Political Use of Models in Sustainable Development

Faculty of Technology, Policy and Management

Shale Gas Exploration in the Netherlands

WM0935TU - Group F, Research Paper

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

This report has been written for the course WM0935TU The Political Use of Models in Sustainable Development. In this course we worked together in a group consisting of five groupmembers.
For this course we were asked to do a case study about a 'wicked' issue where different stakeholders and the use of scientific models are involved. The case study we chose is about shale gas and the method of fracking, and more specific; about whether the Dutch government should allow exploratory drillings on the Dutch soil or not. Since there are a lot of different stakes and opinions involved from different stakeholders, this is a wicked problem. On the one hand there is the demand for energy but on the other hand the urgency for more sustainable energy sources is growing. And besides that people living in the concerning area are also involved in the debate. This wickedness has led to a lot of discussion in the Netherlands, and this process is still ongoing. The use of scientific models contributed to the developments concerning this debate. These are some of the main reasons this particular debate was chosen as case study.

The input for this case study will come from different sources. A combination of theoretical backround, literature, our own different backgrounds, scientific perspective, non-scientific perspective and expert knowledge all contributed to this process and report. After introducing the research questions in the next paragraph, a short introduction on shale gas and the method of fracking will be given. At the end of this chapter a structure of the report is explained.

1.1 Research questions

The debate about exploratory drillings in the Netherlands has led to the following research question:

> What is the role of geological models in the political debate on exploratory drillings for shale gas in the Netherlands?

In order to answer this question, the next subquestions will be analysed in this report:

1. What is shale gas and what is the political debate about? Is it a wicked issue?
2. Which stakeholders are involved in the debate on shale gas and what positions do they take?
3. What are the models used for the exploration and production?
4. How are the results of the geological models used by the various stakeholders to strengthen their arguments?

1.2 What is shale gas and how does the method of fracking work?

Shale gas is natural gas contained in layers of clay -shales- in the subsurface (1.1). The layers are compact and hard to penetrate. This shale gas is produced by using a technique called fracking. To produce shale gas more water and chemicals are required than for producing conventional gasses. The end product of shale gas is the same product as normal gas, so the current infrastructure can be used. In order to assess the profitability and the availability of shale gas exploratory drilling is required. This technique of fracking creates fractures in the somewhat impermeable shales in

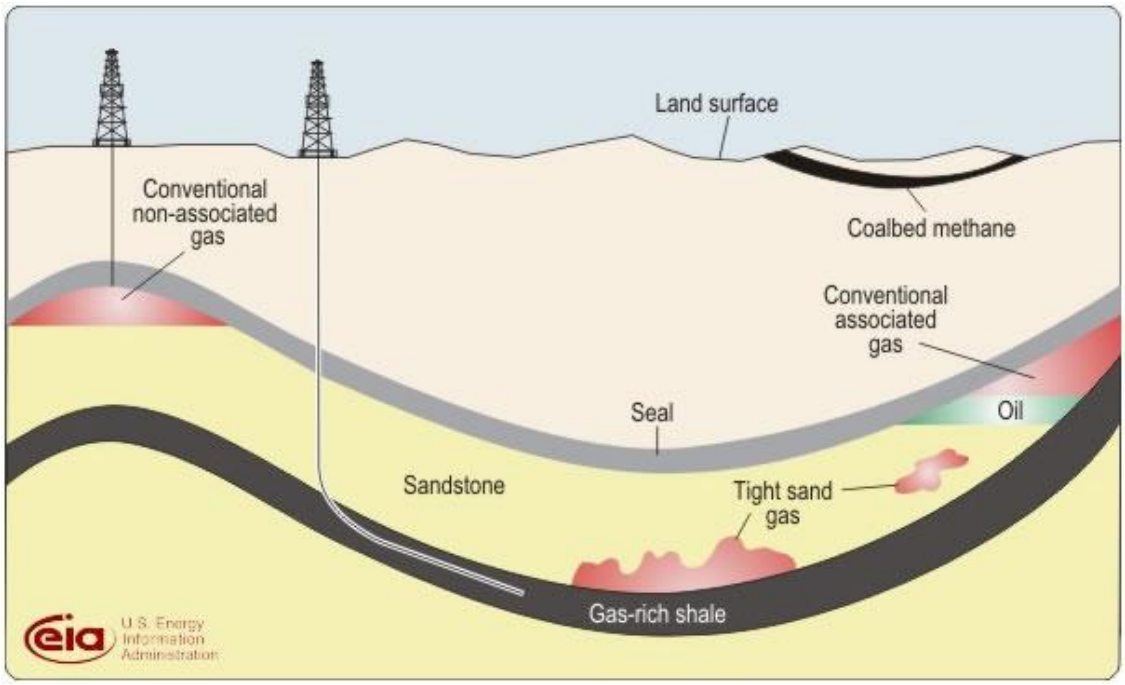

Figure 1.1: Profile of subsurface - black layer contains shale gas

order to let the gas out. Using fracking technology, cracks are made in a gas-containing layer by pumping high-pressure fluid and sand into this layer. The fluid consists of 90-96% water, 3-9% sand or ceramic beads (also called the 'proppant') and 0.5-3% chemicals. The sand or ceramic beads ensure that the created cracks remain open after the fracking operation, through which the gas can flow more easily into the well. Without the grains the cracks would close again after the fracking operation (TNO, 2013).

