“Unconventional gas in the Netherlands”

Including results from TNO study “Inventory non-conventional gas” (2009)

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21 April 2010 PGK
EBN

• Mission

“For Dutch society, EBN realises profitable development of energy resources and the exploitation of the deep subsurface”

– Focus on oil and gas production and other subsurface energy
– Make use of assets and knowledge of subsurface
– Generate a net gain: financial, clean, reliable, affordable
– Serve interest of society
Duties

• Role of EBN as defined in revised mining law of 2008:

  – participating in oil and gas exploration and production (today 40%)
  – participating in transport and storage of natural gas
  – carrying out tasks in connection with Groningen production licence and participation in GasTerra B.V.
  – providing advice to and carrying out tasks for the Dutch Minister of Economic Affairs

More information: www.ebn.nl
Sense of Urgency: Outlook Dutch E&P

Historic production & forecast

- Groningen
- Futures offshore
- Offshore small fields
- Futures onshore
- Onshore small fields

Year

Produced volume (BCM)
Offshore infrastructure is nearing its end
Ambition 30 BCM in 2030
Gap ~250 BCM
Roadmap

• Decline of non-Groningen production must be limited to approximately 1% per year

• required: 250 BCM new production
  • More recovery from existing fields
  • Development of stranded fields
  • Drilling new prospects
  • *Unconventional resources must contribute to the hydrocarbon mix as soon as possible. First shallow and tight reservoirs, later on shale gas, CBM might play a (modest?) role*
Inventory of unconventional resources: Why?

1. No overview of unconventionals in NL

2. Last decade rapid developments in the USA

3. Rapid decline gas production from conventional resources in NL
USA unconventional gas

EXHIBIT 6: NATURAL GAS PRODUCTION BY SOURCE (tcf/year)

Onshore unconv
Onshore conv
Offshore
Alaska

Source: EIA, 2008

- Source: Modern Shale Gas Development in the United States: A Primer, 2009
What is unconventional about unconventional gas?

- Conventional trap – unconventional production techniques
- Unconventional trap (not gravity driven)
Unconventional gas

- Conventional trap:
  - Shallow gas
  - Tight gas

- Unconventional trap:
  - Coal Bed Methane (CBM)
  - Shale Gas
  - Basin Centred Gas

- Characteristics
- Gas-In–Place Volume estimates based on regional assumptions!
Shallow Gas

- Identified directly from seismic data (bright spots)
- Bright spots present in large delta system (Eridanos delta)
- The shales in this delta system are only capable of sealing limited gas column lengths
- Biogenic or thermogenic gas?
Shallow Gas

- Bright spots on structural highs (above salt domes) or in stratigraphic traps
The Eridanos Delta

Above Eridanos delta

A
A
B
B
D
D

Long offset NSR data, courtesy of Fugro-TGS
The Eridanos Delta

Long offset NSR data, courtesy of Fugro-TGS
Shallow Gas

- Mainly confined to Northern offshore
- Unconsolidated sediments, risk: sand production
- Low pressure, compression from day 1
- First field A12 produced by Chevron, second field F02 now developed by Suncor (former Petro-Canada)
- Which bright spots have sufficient gas volume to justify development?
Tight gas

- Conventional trap
- Reservoir rock with low permeability thickness
- Heterogeneous reservoir, permeability decrease by diagenesis, hard to predict
- Production rates low, can be increased by “fraccing”
- Tight gas is already produced in NL
- Several fields “stranded” because of tightness
Tight gas volumes

- Only defined for Rotliegend and Triassic Buntsandstein
- GRV based on potential conventional closures defined on TNO’s regional maps
- Probability of tightness is defined by fraction of wells in the specified areas that have an initial Q50 of < 100,000 m³/d
- N/G and Φ distributions based on wells
- Average Sg = 0.5
Coal Bed Methane (CBM)

