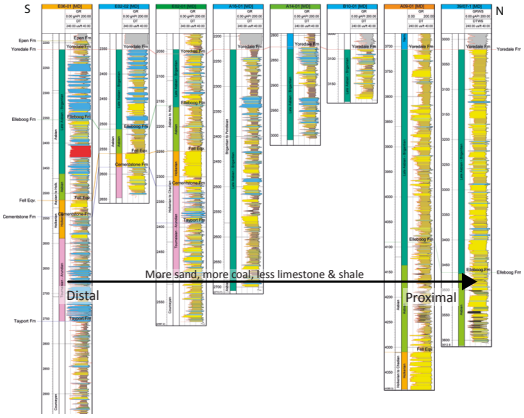

Figure 3. Well correlation panel of the Visean, illustrating lithological trends. The location and legend are presented in fig. 2.

Source and charge

- **Lower Carboniferous Scremerston coals** are the most promising source rocks in the northern part of the study area
- In the southern part charge may occur from **Lower Carboniferous basinal shales** and laterally from **Upper Carboniferous Westphalian coals**

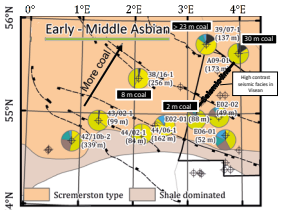

Figure 4. Palaeogeographic chart and lithological statistics for the Lower–Middle Asbian. Coal content increases towards the north. Legend presented in fig. 2 (UK palaeogeography after Kearsey et al., 2015, 2017 and UK structures after Arsenikos et al., 2015).

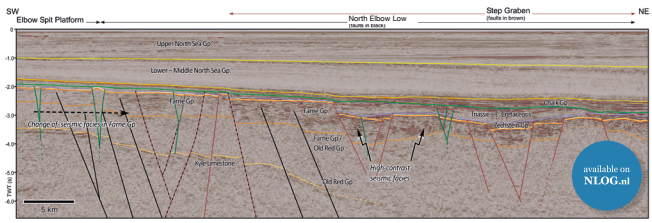

Figure 5. Seismic section across the North Elbow Low. The Visean Elleboog Formation has a high contrast seismic facies presumably caused by the presence of coals. Location presented in fig. 4. Public seismic line NSR32294.

Seal and trap

- Numerous fault and dip closures at BPU level, below Silverpit shales and Zechstein salt, which are proven regional seals
- Fault dip closures are dependent on juxtaposition sealing across faults
- Presence of intra Lower Carboniferous seal(s) would provide large upside

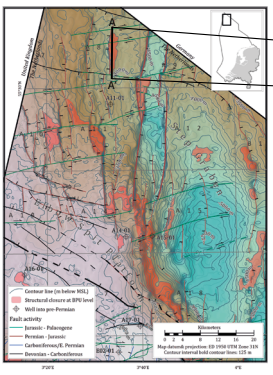

Figure 6. Structures at BPU level in the A quadrant, illustrating the types of structure that may form traps for hydrocarbons. The figure should not be regarded as a detailed assessment of the prospectivity of the area.

Lead

A8-Kilimanjaro lead

Reservoir	Namurian & Visean clastics
Seal	Silverpit shales and salts & Zechstein salt
Source	Scremerston coals

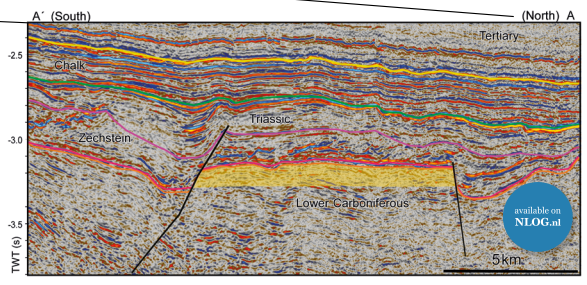

Figure 7. Example of a lead (A8-Kilimanjaro) at BPU level (public 3D seismic data). Location in fig. 6.