This process is also used in producing natural gas from conventional reservoir rock layers, although shale gas production normally takes place with a greater number of fracking operations in the same horizontal wellbore. The reason for this is that with extracting conventional gas, the gas is contained as one large bubble of gas and so the gas converges to the extracting point. This is not the case with extracting shale gas, because the gas is contained in small amounts and spread over a shale. The shale gas does not converge to the well so in order to keep extracting the same amount of shale gas, more wells should be built. The efficiency of one well rapidly deteriorates, and in a matter of five years, the efficiency can be questionable.

Initial exploratory drillings contribute to knowledge on the effectiveness of fracking at a particular location, and also give information about the possible risks and effects of fracking. The role of these exploratory drillings is the main issue in this debate (TNO, 2011).

1.3 Structure of the report

In order to find an answer to the subquestions and research question as stated in the previous sections, the use of the models that were a part of this debate will be analysed in Chapter 2. After that a chronological overview of the debate will be given in Chapter 3 to get a total picture of the developments and interactions between the different stakeholders. These stakeholders will be discussed and analysed in Chapter 4. In Chapter 5 the theoretical analysis will address the 'wickedness' and will give a perspective on boundary work. A summary of the interview with Rene Peters is included in Chapter 6. After that an answer to the research question is concluded in Chapter 7. The discussion in Chapter 8 reflects on the project and results.

Chapter 2

Model Description

There are several ways of defining a model. A model can be a tool based on science that tries to explain or forecast certain phenomena. During this course we used the following working definition:

"A model is a material, digitalized, and/or conceptual realization of a simplified and manageable representation of a segment of reality. What is considered as an appropriate simplification or as manageable depends on the function of a model: acquiring knowledge, testing possibilities, or providing an example for action." (Pesch & Cuppen, 2013)

In this chapter we will discuss several models that were used in the debate on exploratory drillings for shale gas in the Netherlands. Starting with the geological models developed by the Geological Survey of the Netherlands. These models are a representation of the Dutch subsurface. Then we will focus more on the research on shale gas reservoirs estimations and possible future exploitation. We will end this chapter discussing some international research on the potential risks of shale gas production.

Since the discussion is about exploratory drillings, it is important to realize, there are no exact data and results from research in the Netherlands available yet. Hence, most of the research on the Dutch case is based on estimations with strong uncertainties. Furthermore, the research on methods and technologies relevant to possible future shale gas exploitation is based on models of the micro-cosmos type. They allow us to test different courses of actions and future scenarios.

2.1 Geological models of the Dutch subsurface

Geological models provide detailed knowledge about the Dutch subsurface. The Geological Survey of the Netherlands (GDN), part of TNO, keeps the results of over a hundred years of research in databases. (Geological Survey of the Netherlands, 2011a) The information is constantly updated and is available for all those who are interested, like companies and (local) governments. GDN has millions of data coming from drillings and measurements .The data is stored within DINO (Data Information Dutch Subsurface).

GDN has developed four models (Geological Survey of the Netherlands, 2011b) for the shallow subsurface based on the hundred thousand drillings and cone penetration tests in the DINO database. The GDN also develops models for the deep subsurface up to a depth of 4 to 5 thousand metres. Subsurface models use all the available knowledge to produce al representation of the subsurface. They predict strata structure and characteristics, including the gases and fluids present.

The models for the integrated basic geological information and links to other databases enable specific questions to be answered, like the risks of subsurface intervention. Excisions can be made from the models for specific purposes, like the possible effects of shale gas production. GDN

describes its own geological models in the following way (Geological Survey of the Netherlands, 2011b):

2.1.1 Digital Geological Model and REGIS-II

In the Digital Geological Model (DGM) the Dutch subsurface is built by digitally stacking the lithostratigraphic layers in the subsurface on top of each other from a depth of 500 metres to the surface. The DGM provides insight into the stratification through thickness and depth planes, thereby making clear the spatial relationships of the layers on a regional scale as map images and profiles.

REGIS-II (REgional Geohydrological Information System) is the hydrogeological refinement of the DGM in which each geological layer (formation) is subdivided into layers whose permeability is good (sandy) and poor (clayey). These layers have been assigned mean geohydrological parameters for use in groundwater studies.

2.1.2 GeoTOP and NL3D

GeoTOP provides a detailed three-dimensional image of the subsurface up to a depth of 30 metres below the surface, that part of the subsurface most intensively used by man. It refines the upper side of the DGM and REGIS-II whereby the subsurface is divided into millions of voxels (little blocks). Each voxel contains information on the type of soil and the corresponding physical and chemical attributes. An example of a GeoTOP model can be found in figure 2.1. The fourth model is NL3D, a low-resolution variant of GeoTOP. NL3D provides information on the soil structure up to a depth of 50 m for the whole of the Netherlands.

