

Geo-perspective

Dutch natural gas strategy: historic perspective and challenges ahead

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Abstract

We highlight a watershed in the natural gas legacy of the Netherlands: after 50 years of successful gas development, production output of conventional fields will decline from 2010 onwards. The projected decline in Dutch gas output will lead to a loss of future income for the State. In the past, E&P companies were prepared to compete for access to Dutch assets and lead in research as well as in the exploration for the development of *conventional* gas resources. Today, this cannot be assumed for the development of unconventional resources. It is not clear from our current state of knowledge whether the riskier unconventional gas resources in the Netherlands will be attractive for E&P companies. For example, are the financial risks for maturing potential unconventional resources into economic proved reserves acceptable to them? The US boom in unconventional gas production was preceded by government sponsored research programmes that stimulated the development of unconventional gas production technology. Decline in domestic gas production in the Netherlands therefore prompts for a dedicated upstream gas research programme. This will help to unlock future value from stranded conventional gas and unexplored unconventional gas resources. If such new gas resources can indeed be developed with the aid of research, undue loss of state income can be mitigated, which makes such a programme a compelling business case.

Keywords: Dutch gas reserves, unconventional gas resources, Groningen field

Introduction

The Dutch State, like most nations, continually aims to optimise its return on the endowed natural resources (Knaap & Coenen, 1987). Most income from petroleum and mineral business operations in the Netherlands is derived from natural gas activities (Fig. 1). Coal is no longer produced in the Netherlands since the last mines were closed in 1973. Dutch oil production was at a modest 72,000 bbl/day in 2009 (MEZ, 2010). But the Netherlands ranked as the world's 6th natural gas producer and 7th exporter in 2009 (OECD/IEA, 2010a). After a major gas discovery in 1959, the Dutch government made a bold move to develop a national gas market by building a national distribution network simultaneous with the onset of production in 1963 (NAM, 2007).

Earnings from the national gas endowment began to accumulate for the State from 1965 onward and the substantial income from the national gas endowment has been part of the

Dutch government's operational budget ever since. The State's '*easy cash from gas*' has generated a total sum of 220 billion Euro during operations over half a century as per January 2010 (Fig. 1). The annual variation in gas income, between € 4.5 and € 14.8 billion over the last decade, has been due to the considerable volatility in global energy prices. Gas income constituted between 1 to 3% of the Dutch GDP (€ 500 Billion). The compounded State earnings of € 220 billion over the 3000 bcm gas produced in 50 years translate to a time-averaged benefit of € 73 million per bcm gas. Over the past decade alone, with higher energy prices, the average State income from gas business averaged about € 100 million per bcm.

'*Dutch Disease*' is a technical term for the inflationary pressure on the national currency (not yet in the Eurozone until 1999, followed by single currency introduction in 2002) due to the influx of new gas money into the Dutch economy (Schotten & Wierds, 2008). Unlike Norway, which created a Sovereign Wealth Fund (SWF) from excess oil and gas earnings to protect its

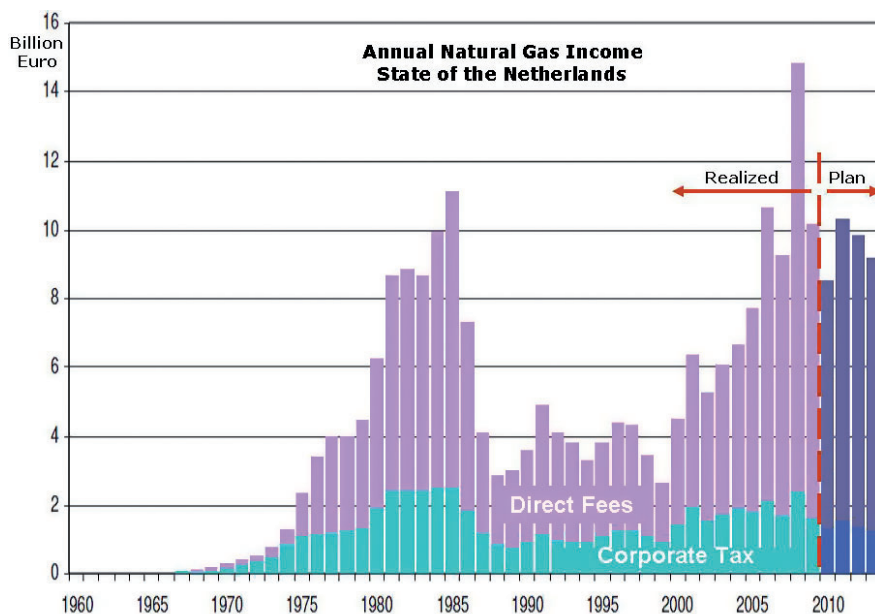


Fig. 1. Annual net income for the Dutch State from natural gas business operations. Corporate Tax income is based on profits realised by up-, mid- and downstream companies in the gas value chain. Direct Fees are income from state participations, licenses, and legal fees. (Data source: MEZ, 2010).

national economy against inflation, the Netherlands has chosen not to install such a SWF. Instead, gas income has been spent by the government over five decades, mostly as sunk cost into durable infrastructure, with the argument that such spending would cushion inflation and future wealth would be generated by the improved infrastructure. The debate to cure the *Dutch Disease* by creating a belated '*Netherlands SWF*' continues until today (Schotten & Wierts, 2009).

The 'Easy Gas Cash' years

What made the State's Gas Cash Cow possible? In the first place, the presence of the Groningen gas field was a geological prerequisite. The subsequent key to the successful development of Dutch gas resources was the provision of an attractive 'hydrocarbon business climate' for E&P companies who bear considerable financial risks when developing potential gas resources into economic proved reserves (Breunese et al., 2005; Breunese & Rispens, 1996; De Jager & Geluk, 2007). In the early days, after the Groningen Field was discovered (1959), the State developed a visionary policy with Exxon and Shell by licensing the development of the required gas pipeline infrastructure to instantly establish a national gas market (Kielich, 1988; Gasunie, 1998; Correlje et al., 2003; Schenk, 2009). The NAM (Nederlandse Aardolie Maatschappij) developed and operates the Groningen Field on behalf of the Maatschap Groningen (60% NAM – which is a 50/50 joint venture Shell/Exxon, and 40% EBN – which is the state representation; cf., Stewart & Madsen, 1987; NAM, 2007; Weijermars & Madsen, 2011). Exxon and Shell have enjoyed enormous returns on investment from their NAM venture. For example, Exxon received a net income of \$ 2.5 billion from its NAM joint venture in 2007, contributing 6% to its corporate net income.