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Previous Years' Posters

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2017

- Your gateway to Dutch data – Subsurface data available free of charge on NLOG.nl
- Your gateway to Dutch data – Learnings from big data analysis by EBN
- Why the Netherlands – Favourable market & tax conditions
- Triassic prospectivity – Lower Triassic reservoir development in the Dutch northern offshore
- Shallow gas – Bright opportunities in the Dutch offshore
- Regional porosity and permeability prediction – 17 Maps of reservoir zones
- Predicting fault sealing – A collaborative project
- Lower Carboniferous – A virtually untested play
- Dinantian carbonates – Exploring potential for hydrocarbons and geothermal energy

2016

- Reservoir properties revisited – Results of data mining in www.nlog.nl
- Dutch Geothermal Development – The other energy resource
- Synergy in Gas Field Development – Dual heat and gas production strategy
- Dinantian carbonates – Exploring for synergy between E&P and geothermal
- Triassic reservoir sands in the Dutch northern offshore – New results from seismic and cutting analyses
- The Late Jurassic in the Central Graben – Further prospectivity in a proven play
- Reservoir potential of the Upper Jurassic: Upper Jurassic shallow marine sandstones in the northern Dutch offshore

2015

- Your gateway to Dutch data
- Structural framework of the Mid North Sea area, Palaeozoic to present
- Source rock potential of the Dutch northern offshore
- Lower Carboniferous clastics: a virtually untested play
- The Triassic Main Buntsandstein play: new prospectivity
- Multi-target exploration combined with minimum facility development
- Prospectivity G and M blocks: analysing the Upper Jurassic play
- The Chalk: towards a better tectono-stratigraphic framework

2014

- Oil and Gas in the Netherlands
- Netherlands Oil and Gas Portal
- Recent exploration studies
- Underexplored Triassic
- Underexplored carbonates play
- Recent oil activities
- New insights from old data
- Innovative low cost development
- Hydraulic stimulation – 50 years of experience

Application for an Exploration Licence in the Netherlands

To effectively manage the extraction of oil and gas in the Netherlands, the rules of the Mining Act (Mbw), the Mining Decree (Mbb) and the Mining Regulations (Mbr) apply. In addition to these specific mining regulations, other legislation such as environmental law also applies. There are various laws and regulations within environmental law that may apply to the extraction of hydrocarbons. These are not further discussed in this summary. An extraction project is divided into four phases in the Mining Act, namely:

1. Surveying (seismic survey)
2. Prospecting (exploration)
3. Extracting (production)
4. Cleaning up (abandonment)

Phases 1 and 2 apply for exploration. This text provides an introduction for companies that want to explore in the Netherlands. This manual is not exhaustive; only the most important laws and regulations are described.

Phase 1: Surveying

Surveying minerals or geothermal energy without a borehole is called 'surveying' in the Mining Act. In fact, this refers to the performance of seismic surveys.[1]

A mining company does not need a permit from the Minister of Economic Affairs and Climate (Minister) for offshore seismic surveys. A separate permission is only required when there are also nature, shipping and/or defence interests in the area concerned.

Notification of seismic survey

If a mining company wants to carry out a seismic survey, it must report this to the Inspector-General of Mines (State Supervision of Mines).[2] This means that at least four weeks before the start of the exploration survey, the mining company must provide information to State Supervision of Mines about which surveys will take place, where and when.[3]

Seismic survey results

The mining company must provide the Minister with the results within one year of the end of the seismic survey. TNO (Technical Research Institute, Netherlands) then checks and manages the data on behalf of the Minister. Seismic data and the accompanying reports are available via www.NLOG.nl five years after the acquisition has ended. For commercial seismic surveys (multi-client surveys) a ten-year confidentiality period applies.

Phase 2: Prospecting

Prospecting concerns the investigation of the presence of minerals using a drill hole i.e. an exploration well. Before starting the exploration well, an exploration license to prospect must be applied for.