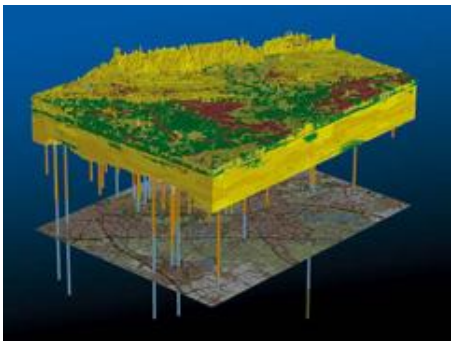

Figure 2.1: GeoTOP-model with boreholes. Source: TNO

2.2 Shale gas in the Netherlands

In this section we will focus on the models that were used for gas-in-place estimates of shale gas in the Netherlands. Furthermore, we will discuss how TNO researches methods and technologies relevant to possible future shale gas exploitation in the Netherlands.

2.2.1 Models to estimate the presence of shale gas

By using existing data from the geological models, a first evaluation from TNO in 2009, commissioned by Energie Beheer Nederland (EBN), confirmed high potential for shale gas in the Netherlands, although estimates were presented with strong uncertainties. Due to these strong uncertainties in gas-in-place estimates, opinion on the potential for shale gas in the Netherlands is divided. (van Bergen, Zijp, & Nelskamp, 2011) Royal Haskoning wrote an additional report on shale gas in the Netherlands. (Royal Haskoning, 2011) The TNO study wasn't only about shale

gas, but was covering research of all different kinds unconventional gas reservoirs. Generally speaking, conventional natural gas is extracted from discrete, well-defined reservoirs. Unconventional natural gas resources are generally found in less permeable rock formations, where resource accumulations may be distributed over a much larger area than conventional gas. Figure 2.2 shows a picture of unconventional oil and gas reservoirs in the Dutch subsurface. (Royal Haskoning, 2011)

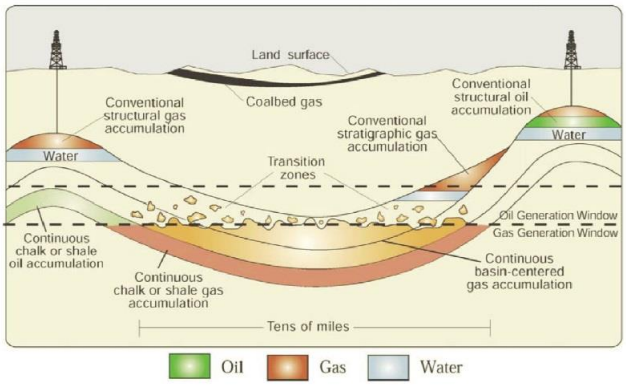

Figure 2.2: Unconventional oil and gas reservoirs (not scaled). Source: TNO

Frank van Bergen et al wrote an article about shale gas potential in the Netherlands for the Geophysical Research abstracts.(van Bergen et al., 2011) In this article they describe how TNO currently works on refining shale gas estimates based on additional data collection and an integrated multidisciplinary approach. The main target formations for shale gas are the Lower Jurassic Posidonia Shale Formation (PSF) and the Carboniferous (Namurian) Epen Formation (CEF). The PSF is known to be present in the onshore West Netherlands Basin from many well penetrations and its distinct seismic character.

Gas logs indicate the presence of gas. Fault-bounded tectonic blocks were identified on 3D seismics with relatively undisturbed deposits. GIIP (Gas Initially in Place) calculations were performed for these individual blocks, based on TOC (Total Organic Carbon) and porosity. TOC values were calculated from logs and cross checked on actual measurements. Eventually you have an estimate of the PGIP (Producible Gas in Place). In table 2.1 you can find reserve estimations, made by TNO. To compare these results, the GIIP and PGIP of the gas reservoirs in Groningen are stated as well. The figures and table we use in this section are from the Royal Haskoning report (Royal Haskoning, 2011), commissioned by EBN, but are originally produced by TNO.

	GIIP, Best estimate (bcm)	PGIP, Best estimate (bcm)
High potential	110000	5600
Medium potential	330000	16000
Low potential	2600000	130000
Groningen	$>$ 3200	$>$ 3200

Table 2.1: Gas reservoirs in the Netherlands. Source: TNO

2.2.2 Shale gas exploitation

Besides reserve estimations, TNO researches methods and technologies relevant to possible future shale gas exploitation. This research includes the minimization of surface footprint, monitoring and simulating of hydraulic fracturing, and looking at alternatives to stimulation. (Shale Gas Information Platform, 2012)

An example of such research is the additional use of biostratigraphy, mainly based on palynology, on top of petroleum evaluations using structural geology, geochemistry, sedimentology, geophysics and petrophysics. This work results in better 3D facies modelling, which determines the type of organic matter, mineralogy and grain size. In turn it can indicate zones with high susceptibility to hydrofracture, or frackability, and high gas content.

Using numerical modeling in combination with an improved 3D facies model can result in an optimized production strategy (lateral and vertical well placement and placement of fracture stages in horizontal wells), which will ultimately decrease drill and fracture activity and drive down costs.