- Gas adsorbed on coals and as free gas in cleats
- Coals are source and reservoir
- Thick Carboniferous present under NL, individual coals seem thin (<10 m)
- Fracking to create sufficient drainage and depressurizing
- Enhanced recovery methods by injecting \( \text{N}_2 \) or \( \text{CO}_2 \) (ECBM)
Static / Dynamic Parameters

- \( GIIP = A \times h \times \rho_c \times G_c \)
  
  \( A = \text{Area} \)
  
  \( H = \text{Cum height coal} \)
  
  \( \rho_c = \text{Density of the coal} \)
  
  \( G_c = \text{Gas content of the coal} \)

- \( G_c = (G_{lc} \times P) / (P_{lc} = P) \)
  
  \( G_{lc} = \text{Langmuir volume (max gas adsorption capacity)} \)
  
  \( P = \text{Pressure} \)
  
  \( P_{lc} = \text{Langmuir pressure} \)
  
  \( G_c = \text{Gas content of the coal} \)

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### Table 1—Parameters Needed for Reservoir Simulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>Coal thickness</td>
</tr>
<tr>
<td>Reservoir temperature</td>
<td>Coal porosity</td>
</tr>
<tr>
<td>Initial reservoir pressure</td>
<td>Coal permeability (as a function of stress)</td>
</tr>
<tr>
<td>Drainage area</td>
<td>Coal damage skin factor</td>
</tr>
<tr>
<td>Wellbore diameter</td>
<td>Coal non-Darcy skin</td>
</tr>
<tr>
<td>Pump capacity</td>
<td>Coal water saturation</td>
</tr>
<tr>
<td>Wellhead pressure limit</td>
<td>Coal compressibility</td>
</tr>
<tr>
<td>Wellbore/annular hydraulics</td>
<td>Coal relative permeabilities</td>
</tr>
<tr>
<td></td>
<td>Coal initial free gas composition</td>
</tr>
<tr>
<td></td>
<td>Coal sorbed gas composition</td>
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<tr>
<td></td>
<td>Coal density</td>
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<tr>
<td></td>
<td>Coal isotherm data for each gas component</td>
</tr>
<tr>
<td></td>
<td>Coal saturation pressure (or initial gas content)</td>
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<tr>
<td></td>
<td>Degree of permeability anisotropy</td>
</tr>
<tr>
<td></td>
<td>Orientation of maximum/minimum stress</td>
</tr>
<tr>
<td>Sand thickness</td>
<td>Sand porosity</td>
</tr>
<tr>
<td>Sand porosity</td>
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<td>Sand gas composition</td>
</tr>
</tbody>
</table>

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October 2009 SPE Reservoir Evaluation

Roadifer and Moore: Coalbed-Methane Pilots – Timing, Design and Analysis
Shale Gas

- Organic rich shales act as source and reservoir and sometimes as seal
- Gas adsorbed on clay particles, dissolved in kerogen or bitumen or in pores or fractures
- Hydraulic fracturing, high well density
- Offshore unlikely to be produced, volumes should be discounted
- Low Recovery Factor

- High Potential: Epen Fm (Carb), Posidonia shale (Jura)
- Medium Potential: also Jurassic Sleen, Aalburg and Kimmeridge Clay
Parameters Shale Gas

• Adsorbed gas:

\[ \text{GIIP_a} = A \times h \times \rho_c \times G_c \]

with

\[ G_c = \frac{(G_{lc} \times P)}{(P_{lc} = P)} \]

\[ A = \text{Area} \]

\[ H = \text{Cum height coal} \]

\[ P_c = \text{Density of the coal} \]

\[ G_c = \text{Gas content of the coal} \]

\[ G_{lc} = \text{Langmuir volume (max gas adsorption capacity)} \]

\[ P = \text{pressure} \]

\[ P_{lc} = \text{Langmuir pressure} \]

\[ G_c = \text{Gas content of the coal} \]

• Free gas:

\[ \text{GIIP_f} = A \times h \times \Phi \times S_g \times B_g \]

\[ S_g = \text{gas saturation} \]

\[ \Phi = \text{porosity} \]

\[ B_g = \text{gas expansion factor} \]