Most of the Dutch gas endowment is still located in the Groningen Field, Europe's largest single field with 2875 bcm EUR (Estimated Ultimate Reserves) as reported per 31 December 2009 (MEZ, 2010). Many smaller conventional gas fields (some 235 in total) have later been discovered both on- and off-shore, with initial recoverable reserves totalling 1648 bcm (MEZ, 2010). The produced volumes and remaining proved reserves (developed and undeveloped) as per 31 December 2009 are given in Table 1. Operating licenses are currently held by NAM, Wintershall, GDF Suez, Chevron, Total, TAQA, Cirrus Energy, Vermilion, Northern Petroleum, SES and Ascent.

The Groningen Field, the most important source of natural gas in the country, reached an annually averaged peak production of nearly 85 bcm per year in 1975. The initial gas strategy was to sell as much gas abroad as possible. At that time the expectation prevailed that the developing nuclear energy would lead to reduced demand for natural gas (Lagraaij & Verbong, 1999; Hoegelijs et al., 2010). Massive social pressure against nuclear power in the early 1970s led to a strategy shift and underlined the importance of an extended gas production life-cycle. The Dutch government decided that from 1974 onward

Table 1. Dutch gas resource portfolio as per 31 December 2009.

	EUR*	Produced*	Reserves left for production*
Groningen Field	2875	1839	1036
Onshore small fields	796	626	170
Territoir total	3671	2465	1206
Offshore small fields	852	668	184
NL totals	4523	3133	1390
Small fields subtotal	1648	1294	354

* All volumes in bcm per year for standard conditions 15° C and 101,325 kPa (source: MEZ, 2010)

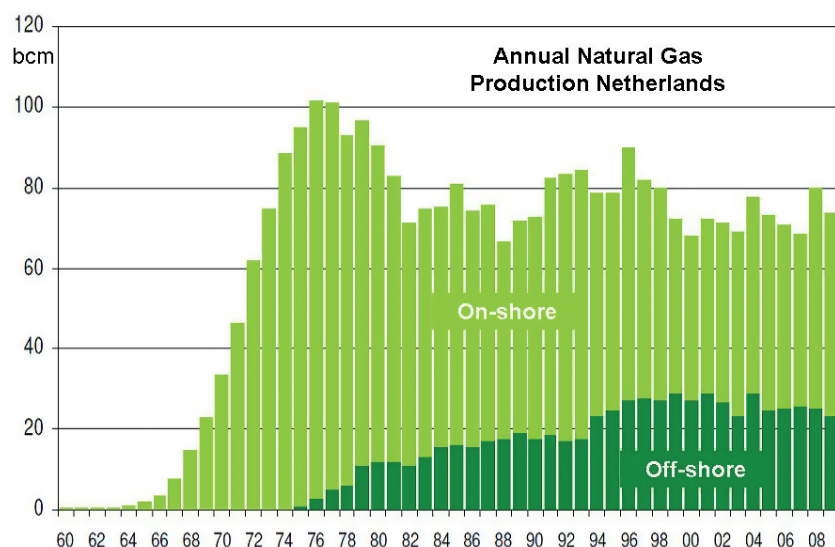


Fig. 2. Annual production of natural gas in the Netherlands. About half of the production is from smaller fields, both on- and offshore; the other half is from the Groningen field, here included in the onshore production – not separately indicated (Data source: MEZ, 2010).

it would actively encourage exploration and exploitation of smaller gas fields and provided the required policy incentive – the so-called ‘Small Field Policy’. Small fields are given priority access above Groningen gas by guaranteeing off-take in the national gas transmission network. This means that these fields can be developed to their maximum efficiency and do not suffer from highs and lows in demand. This policy has been further successful in extending the production life-cycle of the Groningen Field (Roels, 2001).

After Dutch gas production peaked in the 1970s, production from the Groningen field was deliberately scaled down to extend its lifecycle and preserve some of the gas for future value (Fig. 2). Groningen now acts as a swing producer to balance seasonal fluctuations in demand. The base load for the Dutch gas system is provided by the 235 smaller fields, which together with Groningen have supplied an average of 75 bcm per year over the past three decades (Fig. 2).

The high gas prices in the early 1980s delivered an increased gas income for the State (Fig. 1) in spite of domestic production cuts in the late 1970s (Fig. 2). Global energy prices briefly peaked in 1985. The State’s natural gas income began to diminish in the period 1985 to 2000 due to a decline in global energy prices. The past decade has seen a recovery (if not explosion) of global energy prices, which explains the steep rise in State income from natural gas over the past decade (Fig. 1), in spite of a more or less steady production output (Fig. 2).

How long will the State’s Cash Cow last?

Recent field overhaul and the installation of compressors have further enhanced the recovery factor and lifetime of the Groningen Field (OGJ, 2009). In spite of the life cycle enhancements by a combination of strategy, policy and technology measures, any field – including the SuperGiant Groningen Field – will eventually come off plateau production and enter into decline (Fig. 3). Over the next 25 years, production from Dutch

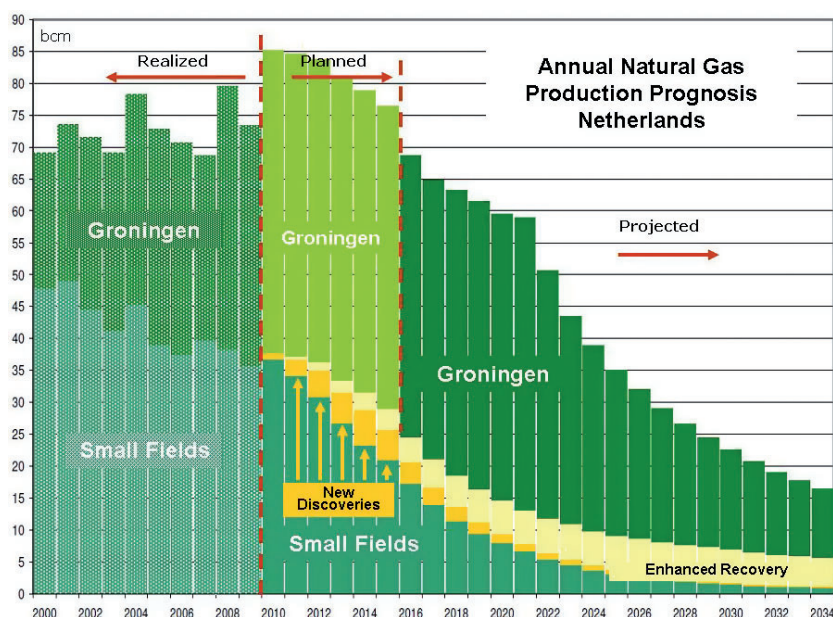
conventional natural gas fields will decline from 85 bcm in 2010 to 15 bcm in 2034 (Fig. 3). By 2034, Groningen and the conventional small fields will jointly produce only some 15 bcm/year.