2.3 Seismic models

The political debate on shale gas production is also a hot topic abroad. In 2011 Cuadrilla did exploratory drills in the UK and earthquakes occurred. Afterwards research made clear the earthquakes were caused because of hitting a natural crack. In this section we will discuss some of the research that has been done in the UK. We will focus on the seismic models that were used. Furthermore, we will discuss if the British research can be adjusted to the Dutch case. Note that, since the exploratory drilling already took place in the UK, the actual seismic effects of these drillings could be measured. While in the Netherlands we can only rely on simulation and estimation models.

2.3.1 Geomechanical models

Due to the registered earthquakes in the vicinity of the fracking well by Blackpool in the UK on April 1st and May 27th 2011, Cuadrilla Resources and the British Geological Survey started developing geomechanical models to investigate the relationship between the fracking and the minor earthquakes, that were registered. (British Geological Survey, 2011a)

Analysis of data from two temporary instruments close to the drill site, installed by BGS after the magnitude 2.3 earthquake on 1 April, places the epicentre of this event within 500 metres of the Preese Hall shale gas drilling site and gives a depth of approximately 2 km. The fluid injection, between depths of 23 km, was ongoing at the Preese Hall site shortly before both earthquakes occurred. The timing of the two events in conjunction with the fluid injection suggests that they may be related. It is well-established that fluid injection can induce small earthquakes. Any process that injects pressurised water into rocks at depth will cause the rock to fracture and possibly produce earthquakes. (British Geological Survey, 2011a) Afterwards research made clear the earthquakes were caused because of hitting a natural crack.

2.3.2 Fracture mapping and rock physics models

The models developed by the BGS for fracture mapping are based on azimuthal analysis of P-wave data, shear-wave splitting analysis of multicomponent data, PS converted-wave analysis and singular value decomposition (SVD) inversion of fracture density using P-AVO. (British Geological Survey, 2011b)

Furthermore, they make use of a rock physics model, that provides the basis for any lithological inversion using seismic data. The analysis allows prediction of seismic properties of shales and shale

gas deposits for given mineral compositions and total organic carbon (TOC). (British Geological Survey, 2011b)

Shale happens to be extremely anisotropic. Seismic anisotropy is the variation of seismic wavespeed with direction. Any seismic data acquired over shale gas deposits will be affected by this strong anisotropy, and processing and interpretation of seismic data have to take anisotropy into account. The BGS Edinburgh Anisotropy Project (EAP) is a research team that uses seismic anisotropy for characterization of natural fractured reservoirs. It is developing further methods for mapping fracture patterns in shales.

2.3.3 Dutch subsurface

In the interview Rene Peters (Peters, 2013) explained that the results from England can partly say something about the Dutch case. Especially since the Netherlands possess this unique dataset DINO, managed by TNO/GDN, that contains a lot of information about the Dutch subsurface. We know we have similar underground, but we dont know if there is as much shale gas to extract as in England. There is a good chance it would be profitable in the Netherlands as well. In Poland however, it was expected there was a lot of shale gas but from 100 testdrills only 25 were positive. So the models that are used to investigate the seismic properties of fracking could possibly be converted to the Dutch case. however, as Mr Peters emphasized, test drilling in The Netherlands is really needed for the decisionmaking, this can be either positive or negative.

Chapter 3

Description of the Political Debate

The topic of shale gas exploration in the Netherlands entered the agenda in 2008, when Cuadrilla Resources Ltd wanted to expand its activities in the Netherlands after the successful exploration in the United Kingdom. However, it has not been part of the active political debate until 2010. The Dutch media have not reported on the topic before either. But this changed by the release of the movie Gasland, on the impact of fracking methods applied in the United States. This American documentary lead to questions in the Dutch parliament about the potential risks involved on the (exploratory) drillings for shale gas in the Netherlands.
In the rest of this chapter the development of the debate will be described in more detail and in order of occurrence.

3.1 Chronological Development of the Political Debate

Preceding the debate, Cuadrilla has requested an exploration license for hydrocarbons in September 2008 for an area of 2026 km^2 in the province of North Brabant for a duration of 5 years. Upon this request, the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) has issued TNO and the State Supervision of Mines (SodM) to investigate the feasibility and based on their advice the license was granted in October of 2009 (Staatscourant 16000, 2009). Both TNO and SodM based their advise on the applicability with respect to the geological models and the potential consequences.

To execute exploratory drillings, the license was transferred to Brabant Resources B.V. (a subsidiary of Cuadrilla) in April 2010. A first location for an exploratory drilling has been found in Haaren, and the municipality assigned a temporary planning permission in August of 2010 (Gemeente Haaren, 2010). Subsequently, a second drill location was found in Boxtel and a permission was assigned in October 2010. To research the location, Brabant Resources B.V. has issued Royal Haskoning and Oranjewoud in June 2011 to study the effects in Boxtel of such an exploratory drilling. For the research they used geological data available from the models used by TNO. But in the end of 2011 the permission for a test drill in Boxtel has been annulled by the district court. The municipality requested this after 600 residents of Boxtel signed a petition against an exploratory drilling (Gemeente Boxtel, 2010/2011). The district court judged that the temporariness of the drill site cannot be guaranteed, because it is highly likely that the location will be used for production once the exploratory research is finished. A similar protest was raised in Haaren by the foundation of 'SchalieGASvrij Haaren' in 2010. This eventually lead to the national organization of 'Schaliegasvrij Nederland' in April 2012 (SchalieGASvrij Haaren, 2010/2013).