Exploration license

An exploration license is granted by the Minister. An exploration license is a market regulation licence and is not a licence for the performance of certain exploration activities.[4] The manner in which an exploration license is applied for and granted by the Minister is laid down in the Mining Act.[5]

The application for an exploration license contains an indication of both an area and a time period. Furthermore, documentation regarding company data[6], a geological report and a work programme is included with the application. The Minister publishes a notification of the application

in the Bulletin of Acts and Decrees and in the Official Journal of the European Union. In the publication, the Minister invites other parties to submit competitive applications. The deadline for submitting a competitive application is 13 weeks. The Minister takes a decision on the application within six months of the end of this submission period. This decision period can be extended once by six months.

The Minister requests advice from State Supervision of Mines and the Mining Advisory Council for the assessment of the application. The Minister may attach additional regulations to the license, such as the obligation or prohibition of certain techniques or activities for (parts of) the area.[7] A notification is made in the Government Gazette of a decision to grant the license.

After granting the license, the Minister can only withdraw or change the license in urgent cases.[8] The license can also be changed at the request of the license holder. For example, to reduce the authorised area, to change the operator or to transfer the license (partially) to another party.[9] However, changing the activity (for example, extraction instead of exploration) or making the area bigger is not possible.[10] An extension of an exploration license period is only possible if the stipulated period for the license proves insufficient to complete the activities.[11]

Work plan exploration

Within four weeks of issuing the license, the operator must submit a work plan to State Supervision of Mines.[12] The work plan includes, among other things: an overview of the main mining activities anticipated over the next five years, maps of the structure of the subsurface, possible drilling work and any construction work, a health & safety plan and an up-to-date organisational diagram including the responsible persons.

Entering into an agreement

Once the exploration license has been granted, the license holder enters into several agreements. The mining company can invite EBN to participate in the exploration. EBN cannot refuse this invitation. The license holder and EBN will conclude an Agreement of Cooperation (OvS Exploration) within six months of granting. This requires the Minister's consent. EBN then participates for 40% in the participation but does not become an exploration license holder or operator.[14] If several parties obtain an exploration license together (co-license holders), they usually also enter into agreements with each other.

Permission to construct a well

Separate permission must be requested from the Minister for an exploration well. For this it is important to determine in time whether an Environmental Impact Assessment (EIA) is mandatory. An EIA process is performed before submitting the request for consent. The operator must inform the Minister of his intention to request a consent decision and ask whether an EIA is required for the license area. The Minister decides at the latest six weeks after receipt of the application. If the Minister decides that an EIA is necessary, this EIA must be submitted to the Minister together with the request for consent.

The operator must request approval at least four weeks before the start of the work. With this application, the operator must, among other things, hand over specific (technical) information about the exploratory drilling to the Minister. The application for approval is published in the Government Gazette. Consent can only be refused in the interest of environmental protection.

BARMM notification

Once a well has been drilled, no separate environmental permit is required for changing, testing, maintaining or decommissioning. An operator who intends to carry out work on a drill hole with a mobile installation must report this to the Minister no later than four weeks before the work in a so-called BARMM report.[15]
More information is available on www.hoewerktgaswinnen.nl and http://wetten.overheid.nl.

1 Chapter 2 of the Mbb and Mbr; 2 Section 49 and 130 Mbw; 3 Article 10 Mbb; 4 See for example Drill hole (Licences) Decree (Bulletin of Acts and Decrees 2017, no. 114)/ Ex. Mem. Safety and Direction (Parliamentary Papers 34348 no. 3); 5 See chapter 2 Mbw and mutatis mutandis provision Section 6(3) Mbw; 6 Article 1.3.1 paragraph 2a and annex 1 Mbr. If several applicants make the application, this information is provided separately for each applicant (Article 1.3.1, paragraph 3, Mbr); 7 Section 13 Mbw; 8 Section 18 Mbw; 9 Section 18(1)(a) Mbw; 10 Section 18(2) Mbw; 11 Section 18(3) Mbw; 12 Articles 4 Mbb and 1.11.1 Mbr; 13 Section 87 Mbw; 14 Section 88 Mbw; 15 Articles 6, 7 and 8 BARMM

A Dutch Exploration Investment Initiative

EBN is looking to co-invest in underexplored acreage of the Dutch Southern North Sea (SNS), where 200-300 Bcm of natural gas is expected to be found at 2-4 km below the subsurface. Deloitte reviewed the Dutch Exploration & Production (E&P) climate.