The predicted gas production shows an average decline of 2.8 bcm/year. As a consequence, the Dutch State’s income from conventional gas will be reducing by some € 250 million per year. The loss for the State’s budget in 2020 will amount to € 2.5 billion. The next section will describe the past security of supply measures, and then explores strategy solutions that remain to stave off the imminent decline in the domestic supply of natural gas.

Dutch Gas Trade – security of gas supply by import/export activities

The Netherlands has established a diversified gas production system. The physical distribution network is supported by the Dutch small field policy and today’s net-export capacity has improved Europe’s security of supply. After Norway, the Netherlands remains Europe’s 2nd largest supplier of indigenous natural gas in 2009 (OECD/IEA, 2010a). In a European context, the imbalance between internal natural gas production and consumption makes Europe vulnerable to security of supply concerns. IEA data show that the domestic gas production of European nations could meet only about 55% of the demand in 2009 (Fig. 4a). The remaining 45% of Europe’s gas was supplied by pipeline imports from Russia, Algeria and Azerbaijan (33%), complemented with 12% LNG imports from Algeria, Qatar, Nigeria, Trinidad and Egypt. The statistics of the International Energy Agency (IEA) further show that of the 16 countries in the OECD Europe, only Norway, Denmark and the Netherlands still harness sufficiently large gas reserves to cover their domestic demand for natural gas for a decade (Netherlands, Denmark) or longer (Norway). All other countries of OECD Europe had become net importers of natural gas by 2009 (OECD/IEA, 2010b).

Fig. 3. Annual production of natural gas in the Netherlands from the Groningen Field and small fields since 2000. Discovery of new conventional small gas fields will add some volume annually, but will not prevent decline, first of small fields, then joined by the Groningen Field's decline from 2021 onward (Data source: MEZ, 2010; Slight mismatch with volumes in Figure 2 is due to bcm correction factor for the lower caloric value of Groningen gas).



For a global comparison, the OECD Europe market for natural gas is only 4/5th the size of the US market (Fig. 4b). In 2009, OECD Europe consumed 17% of the world's natural gas, and is the world's 3rd largest gas consumer after the US and the former Soviet Union. The former USSR consumed 20% – but is a net exporter. The US consumed 21% of the world's total natural gas production. North American gas production accounts for nearly all its consumption, complemented with less than 1% by LNG imports. This is in stark contrast with the European gas imports of over 45% from outside the EU zone.

The Netherlands has supplemented part of its gas export capacity through the import/export trading of gas (acquired from abroad). For example, the 2009 total Dutch gas exports of 55 bcm (Fig. 4c) were over a half from excess production of domestic gas (30 bcm), while the remainder came from re-exporting trade gas imports. In 2009, trade gas imports were bought by the Netherlands from: Norway (13 bcm), UK (5 bcm), Russia (4 bcm), Denmark (2 bcm) and Germany (1 bcm). The Dutch domestic consumption of natural gas has risen from about 40 bcm in 1973 to 49 bcm in 2009. By 2022, the projected domestic demand of about 50 bcm in the Netherlands can no longer be covered by the declined domestic gas production (Fig. 3). This means that from 2022 onward the Netherlands will become a net importer of natural gas, unless new ways to access local gas resources are found.

Gas Roundabout – security of gas supply by infrastructure projects

The Dutch Ministry of Economic Affairs has been an early complier to the European Gas Directives. The EU gas directive of 1998 laid the basis for the liberalisation and regulation process in Europe. The introduction of market liberalisation, pioneered in the US under strong federal governance (legislation,

regulation and deregulation) has only just begun in Europe. Deregulation of previously regulated wellhead prices, as in the US, was nowhere needed in the EU, as wellhead prices were never regulated in Europe. The Netherlands has now fully unbundled the midstream and downstream gas distribution networks from the gas trading and sales companies. The principal midstream transmission segment remains fully State-owned (Gasunie) and gas trading and sales are partly privatised (GasTerra). Downstream gas distribution networks are traditionally owned by municipalities, and were partly privatised over past decade.

The EU's 3rd legislative energy package of 2009 has laid a further basis for improved federal cooperation between energy regulators of the EU member states by the creation of ACER (Agency for Cooperation of Energy Regulators) and ENTSO (European Network of Transmission System Operators). ACER will remove impediments in the natural gas value chain and streamline the regulatory decision-making processes in Europe, but much remains to be done to create a truly flexible European gas market (McCredie & Weijermars, 2011; Weijermars & McCredie, 2011).

The Dutch Ministry of Economic Affairs has been very proactive in developing a robust energy infrastructure vision for the future. State-owned Gasunie remains the principal midstream gas transmission provider in the Netherlands, but has ventured to expand transmission capacity to build the NW European Gas Roundabout (Fig. 5). Gasunie's projects include a LNG Gate terminal (with partner VOPAK) in Rotterdam to be operational in 2011, and a 9% participation in Gazprom's Nord Stream pipeline to be completed in 2012. Gasunie's over-the-border expansion and acquisitions in Germany exposes the company to an increased risk profile. The 2010 lowering of Gasunie's credit rating from AAA to AA– was motivated by Moody's as due to a lowering of tariffs at Gasunie's German

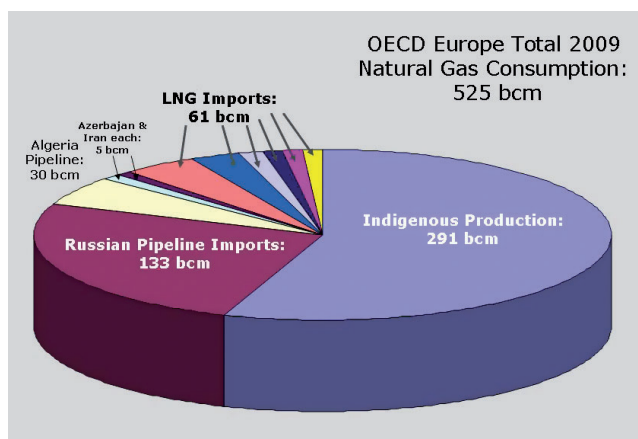


Fig. 4a. Gas supply origin for OECD Europe. LNG imports account for 12% of total consumption and come from Algeria (21 bcm), Qatar (15 bcm), Nigeria (8 bcm), Trinidad (6 bcm), Egypt (5 bcm) and other sources (6 bcm). (Data source: OECD/IEA, 2010b).