The first time shale gas was part of the political debate was on June 8th of 2011, when the Minister of EL&I Maxime Verhagen replied to the parliament on questions about the progression of shale gas production in the Netherlands. In a letter to the house of representatives he provides

information and motivation on the position of the government with respect to shale gas. He also describes the development of other European countries, where Poland and the United Kingdom are interested in shale gas exploration, but Germany and France are against this unconventional gas winning. Nonetheless, the Minister emphasizes that the knowledge of the Dutch subsurface by TNO and supervision of SodM ensures that safety of residents and environment are guaranteed (Ministry of EL&I, 2011a).

However, only two weeks later Minister Verhagen replied in another letter to the house of representatives on the criticism raised by the parliament regarding the decisions made with respect to exploratory drillings. First, he explains in more detail the process of shale gas production and stresses that all the separate techniques used in this process are already being applied on both land and sea. Furthermore the Minister acknowledges the concerns that have been raised by residents and municipalities close to a exploratory drill location. He relates these concerns to recent reports on groundwater contamination in the United States and earthquakes in the United Kingdom as a consequence of shale gas production. The SodM has therefore issued Cuadrilla (which is authorized to extract shale gas in the UK) to investigate these tremors on June 14 of 2011. Pending this investigation, Verhagen has promised that all (exploratory) drillings for shale gas in the Netherlands have been suspended (Ministry of EL&I, 2011b).

Now that the issue has gotten political attention, the media started reporting frequently on shale gas. In particular, the documentary Gasland was shown on Dutch television in September 2011. These media reports have since then regularly raised questions by different members of the parliament: e.g. Van der Werf (CDA), Van Tongeren (GroenLinks) and recently Dik-Faber (ChristenUnie) (Kamervragen, 2011/2013). The concerns expressed by these members of the parliament were focused on the the technicalities of shale gas and the potential risks of the production by Cuadrilla. Furthermore, they question the state of affairs in which licenses for exploration have been assigned. All these concerns and media pressure led to the decision of Minister of Economic Affairs Henk Kamp in September 2012, that the exploratory activities by Brabant Resources B.V. will be suspended once more. This time, a national independent research will carefully indicate all potential risks and consequences involved with exploration and production of shale gas in the Netherlands. In March 2013 this research has been contracted to the engineering and consulting organization of Witteveen+Bos. Furthermore, Arcadis and Fugro are employed as subcontractors to assist with the implementation. Once again, the research of Witteveen+Bos will be based on the geological data available from the models used by TNO. The research will be completed on July 1st and will be presented to the members of parliament. Based on the outcome of this research will Minister Kamp either prohibit or permit Brabant Resources B.V. to start with exploratory drillings (Ministry of Economic Affairs, 2013).

The chronological development of the political debate as described above is given in Table 3.1. The stakeholders that have been mentioned will be analysed in detail in the next chapter where also the specific use of the geological models is explained.

2 September 2008	Cuadrilla requested a license for hydrocarbon exploration in North Brabant
6 April 2009	TNO advises the Ministry of EL&I on this request
19 May 2009	SodM advises the Ministry of EL&I on this request
26 October 2009	The requested license was granted by the Ministry of EL&I
24 January 2010	The documentary Gasland was released in the United States
4 April 2010	Cuadrilla's license transferred to its subsidiary Brabant Resources B.V.
31 August 2010	Haaren assigned a temporary planning permission to Brabant Resources B.V.
1 October 2010	Foundation of SchalieGASvrij Haaren

8 October 2010	Boxtel assigned a temporary planning permission to Brabant Resources B.V.
8 June 2011	Royal Haskoning and Oranjewoud investigate the drilling location in Boxtel
8 June 2011	Minister Verhagen first replied to questions of the parliament on shale gas
14 June 2011	SodM issued Cuadrilla to investigate tremors in the UK, the Dutch exploratory license was suspended
20 June 2011	Minister Verhagen again replied to questions of the parliament on shale gas
2 September 2011	Gasland was shown on Dutch television
8 September 2011	Van der Werf (CDA) questions Minister Verhagen
7 October 2011	Van Tongeren (GroenLinks) questions Minister Verhagen
21 October 2011	600 residents of Boxtel signed a petition of Schaliegas Vrij Boxtel
25 October 2011	The temporary planning permission in Boxtel has been annulled
3 April 2012	Foundation of Schaliegasvrij Nederland
5 September 2012	Minister Kamp suspended all exploratory licenses and issued an independent research
11 March 2013	Witteveen+Bos, Arcadis and Fugro have been contracted to carry out the research
15 March 2013	Dik-Faber (ChristenUnie) questions Minister Kamp
1 July 2013	The research is expected to be complete

Table 3.1: Chronological development of the political debate with respect to the various stake-holders

Chapter 4

Stakeholder Analysis

A stakeholder can be defined as someone who can affect or is affected by the issue at stake. Different stakeholders have different interests and different roles in the debate. In this chapter we will zoom in on the stakeholders and their interests, power and roles. We will first discuss several stakeholders and their positions in more detail. Then we will give an overview of the interaction between the various stakeholders through a Stakeholder Map. In the last section we will classify them by their power and interests.