Key messages

- The Netherlands has a good and stable business climate and E&P ecosystem, prospectivity is most naturally suited to small & medium sized E&P
- The Dutch regulatory and fiscal climates are generally benign
- Small investors with experience in NL like the investment climate and the strong incremental returns
- Small investors appreciate EBN's large investment share in the exploration phase as it gives them certainty and reduces their risk

The Dutch North Sea includes many underexplored areas, where both practical experience and geological and geophysical studies show circumstances to be right for the presence of oil and/or gas. The abundance and high quality of available data and EBN coordinated research efforts drive exploration efforts and success rate of the Dutch SNS to be the highest in the area.

EBN co-invests in E&P, typically with a 40% investment stake. EBN, as nonoperating partner, aims to attract both E&P capabilities as well as pure financial investments from e.g. private equity or pension funds to increase Dutch natural gas production.

EBN promotes investment in underexplored areas to increase production and reduce the gap between gas production and demand. This is part of EBN's broader strategy to energize the transition to a climate neutral energy system, given that Dutch natural gas is the preferred fossil fuel to meet market energy demand.

Prospectivity

- Relatively low investment capital required
- Offshore assets are well maintained
- Well developed and competitive oil field services
- Downstream access to Northern & Central European markets

E&P ecosystem

- Mitigation of exploration investment risk with EBN 40% stake
- Partners are supported by EBN with data and certainty
- Investment partnerships gain credibility from EBN

Business climate

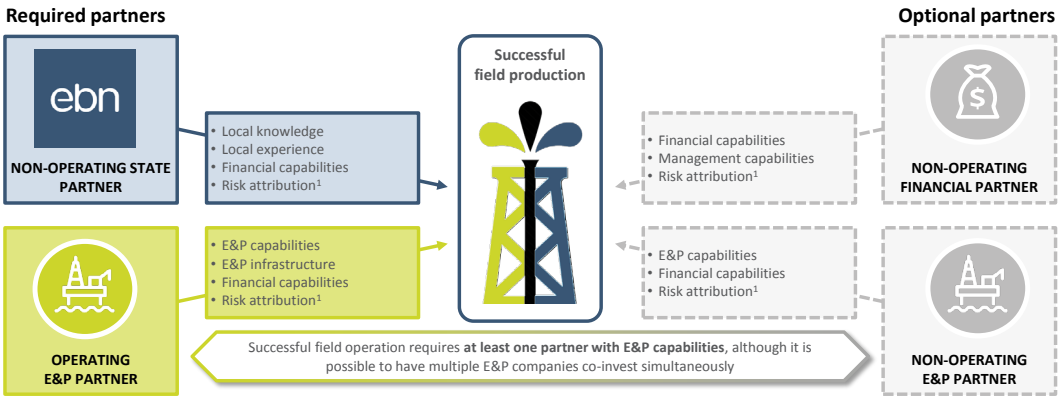
- Stable Macro factors (political, economical, etc.)
- Very open to do business
- Clear distinction between on- and offshore investment policy

Regulatory

- Stable regulatory regime
- With the open door policy you can apply for licences at any time

Fiscal

- Stable and beneficial fiscal regime
- Marginal Fields Tax Allowance: 25% gross tax deduction



Note: 1. By jointly investing in E&P, stakeholders share financial risks, thereby lowering the overall risk profile of their investment portfolio.