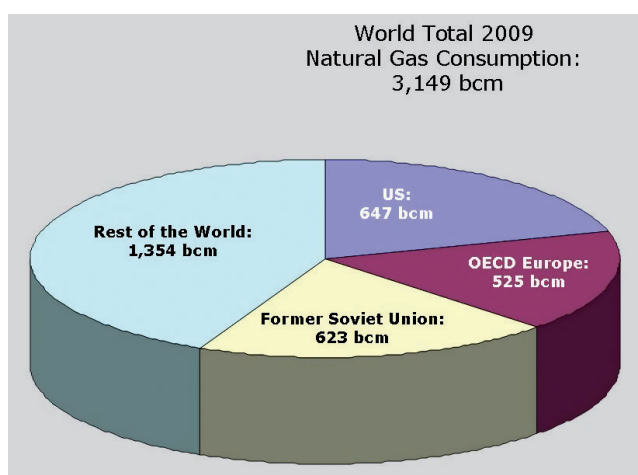


Fig. 4b. Gas flows in the world to consumers. (Data source: OECD/IEA, 2010b).

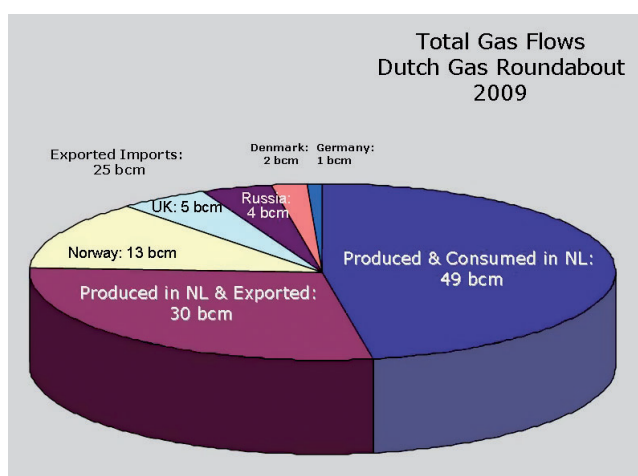


Fig. 4c. Gas flows in the Dutch Gas Roundabout: 49 bcm stays in the Netherlands and 55 bcm was exported, partly from domestic sources, and partly from re-export of trade gas bought from abroad. (Data source: OECD/IEA, 2010b).

subsidiary (Gasunie Deutschland) by some 7%, under pressure of Bundesnetzagentur, the German regulator watchdog. Infrastructure companies charge tariffs for services rendered to recover their capital cost sunk into fixed assets. Only modest returns on investment are permitted, so that this regulation is not constructive to generate profits from transmission services (Weijermars, 2010a). Such infrastructure projects remain essential for ensuring security of energy supply for the Netherlands. One conclusion is that the Dutch State's aim with the NW European Gas Roundabout must be to ensure security of supply – it is unlikely to fill an emerging income gap from upstream gas operations. Gasunie's entrepreneurial midstream gas transmission projects are prompted primarily by the Dutch State's strategy for security of natural gas supply in NW Europe.

Energy Strategy Options – a 'doing-nothing scenario' is costly

Dutch energy strategies for natural gas have been executed under the direction of the Dutch Ministry of Economic Affairs (Köper, 2003, 2008). The past strategy choices seem sound and defensible. The State's gas assets management organisation (EBN) has a steep target to cushion the decline in domestic gas production from conventional gas. Figure 6 includes EBN's target estimates of new discoveries and enhanced recovery (EBN, 2010). Nonetheless, in the next 25 years, Dutch conventional gas production will have fallen from 85 bcm in 2010 to 15 bcm in 2035.

Taking into account the EBN cushion targets (EBN, 2010), the projected decline in conventional gas production will lead to a loss of State income. The loss of income from declining gas business increases over the coming decade at a rate of € 250 million per year. This decline compounds into a loss in State

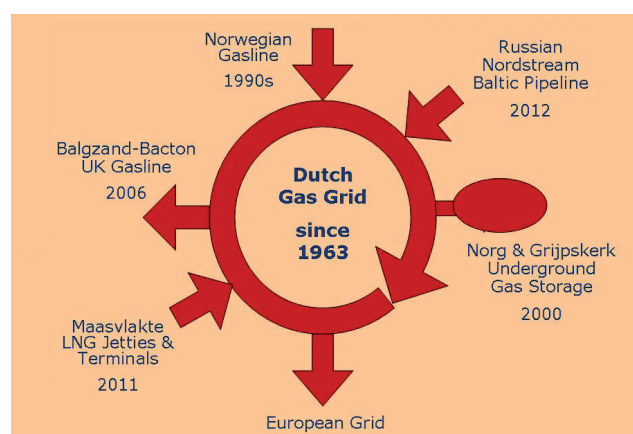


Fig. 5. The Dutch gas grid of Gasunie has provided homes and industries with natural gas since 1963. Gas is distributed from the giant Groningen Field (produced by NAM) throughout the Netherlands and abroad. New suppliers (i.e., Norway, Russia, and spot market LNG) now compete with NAM in an international gas market to supply natural gas at the best price. (Weijermars, 2011a).

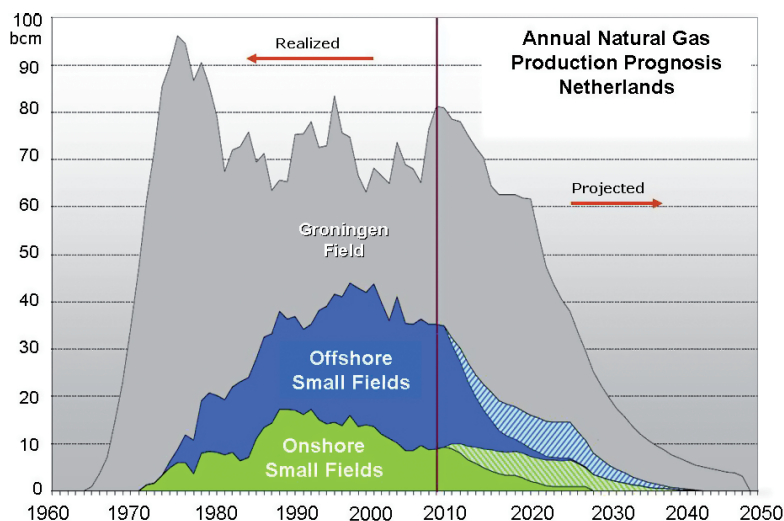


Fig. 6. Annual production of conventional natural gas in the Netherlands from the Groningen Field and small fields over the full life cycle 1963-2050. Discovery of new conventional small gas fields will add some volume annually (shaded area), but will not prevent decline, first of small fields, then joined by the Groningen Field's decline from 2021 onward (Data source EBN, 2010; Slight mismatch with volumes in Figure 2 is due to bcm correction factor for the lower caloric value of Groningen gas).