4.1 Stakeholder Description

In the following tables we will discuss several stakeholders in more detail. We will focus on the interests, role, point of view and how they make use of the models. Most of the arguments (pro and con) that are used can be found in the Argument Map initiated by TNO in Appendix B.

Ministry of Economic Affairs

Interests	The mission of the Ministry of Economic Affairs is to promote sustainable economic growth in the Netherlands.
Role	The Ministry has issued TNO and the State Supervison of Mines to investigate the potential and effects of shale gas production in the Netherlands. The Ministry is able to grant licenses for exploratory drillings.
Arguments Pro	• The state benefits from the sale of shale gas, as shareholder, receiver of royalties or through taxes. • Shale gas production strengthens the national economy and boosts the local economies. • Shale gas production contributes to the energy supply of the Netherlands.
Arguments Con	• Shale gas is expensive and its profitability is unclear. • Shale gas production may lower the value of property: house prices may fall in the vicinity of a well. • Shale gas can create international tensions: safety and environmental risks for neighbouring countries. • Shale gas production requires amendments to existing law and legislation.

Use of model	Uses the model to show that there is shale gas available. Test drills would also help them with the decision for exploiting shale gas for profitable production.

Political Parties

Interests	Political parties often espouse an ideology or vision. The opinions of the Dutch political parties on shale gas are diverse. Part of the public resists shale gas production and this can cause political upheaval.
Role	If the PvdA turns against test drillings, the majority of the Lower House will likely be against exploratory drillings in the Netherlands.
Arguments Pro	• Shale gas helps to satisfy the growing demand for energy and can support other forms of energy production. • Shale gas production strengthens the political position of the Netherlands: the international negotiation power increases and shale gas reduces the dependence on energy supply from other countries. • The production of shale gas could be financially profitable for the Netherlands.
Arguments Con	• Part of the public resists shale gas production and this can cause political upheaval. • Shale gas production requires amendments to existing law and legislation. • Shale gas production harms the environment in the Netherlands.
Use of model	Political parties used the models in a wide variety. They have looked at the profitability and the potential risks using the models.

Dutch residents is the vicinity of a well

Interests	Having a well in the vicinity of their homes could effect their lives in several ways.
Role	They can assert their influence by voting for a specific political (local) party and by protesting against the drilling licenses in their neighbourhood.
Arguments Pro	• Shale gas production increases regional employment. • Offers business opportunities to local companies close to the production area. • Infrastructure built to produce shale gas remains beneficial to the local community after production stops.
Arguments Con	• House prices may fall in the vicinity of production wells. • Residents are scared of the perceived environmental risks of fracking. Harmful substances in the shale gas layer, like radioactive materials, may come to the surface. • Shale gas production could negatively impact air quality. • The drilling could cause earthquakes and other seismic risks.

Dutch taxpayers	
Interests	They can have environmental reasons, economic reasons or other reasons to be for or against a test drilling.
Role	They can assert their influence by voting for a specific political (local) party and by protesting against the drilling licenses.
Arguments Pro	• Dutch taxpayers will benefit from the profits of the drillings. If exploratory drillings lead to a successful and profitable gas production, the Dutch taxpayer will benefit from this.
Arguments Con	• Exploratory drillings cost money which will be paid by the taxpayer. If the exploratory drillings do not lead to actual profitable gas production the Dutch taxpayer will lose money on the drillings. • The Dutch taxpayer can be against the drillings by environmental or personal reasons.

Environmental organizations/NGOs	
Interests	Environmental organizations have the environment at stake. They will fight for the preserve of nature over economic benefit. They will represent the environmental issues. They do not benefit from any profit of the project and are merely concerned with reducing the impact on the environment.
Role	Protesting against shale gas production in the Netherlands. They try to create awareness of the potential effects on the environment by lobbying and through media exposure.
Arguments Pro	• Gas is a cleaner source of energy than coal or oil, so producing gas is a cleaner alternative than building a new oil or coal installation for energy.
Arguments Con	• Drilling can lead to various environmental concerns. Those issues are pollution of ground water, horizon pollution and other environmental burdens. • Althought gas is cleaner than oil or coal it still is not an renewable energy source. Investing in shale gas can conflict with the investments in cleaner and more sustainable energy sources.
Use of model	Used the model to show that there is water in the area, which can be affected by the chemicals used by fracking.

Fracking Engineering Companies	
Interests	Potential contractors, would like to have a license for exploratory drillings in the Netherlands.
Role	Lobbying for the licenses and are also involved in the research.
Arguments Pro	• Without (shale) gas production no work, no profit, etc.
Arguments Con	• Negative publicity if something goes wrong.