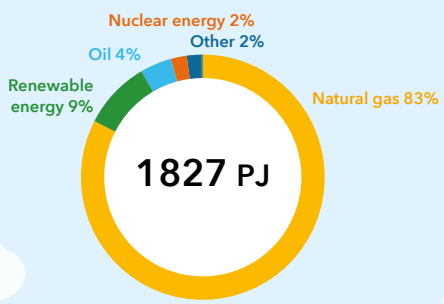
ENERGY IN THE NETHERLANDS

SUPPLY

DEMAND

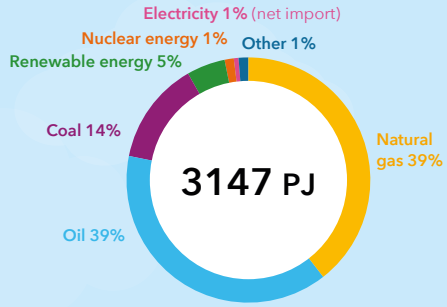
Energy is a basic need and everyone uses it. It is produced from various sources and transported to end customers, often converted into power or heat. Supply has to match energy demand every single day. Energy makes sure the lights go on, houses are heated and hot water is available, it powers cars and ships and is ubiquitous in our daily lives. The production and use of fossil fuels causes emissions of greenhouse gases. This infographic shows the Dutch energy system and its greenhouse gas emissions. We hope this information will provide the basis for good discussion.
More information can be found on www.energieinnederland.nl.

Energy production



2018

Primary energy demand



Oil refining
11 Mton

Power production companies [1]
52 Mton
(allocated to sectors)

Gas and oil production
2 Mton

Total
197
Mton CO_2-eq

Other greenhouse gases
29 Mton
(CH_4, N_2O, F-Gases)

Services, Waste & Water
28 Mton
(11 Mton direct)

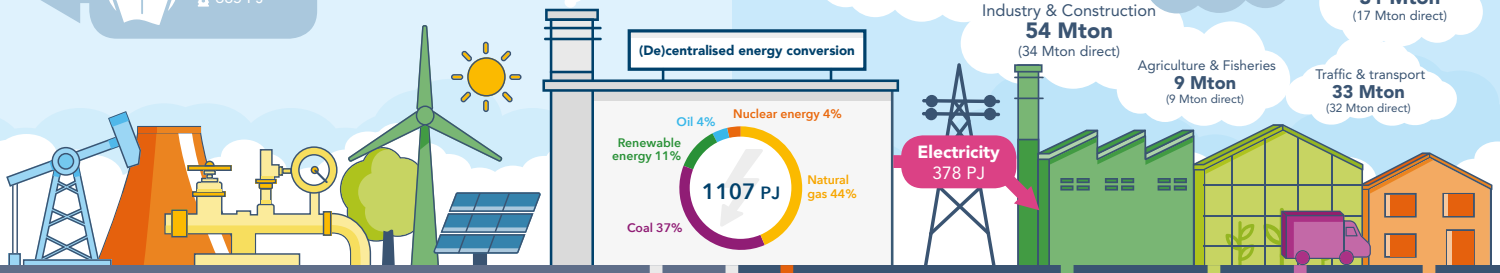
Industry & Construction
54 Mton
(34 Mton direct)

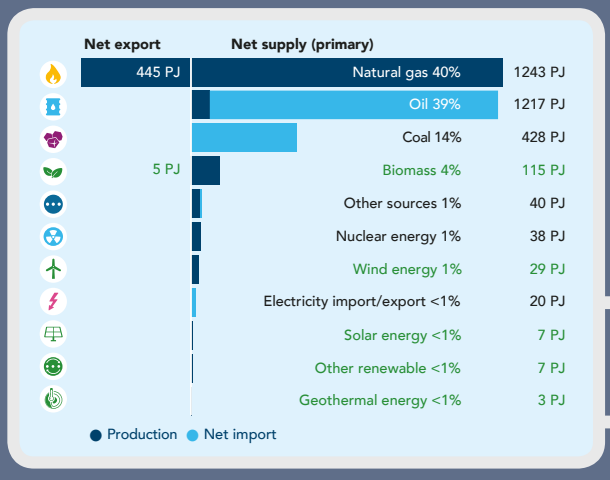
Agriculture & Fisheries
9 Mton
(9 Mton direct)