earnings of $(1 + 2 + 3 + \dots + N) \times 0.25$ billion Euro after N years. After a decade (by 2020) the compounded loss will increase the national deficit by € 13.75 billion. After 25 years (by 2035) the compounded loss of income for the State will amount to € 81.25 billion. In 2035, the reduction in the State's income from natural gas will amount to some € 7 billion less gas income on *budget year basis*, as compared to 2010. This loss of current income is due to diminishing conventional gas production leading to lower corporate tax from gas business, fewer exploration and production licenses, and fewer participations by the State (via EBN). No price correction is attempted in the above estimates, any structural long-term rise or fall in global energy prices would affect the future gas revenues.

The scenario of compounded future loss of income for the State from gas business is in stark contrast with the handsome earnings from gas over the past 50 years. The Netherlands has been fortunately endowed with Europe's largest single gas field, but the Era of 'Easy Cash from Gas' seems now to be fading out. Discussions on the need for a Sovereign Wealth Fund may continue, but Dutch conventional gas fields will go off plateau production in the next decade. By 2022, the Netherlands can no longer cover domestic gas consumption from its domestic production as the production from conventional gas resources will drop below 50 bcm; the Netherlands will become a net importer of natural gas.

Dash for unconventional gas

Past strategy measures in the Netherlands have mostly been focused on security of supply issues and on optimising the income from Dutch conventional gas business. The inventory of proved *conventional gas reserves* and cumulative production has been tallied since shortly after the start in 1963 (Fig. 7). New technology and new discoveries have from time to time helped to push up the reserve curve in spite of continuing depletion of reserves by gas production. The jump in reserves in 1990 that temporarily lifted the declining reserve trend was

mostly due to wider application of 3D seismics (Herber & De Jager, 2010). A renewed and significant growth of reserves from conventional resources is now becoming progressively unlikely in the Netherlands, and only minor additions are expected in the latest EBN inventory. EBN(2010) forward estimates for conventional discoveries and EOR are included in Figure 6.

The emerging supply gap from Dutch conventional gas can possibly be closed by exploration and development of *unconventional gas resources*. The technology and knowledge to develop unconventional gas resources have been explored in North America (i.e., the US and Canada) over the past three decades, and has accelerated over the past five years. Countries in South America, Europe, Asia and Australia, have now also

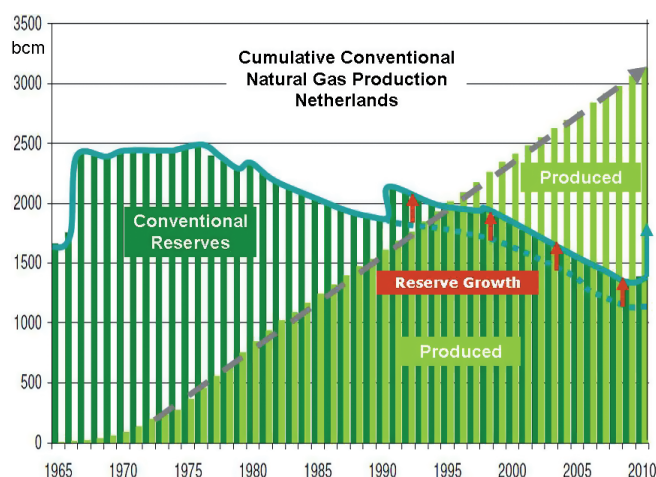


Fig. 7. Cumulative production of conventional natural gas (straight line) and remaining proved reserves (EUR) of conventional gas, as accounted for every year by adding proved reserves reported in the annual reports of E&P companies operating in the Netherlands. In 2010 the remaining proved reserves of conventional natural gas amounted to 1390 bcm, of which 1036 bcm is in the Groningen Field; cumulative production from all fields combined amount to 3133 bcm, as per 31 Dec 2009, see Table 1 (Data source: MEZ, 2010).

begun – or continue – to evaluate their potential of unconventional gas resources. Such resources may have become technically recoverable and can be developed into economically proved reserves based on 30 years of accelerated development in the US. Detailed inventories of unconventional gas resources have been published by Canada (PTAC, 2006) and the US (NPC, 2007; Navigant, 2008; CRS Report, 2009; DOE, 2009; PGC, 2009; see Marcellus case study by Engelder & Lash, 2008).

Most EU countries are now assessing their own unconventional gas resource potential, with Poland in the lead (e.g., ORLEN, 2010). Unconventional gas strategy drivers vary somewhat across Europe. For example, Poland is for 50% dependent of Russian gas imports, and wants to reduce its dependency on these imports while also replacing a portion of power supply from polluting coal generators by gas generators to meet EU targets. Germany too is keen on unlocking its own gas potential (BGR, 2009) as domestic gas consumption is now for 80% dependent on pipeline imports from three sources: Russia (31%), Norway (29%) and the Netherlands (20%). On August 8th, 2010, the German Research Center for Geosciences (GFZ) started a scientific drilling project in the Danish Alum shale, a dense Cambrian deposit of some 500 million years old – a prospective resource for shale gas in both Germany and Denmark.

Hopes are high in Europe to improve its security of supply by upgrading prospective unconventional gas resources into securely proved reserves – but the significance of the volumes has yet to be established by further research. For example, the inventory of Dutch unconventional gas resources by TNO (2009) showed considerable volumes of possible in-place and unrisks resources (Fig. 8), but these estimates are not yet very accurate, and cannot be so at this stage: unconventional resources mapped so far are un-risked. The classification of unconventional gas resources itself is not yet well defined in the Netherlands. For example, shallow gas and tight gas in conventional traps (with normal gas-water contact, e.g., Crouch et al., 1996; Van Hulten, 2006), are not included in the brief review of unconventional gas potential resources in the Dutch

subsurface by Herber & De Jager (2010). In contrast, TNO/EBN did include these resources in their estimates of potential unconventional gas resources (TNO, 2009). In fact, the conventional EURs reported by MEZ (2010) include a fraction of shallow gas and tight gas (Jan de Jager, *review communication 30-12-2010*).