Comparison size US and Dutch shale basins

- Dutch territory experienced complex multi-phase tectonics resulting in small size basins

Shale Gas Opportunities and Challenges* (1)

Learnings from North America to date

- thick sequences of shale with variable amounts of gas exist in many/most basins
- shales are extremely heterogeneous in their properties but at a scale not generally considered
- early views that organic geochemistry is “the” screen for prospectively is proving incorrect

* From M. Bustin et al. AAPG conf. 2008
Shale Gas Opportunities and Challenges* (2)

* Learnings from USA to date

  - main risk is reservoir access- and mechanical stratigraphy
  
  - Gas shale producers have no confidence in their GIIP calculations, or they do not believe them at all
    - some numbers are ridiculously high or low
    - production data does not match GIIP
    - GIIP still unknown after several 1000 wells

* From M. Bustin et al. AAPG conf. 2008
Shale Gas Opportunities and Challenges* (3)

Challenges

- screening exploration targets
- determining intervals to frac or drill horizontals
- predicting production rates
- predicting decline rates
- predicting EURs
- determining drainage areas (spacing units)

* From M. Bustin et al. AAPG conf. 2008
Evolution in shale gas developments in the USA

- **Characteristics of early shale gas developments:**
  - Depth 150 – 800 m
  - Vertical hydraulic fractured wells from individual well pads
  - Initial production rate of 3000 m$^3$/d
  - Reserves per well 10 million m$^3$

- **Characteristics of current shale gas developments:**
  - Depth 1000 - 4000 m
  - Horizontal wells with multiple hydraulic fractures. Multiple wells per pad
  - Initial production rate of up to 600,000 m$^3$/d in Haynesville
  - Reserves per well up to 200 million m$^3$
Barnett: recovery / well

Based on 1084 wells, OGJ, 2009
Production behaviour
Shale Gas

- Strong initial decline
- Flat decline curve
- Refracking can revive production to higher levels

Source: Using the Barnett Shale To Understand Global Resource Play Deliverability, R. Hovey, SMI Conf 2010 London
Basin Centred Gas

- Abnormally pressured tight reservoir with no obvious trap
- Possible locations offshore: see map
- Most speculative play
  Least likely candidate for economic developments in NL
SPE resource classification (PRMS)

Sub-classify by Project Maturity

- Production
  - Reserves
    - On Production
    - Approved for Development
    - Justified for Development
  - Contingent Resources
    - Development Pending
    - Development Unclarified or On Hold
    - Development not Viable
  - Prospective Resources
    - Prospect
    - Lead
    - Play
  - Unrecovered

Range of Uncertainty

Increasing Chance of Commerciality

Commercial Criteria

Discovery Criteria

Not to scale
SPE resource classification (PRMS)

Sub-classify by Project Maturity

- **Reserves**
  - On Production
  - Approved for Development
  - Justified for Development

- **Contingent Resources**
  - Development Pending
  - Development Unclarified or On Hold
  - Development Not Viable

- **Prospective Resources**
  - Prospect
  - Lead
  - Play

**Range of Uncertainty**

- **Shallow gas**
- **Tight, CBM, Shale & BC gas**
GIIP Shallow & Tight Gas

- **Shallow gas:** Unrisked In-Place Volumes 35 – 95 BCM
  - Area bright spots calculated
  - General Area-GIIP-ratio assumed (0.08 BCM/ km$^2$)
  - Stacked multiple bright spots represented by area of largest bright spot
  - Cut-off 13 km$^2$ ~ 1 BCM

- **Expected Recovery Factor 30-70%**

- **Tight gas:**
  - Unrisked In-Place volumes in “proven plays” 150 - 230 BCM (Rotliegend and Bunter only)
  - In “Stranded Fields” at least 50 BCM
  - Possibly volumes (undefined) in potential new plays like Lower Carboniferous Tight Carbonate Reefs.
Shallow gas volume cut-off
Potential unrisked GIIP from TNO report
Resource Triangle
(Holditch 2003)