Use of model	Uses the model to show that shale gas is available. They want to verify the model by test drilling. Cuadrilla used geological models to investigate the relationship between fracking and minor earthquakes registered in the UK during fracking. Cuadrilla used the geological models to research the possibility of drink water contamination (Royal Haskoning, 2011) and concluded that the change of drinking water contaminations is extremely small.

Water companies, soft drink manufacturers, brewers, etc

Interests	These companies rely on the ground water for their products. Their interest will be to maintain a clean source of ground water.
Role	Try to inlfuence the debate by speaking out against shale gas production in the media.
Arguments Pro	• Their market will grow because the number of workers in the vicinity grows.
Arguments Con	• They rely on the ground water, if this gets polluted they will have to deal with the polluted water. • The drillings could affect the infrastructure in a negative way. Reducing their effectiveness in transportation.
Use of model	Used the models to show that there is water in the area, which can be affected by the chemicals.

Energie Beheer Nederland (EBN)

Interests	EBN B.V. is active in exploration, production, storage and trading in natural gas and oil and is the number one partner for oil and gas companies in the Netherlands.
Role	EBN commissioned the first evaluation of TNO that confirmed high potential for shale gas in the Netherlands. Also the report by Royal Haskoning on shale gas in the Netherlands was commissioned by EBN.
Arguments Pro	• Shale gas production helps to satisfy the growing demand for energy. • Shale gas can reduce gas imports or substitute conventional gas production.
Arguments Con	• It is unclear how much gas can be profitably produced.
Use of model	Many of the shale gas reservoir estimations and research was commisioned by EBN.

TNO

Interests	The Netherlands Organization for Applied Scientific Research, TNO, is an independent research organization, which aims towards a robust transition to sustainable energy supply.

Role	As a research institute and geological survey of the Netherlands, TNO has a broad knowledge of the Dutch subsurface and governs the database containing all data and information on the subsurface of the Netherlands. A first evaluation from TNO in 2009, commissioned by Energie Beheer Nederland (EBN), confirmed high potential for shale gas in the Netherlands. TNO developed most of the geological models that are used in the debate. Furthermore, TNO gives lectures to governmental institutes and information to the media, explaining the concepts of shale gas to the general public. Recently TNO has initiated the development of an Argument Map for shale gas exploitation in the Netherlands.
Point of View	TNO tries to be a neutral party in the debate and wants to take all different aspects into account. Rene Peters (TNO) emphasized in the interview (Peters, 2013) that test drillings are very important in the decision-making process. Right now there are a lot of arguments pro and against drilling for shale gas, but it is only after the test drills we know how relevant these arguments really are.
Use of model	Key holder in the research in the Netherlands.Besides shale gas reservoir estimations, TNO researches methods and technologies relevant to possible future shale gas exploitation.

State Supervision of Mines (SodM)

Interests	Ensuring that mining activities and the transport of natural gas are performed in a socially responsible manner.
Role	State Supervision of Mines (SodM) oversees the compliance with statutory regulations applicable to mineral exploration, extraction, storage and transport of minerals, focusing on the aspects of health, safety, the environment, effective extraction and soil movements. The department falls under the ministerial responsibility of the Minister of Economic Affairs, Agriculture and Innovation.
Point of View	According to Rob van Elsen from SodM, the risks involved with shale gas production are comparable to the risks that occur by conventional drilling activities. SodM agrees with TNO, that without exploratory drillings no decission can be made on whether you start real drillings for shale gas in the Netherlands, or not. (SodM, 2011)
Use of model	SodM is involved in the research on shale gas reservoirs and the possibilities for shale gas production in the Netherlands. They use, among others, geological models and risk models to support their point of view.

4.2 Stakeholder Map

Ministry of Economic Affairs, political parties; fracking engineering companies, Dutch residents in the vicinity of a well; environmental organizations/NGOs; Water companies, soft drink manufacturers, brewers etc., investors/investment banks; Dutch taxpayers. These different stakeholders uphold different world views and thus their opinion towards shale gas production are not all aligned. Among them, the Ministry of Economic Affairs, political parties and investors might have high interest and power at the planning phase and beginning of the implementation phase as they make plans and steer the direction of national economy. Fracking Engineering Companies also have strong interests in shale gas production projects and might compete with each other

when the government announced a project to be implemented. Dutch residents in the vicinity of the well are highly influenced by nearby production projects, especially when the project caused groundwater contamination or triggers earth quakes.