Upstream Gas Research – will the Netherlands lead or trail behind?

Given the decline of Dutch conventional gas production, the upstream natural gas business in the Netherlands may benefit from further research aimed at stimulating the development of unconventional natural gas resources. In a mature exploration area like the Netherlands, focus should be on research that leads industry into new technology development to reduce cost and operational risk, increase recovery, and minimise surface impact.

What is happening elsewhere right now?

The US State Department has initiated a Global Shale Gas Initiative and held a first series of workshops in 2010 for other countries wanting to replicate US legislation and regulation of shale gas operations and process (Corbin, 2010). A meeting was held in Washington on August 24, 2010, with 17 countries represented to discuss the importance of shale gas as well as a lower-carbon fuel option. The US has already signed MOUs with India and China for cooperation on shale gas projects and resource evaluation. A first workshop in China was held in November 2010. The US also held a high level US-Poland Energy Round Table in Washington in June 2010.

MIT (Boston) has recently initiated a shale gas research programme (MIT, 2010) under the umbrella of its Energy Initiative. Shell joined the consortium with 25 million USD sponsorship and BP earlier joined, also with a 25 million USD investment. Delft University of Technology participated in the preparation of another major US Research Programme titled *‘Transition the Energy Mix: Taking Natural Gas Seriously’*, led by the Bureau of Economic Geology UT Austin, scheduled for a 2-year period 2011-2013. Colorado School of Mines launched the Unconventional Natural Gas Institute (UNGI) with a workshop on 21 October, 2010, dedicated to technical and economic challenges in commercial development of unconventional gas reservoirs. Texas A&M University’s Crisman Institute for Reservoir Management has activated a center for unconventional resources in 2005.

The US has a 30-year long track record in preparing the ground for industry’s maturation of unconventional gas resources in dedicated research programmes. Figure 9a shows how the R&D programme on CBM (\$ 30 million; 5-year long programme between 1978 and 1982 by the US Department of Energy) enabled the development of Coalbed Methane production in 1983. Likewise, the acceleration in commercial development of shale gas in the early 1990s was preceded by a 15-year long

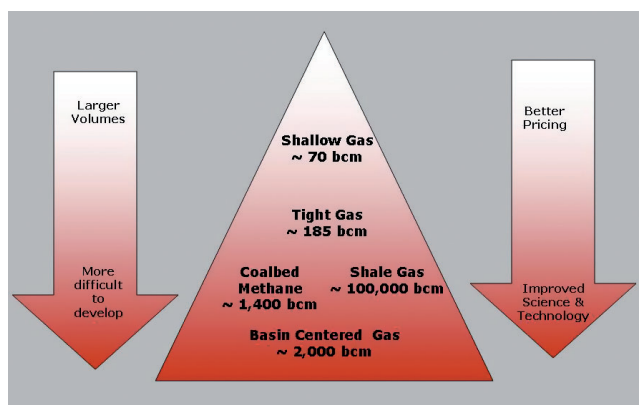


Fig. 8. Resource triangle showing un-risked unconventional gas resources in place in the Netherlands. (Source: data from Scheffers et al., 2010; Resource Triangle Principle after Holditch, 2003).

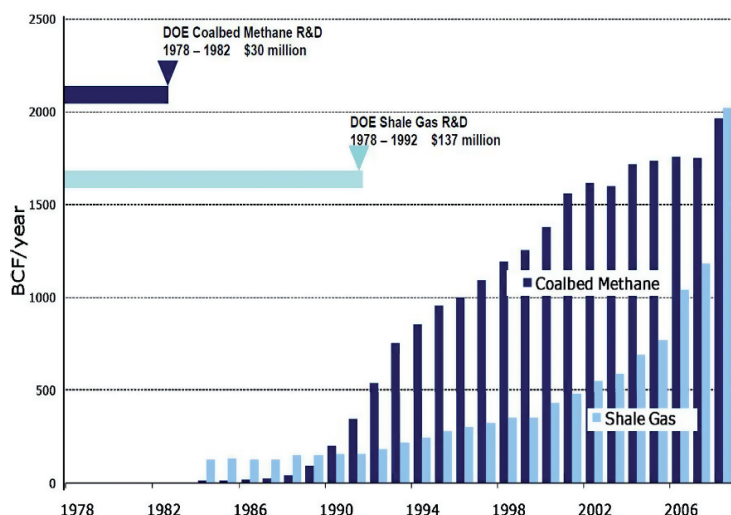
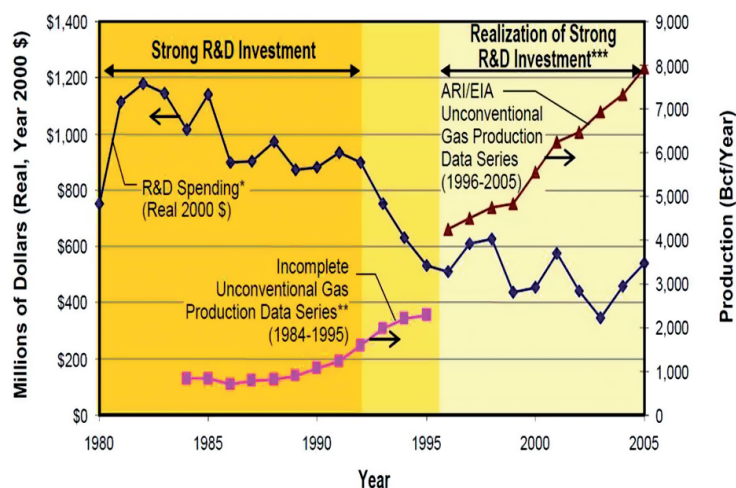


Fig. 9a. The acceleration in annual production of US Coalbed Methane (CBM) and US shale gas were both preceded by R&D investments, in the preceding periods indicated, by the US Department of Energy (DOE) to improve the technology and knowledge of these unconventional gas resources. (Source: Corbin, 2010).

Fig. 9b. Annual increases of total US unconventional natural gas production (climbing lines to the right scale) were triggered by R&D investments made over the 25 year period between 1980 and 2005 (left hand scale). (Source: ARI, 2007).