Resource triangle for unconventional gas reservoirs

- Basin Centered gas (~2000 bcm)
  - Coalbed Methane (~1400 bcm)
  - Tight gas (~185 bcm)
  - Shallow gas (~70 bcm)
- Increased pricing
  - Improved technology
- Larger volumes
  - More difficult to develop

Modified from NPC 2007
Challenges unconventional gas

- **Subsurface**: Are the volumes really there?
  - Explore & identify sweet spots
  - Characteristics of resource plays so far unknown

- **Technology**: Can we get enough gas to surface at a reasonable price?
  - Fraccing, how much gas can be recovered per well?
  - Offshore: Aging of infrastructure, are the opportunities matured early enough?
  - Can we reduce (well) costs?

- **Social-Economic**: To what (social) price?
  - High well density in densely populated areas
    - Environmental impact
  - European gas market development
Subsurface

- Identify sweet spots
  - Better 3D seismic imaging and characterisation tools
  - Imaging while drilling
  - Efficient well performance analysis

- Characteristics of resource plays so far unknown
  - Data collection during drilling, completion and stimulation
  - Integrated reservoir characterisation of above data with laboratory measurements
  - Understanding of basin scale petroleum systems
Technology & Costs

- Technological developments so far
  - From vertical to horizontal wells
  - Single stage frac to multiple stage hydraulic fracturing
  - One well per pad to multiple wells per pad

- Impact of technology on US & Canadian oil & gas
  - Hydraulic fracturing improvements
  - Drilling and completion costs reduction
  - Economy of scale
  - Sweet spot identification by various methods.
Spacing of well pads in NL (Schoonebeek)
European gas market development

- Less domestic production in EU
- By 2020 around 60% of EU consumed gas imported
- Concern about dependence on few suppliers
- Concern on influence of transit countries
- Role of LNG in 2020 uncertain
Groundwater pollution

Source: Modern Shale Gas Development in the United States: A Primer, 2009
Maturing of unconventionals takes time
Profitable production of unconventional gas in the Netherlands possible?

- Definitely, shallow gas & tight gas (the “better” ones)
- Likely, shale gas
- Maybe, CBM, Basin Centred Gas

Present day conditions:
- Rig prices are higher in Europe than in USA
- No financial stimulation
- Only onshore potential for CBM and Shale Gas from economic perspective
- Intensive use of surface and subsurface; licensing difficult and time-consuming

- Key parameter is oil/gas price
Way forward

- Improve knowledge in NL, expertise from USA, Canada, Australia
  - GFZ (Potsdam) with TNO (NL), BGR (DE), BGS (UK), GEUS (DK), IFP (F)

- Improve technology, higher production for lower prices
  - Pilot projects (industry, JIP’s)

- Stimulate unconventional exploration and production (e.g. tax incentives)
  - Increasing industry activity unconventionals (Very recently companies show interest in acquiring acreage for exploration of unconventional gas: Cuadrilla, Queensland)

- EBN is willing to participate in unconventional gas E&P
Conclusions

- TNO study confirms that there are strong indications of ample unconventional resources in NL subsurface.

- Further study and pilot projects are necessary to investigate to what extent these resources can be produced.

- A time span of at least a decade can be expected for maturing these resources,

  but

- Profitable development depends on technology development and a positive social-economic environment.
References

- TNO report: TNO-034-UT-2009-00774/B
  “Inventory non-conventional gas”
  by Muntendam-Bos et al.
  www.ebn.nl

- Modern Shale Gas Development in the United States:
  A Primer.
  by Ground Water Protection Council and ALL Consulting
  fossil.energy.gov

  unconventional gas subgroup of the technology task group of
  the NPC Committee on global oil and gas:
  by Holditch et al.
  www.npc.org

- Shale Gas Opportunities and Challenges
  by Marc Bustin et al..
  www.searchanddiscovery.net/documents/2009/40382bustin/n
  dx_bustin.pdf