Households
31 Mton
(17 Mton direct)

Traffic & transport
33 Mton
(32 Mton direct)

International transport:
685 PJ





For energy conversion:
1107 PJ

Direct:
2040 PJ

(Residual) heat:
165 PJ

Losses:
729 PJ

Direct consumption:
1875 PJ

1 PJ = 0.28 TWh

Final consumption

46%

Industry & Construction
1116 PJ

50% Raw materials
- Oil 85%
- Natural gas 15%

37% Heating
- Natural gas 43%
- Oil 27%
- Heat (incl. from CHP) 24%
- Coal 5%
- Other 1%

11% Power & light
- Electricity 100%

2% Mobility
- Oil 100%

7%

Agriculture & Fisheries
157 PJ

65% Heating
- Natural gas 51%
- Heat (incl. from CHP) 42%
- Geothermal heat 3%
- Biomass 3%
- Oil 1%

20% Power & light
- Electricity 100%

15% Transport
- Oil 100%

18%

Transport
443 PJ

99% Transport
- Oil 98%
- Electricity 2%

1% Raw materials
- Oil 100%

12%

Services, Waste & Water
286 PJ

52% Heating
- Natural gas 85%
- Heat (incl. from CHP) 7%
- Ambient energy 3%
- Oil 2%
- Biomass 1%
- Electricity 1%
- Other 1%

45% Power & light
- Electricity 100%

2% Transport
- Oil 100%

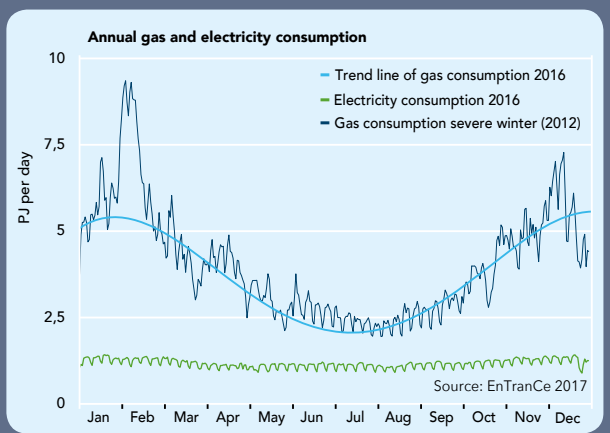
1% Raw materials
- Oil 100%

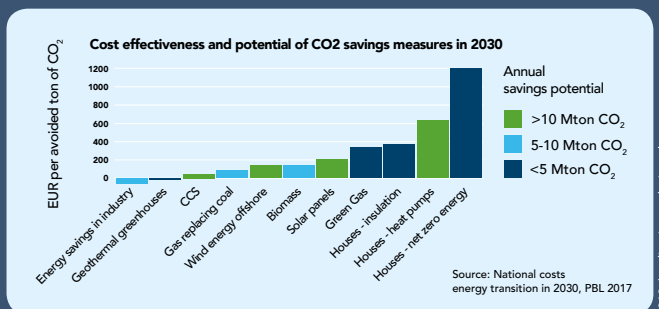
17%

Households
416 PJ

82% Heat
- Natural gas 87%
- Biomass 6%
- Heat (incl. from CHP) 4%
- Electricity 2%
- Ambient energy 1%

18% Power & light
- Electricity 100%





energie in nederland.nl

ebn

[1] Emission Electricity generation companies allocated to end-use sectors based on EBN analysis.
For an explanation, datasets and disclaimer see www.energieinnederland.nl.
Source: CBS unless otherwise indicated. Reporting year 2016.

2018 / realisation: a-design.nl

Ministry of Economic Affairs
and Climate Policy

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