DOE-sponsored research programme (\$ 137 million) executed between 1978 and 1992 (Fig. 9a). US independents played a considerable role in pioneering unconventional gas development as well; the total R&D spending on unconventional gas developments, by DOE and industry sources in the US, amounted to \$ 1 billion per year in the early 1980s, and continues at a rate of \$ 0.5 billion/year after the millennium turn (Fig. 9b).

The US Energy Policy Act of 2005 established a fund of \$ 14 million/year for the next 10 years for unconventional gas R&D (1/5th of the annual energy R&D budget allocation of \$ 50 million). The fund is used for the Research Partnership to Secure Energy for America (RPSEA), a non-profit corporation of a consortium of premier US energy research universities, industry and independent research organisations. In the area of unconventional gas, RPSEA goals are (Reeves et al., 2007):

- Increase the technically recoverable resource base by 30Tcf.
- Convert 10 Tcf of technically recoverable to economically recoverable resource.
- Develop technology to minimise environmental impact of developing unconventional resources.
- Emphasise science-building capacity and effective technology dissemination.

CSIRO in Australia is currently developing a shale gas research programme to cover research issues and the delivery of services to the Australian gas industry (CSIRO, 2009). The CSIRO Shale Gas Research Center is aimed at furthering the understanding of the petrophysical & geomechanical properties of shale and clays by using a combination of experimental and theoretical research. Wellbore stability, pore pressure prediction, seal integrity, organic matter characterisation, fluid mechanics of gas migration and hydraulic fracturing are engineered, specifically for application to the Australian shale gas potential.

In Europe, the German Research Center for Geosciences (GFZ) started a Shale Gas research program (GASH, 2009). This first European interdisciplinary shale gas research initiative runs initially for three years. The project is sponsored by the following companies: Statoil, ExxonMobil, Gas de France SUEZ, Wintershall, Vermilion, Marathon Oil, Total, Repsol and Schlumberger. Besides the development of a GIS-based European black shale database, 12 research projects are being conducted by a multinational expert task force drawn from research institutions, geological surveys, universities and consultants. The overall project goal is to predict shale gas formation and occurrence in time and space. GASH focuses on

the potential gas shales of Europe, especially on the Alum Shale (Denmark), and the Posidonia and Carboniferous Shales in Germany.

What have global E&P companies done on unconventional gas exploration in Europe so far?

Europe needs natural gas for a clean transition from fossil energy to sustainable energy alternatives. The importance of unconventional natural gas development in a European context has been outlined elsewhere (Weijermars et al., 2011). The exploration of unconventional plays has only just begun in Europe (Bernstein, 2010; Geny, 2010). Approximately 30 wells will be drilled into unconventional resources between 2009 and 2012. ExxonMobil has already drilled 10 exploratory wells in Germany in 2009. Shell has completed a first shale gas well in Sweden's Alum shale in Q1 2010 and plans two more. Poland has seen the most intensive interest: Lane/Energy/Conoco-Phillips will drill three wells into the Silurian and Ordovician shales of the Polish Baltic Basin; BNK Petroleum will also drill a well in the same region; Marathon Oil has scheduled a first well in 2011. The UK Cheshire Basin is targeted for drilling a shale-well by Cuadrilla Resources in 2010. France sees activity in shales of the Berg region, Montelimar, from TOTAL/Devon, GdF Suez / Dale Gas / Schueblack, and Mouvoil who planned to shoot new seismic lines in 2010. TransAtlantic will drill a shale gas test well in Romania. In the Netherlands, unconventional resources have not yet been targeted as per December 2010. Cuadrilla Resources plans to drill a shale gas well near Bostel, but there is a public relations battle to be won. A Dutch government report is due to assess the risk and consider further policy measures.

Some traditional European E&P companies have bought stakes in US companies to learn more about unconventional gas plays. For example, in 2010 Shell has acquired Eastern Resources in a 4.5 billion USD deal. In 2009 BP, Statoil and Total entered into separate joint ventures with Chesapeake already. So far, Canadian and US unconventional gas companies have mostly confined their interest to the development of North American resources.

Can the Netherlands still provide an attractive 'hydrocarbon business climate'?

In the past, E&P companies were prepared to lead in exploration for the development of conventional gas resources. This cannot be assumed today for the development of unconventional resources. It is simply not clear from our current state of knowledge whether the riskier unconventional gas resources in the Netherlands will be sufficiently attractive for E&P companies to pursue development. Current estimates of the Dutch unconventional gas potential range from 10^2 bcm technically recoverable resources (Herber & De Jager, 2010) to unrisks resource estimates totaling 10^5 bcm (TNO, 2009).

Ideally, the steep decline that sets in by 2021, based on reliable depletion models of *conventional gas production* (Fig. 6) should be cushioned or reversed by the commercial *development of proved unconventional gas reserves*.

EBN has already identified the need to stimulate upstream gas activity in their 30-30 vision statement (EBN, 2010). In order to maintain the current – approximate 30 bcm annual production (outside Groningen) until the year 2030 – significant R&D initiatives are required to unlock new conventional and unconventional gas. More specifically: improved knowledge on the potential presence and recovery of tight gas, shale gas, shallow gas and coalbed methane are essential before we can assist in fulfilling tomorrow's energy needs.

The US track record outlined here (Figs 9a & b) shows research can help to mature unconventional resources into economic reserves. A better knowledge base could improve the Dutch attractiveness for investment by E&P companies into unconventional gas activities. It seems premature to expect that industry stakeholders in the Dutch natural gas business will be the driving forces in optimising solutions for producing unconventional gas resources in the Netherlands as long as it is not yet established that such unconventional resources in the Dutch subsurface can be economically developed. Ownership and any ultimate benefits of the unconventional resource potential pertain to the Dutch State and future production partners. Optimised conventional and unconventional natural gas recovery could benefit the State by improving security of supply and mitigating an undue decline in the State's income from natural gas business.

Dutch subsurface conditions (Wong et al., 2007) therefore must be studied with a specific focus on unconventional gas potential and production options based on current and new research insights. The process of reserve maturation for unconventional gas is invariably driven by NPV (based on EUR projections) and IRR (based on well flow rates versus cost control); regulation and fiscal stimuli packages may provide additional incentives for field development. The themes that require attention in a dedicated research effort are:

- Closing exploration gaps and sweet spot identification.
- Depositional and structural models; diagenetic burial history; play analysis.
- Play-based analysis to get a better grip on comingled production.
- Optimisation of the hydraulic fracturing process; fracture orientations; slim-hole modeling.
- Modeling type curves of production prior to commercial development in order to reduce the uncertainty in well productivity and consolidate proved reserves.
- History matching the prototype reservoir models against actual production ('history matching').
- Production pressures; open-hole underbalanced production modeling; down-hole pressure and temperatures. Recovery factors and spatial variations; Langmuir curves.

- Geo-environmental modeling; fluid management and disposal; operational footprint reduction; reducing GHG emissions.
- Field development plans & play analysis of Dutch unconventional resources (industry workshops).
- Reduction of FD&A cost; reduction of lifting, gathering & processing cost.
- Transparency & templates with typical case examples for Dutch E&P tax mechanisms.

The aging infrastructure and evacuation of tail-end offshore fields in the North Sea means such research themes should be accelerated without undue delay. Some of the asset value of infrastructure could possibly be utilised in future CCS projects (Breunese, 2006), but is not seen as a viable alternative income source for the State. The engagement and results generated by dedicated upstream research projects could provide new remedies to counter the steep decline of conventional gas production (Fig. 6). Further incentives for the E&P industry should be targeted at the development phase, in order to increase economic attractiveness for difficult reservoirs, both conventional and unconventional.

Recommendations and conclusions

The Netherlands, after Norway still Europe's 2nd largest indigenous supplier in 2009, has entered the decline phase of its conventional gas production in 2010 (Fig. 3). This position paper broadly outlined past and future trends in cash flows from natural gas production. The State's annual income from natural gas business varied between € 4.5 and € 14.8 billion over the past decade, which constituted between 1 and 3% of the Dutch GDP (€ 500 billion).

A dedicated research programme is proposed to address the new challenges faced by the Dutch upstream gas industry implied by the onset of decline in conventional gas production. Research into the presence and recovery of conventional and unconventional natural gas resources could reinforce the Dutch position at the source of the natural gas value chain and as a major European gas producer. The driving motives for the urgency of such a programme are as follows:

1. The North American track record shows unconventional gas companies have incurred massive impairment costs due to indistinctive hit-and-run acreage acquisitions, which has been paid for by speculative equity investments (Weijermars & Watson, 2011).
2. A more selective FD&A approach is needed worldwide to improve the cash margins of unconventional gas plays (Weijermars & Watson, 2011).
3. Industry has been slow worldwide to invest in R&D and improve the E&P methods used in unconventional gas developments; most programmes are still sponsored by government research agencies while the major oil companies are still evaluating – and not committing to – the potential of unconventional gas resources.
4. Attention of the major industry players in unconventional gas is now primarily focused on emerging opportunities in the US, Poland, South Africa, Australia, Indonesia, India and China.
5. New play development has slowed down somewhat (world-wide) due to a global value gap between full cycle cost of new unconventional gas supplies and concurrent natural gas prices (Weijermars, 2010b, 2011b).
6. Buying new developed gas reserves is no option for companies active in the Netherlands as such indigenous reserves do not exist yet. The global gas glut provides some time for the Netherlands to find new solutions to mitigate the decline of its indigenous natural gas production.
7. New gas reserve replacement options for the Netherlands must be studied further; it is therefore essential to identify and develop tools and methods that aid the accelerated development of new technically recoverable resources and economic proved reserves in the Netherlands.
8. The Netherlands can capitalise on its past legacy and maintain a leading position in global upstream gas research. Technology application and development holds the key to unlock and mature new Dutch gas supplies for the future.

Current estimates of Dutch potential unconventional resources range between 10^2 (technically recoverable; Herber & De Jager, 2010) and 10^5 bcm (unrisked; TNO, 2009). Research can help to mature part of these resources into economic reserves. Each extra bcm produced brings approximately € 100 million return to the State. Such a cost-benefit projection makes a compelling business case for the recovery of new natural gas resources by stimulating research aimed at enhanced recovery of natural gas from both conventional and unconventional resources in a dedicated upstream research programme.

An upstream gas research programme would be complementary to the EDGaR consortium, initiated first in 2005 to help address pressing research issues (EDGaR, 2010). Finally launched in 2009/2010, EDGaR now is a € 44 million project sponsored by the Dutch government and cost-matched by several parties. The focus is on security of supply mostly in terms of mid and downstream regulation matters; there is a minor allocation for CCS research. However, EDGaR does not address the need to improve upstream cash flow by optimising new technology and new upstream solutions for the Dutch natural gas business. Research on regulation of the natural gas value chain may be useful but delivers no new gas molecules to Dutch stakeholders. The emerging Dutch supply gap requires a research focus that proactively addresses upstream opportunities. State-of-the-art developments in global upstream gas business should be fully brought into focus in a comprehensive research programme aimed at improving our knowledge on the natural gas business.

Delft University of Technology has launched (early 2011) the Unconventional Gas Research Initiative (UGRI; see Weijermars et al., 2011). The programme's research focus is developed in close coordination with global knowledge partners (<http://ugri.tudelft.nl>). Our vision is: *to become a leader in unconventional gas R&D by optimising technology application & enabling value creation*. UGRI's aim is: *to accelerate and foster the environmentally responsible development of unconventional gas resources for play openers in Europe by providing integrated research & knowledge support*. The programme's run-time is scheduled for the next decade and must reach the stated goals by 2020.

Abbreviations used

ACER	Agency for the Cooperation of Energy Regulators
ARI	Advanced Resources International
bcm	billion cubic metres
BEG	Bureau of Economic Geology
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
CBM	Coal Bed Methane
CCS	Carbon Capture and Storage
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DOE	Department of Energy
E&P	Exploration & Production
EBN	Energie Beheer Nederland
EDGaR	Energy Delta Gas Research
ENTSO	European Network of Transmission System Operators
EUR	Estimated Ultimate Reserves
FD&A	Finding, Development & Acquisition
GASH	An interdisciplinary Gas Shale research project
GDP	Gross Domestic Product
GFZ	Geoforschung Zentrum
IEA	International Energy Agency
IFP	Institut Français du Pétrole
IRR	Internal Rate of Return
LNG	Liquefied Natural Gas
MEZ	Ministerie van Economische Zaken
MIT	Massachusetts Institute of Technology
MOU	Memorandum of Understanding
NAM	Nederlandse Aardolie Maatschappij
NPC	National Petroleum Council
NPV	Net Present Value
OGJ	Oil & Gas Journal
PGC	Potential Gas Committee
PTAC	Petroleum Technology Alliance Canada
R&D	Research & Development
RPSEA	Research Partnership to Secure Energy for America
SWF	Sovereign Wealth Fund
TNO	Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek
UGRI	Unconventional Gas Research Initiative
UNGI	Unconventional Natural Gas Institute

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