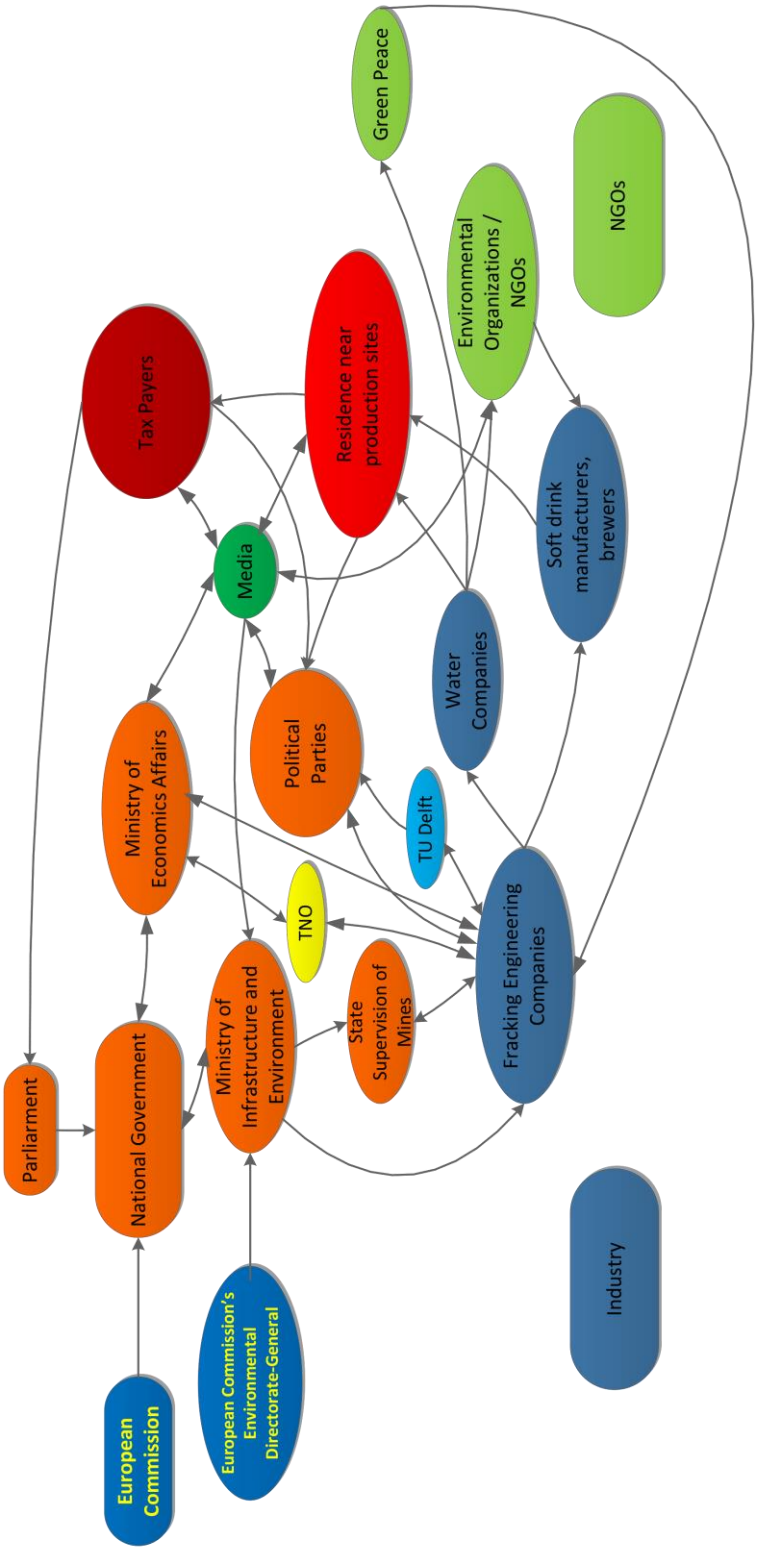

Figure 4.1: Stakeholder map

As the Stakeholder Map in figure 4.1 shows, although these stakeholders uphold different interests and worldviews, they are tightly linked to each other. Their interaction makes the whole network a complex adaptive system. Complex adaptive system is defined as a dynamic network of many agents acting in parallel, constantly acting and reacting to what the other agents are doing. The overall behaviour of the system is the result of a huge number of decisions made every moment by many individual agents. From the stakeholder map, we could see that the European Commission and especially the Environmental Directorate-General will regulate the Dutch governmental policy by the standard uniform Directives issued, Dutch government will formulate national policy according to the EC Directives.

The Ministries in the map will endow State Supervision of Mines the authority of acting as consultant for the fracking companies and projects. TNO is also involved as think tank for both policy makers and companies decision makers. Political parties have strong lobbying motivation towards steering the shale gas projects towards different directions. They may provide different views and scenarios to back up their argumentation. The arguments they provide will result from both their political standpoints and also the methodology they use for future planning. Using Direction Studies, Forecasting and Backcasting will lead them to different conclusions and thus will result in different effect in the system. In this sense, we can also conclude that the model (here lets say the methodology of future studies) will also have strong influence on the political debate just as this whole report elaborates.

Media is one of the most important intermediate in the stakeholder system and they also makes the system more complex. Many agents needs to have contacts with media to have their worldviews/perspectives/standpoints delivered to public and in this way to augment their power in this system. Local inhabitants might be marginal stakeholders, but they choose to express their voice to the media and maximize their power by raising consensus among the whole country or even lead a political upheaval. In this way, the media makes the marginal stakeholders interest protected. Then the Ministries might need to organize stakeholder dialogues, such as using Q-methodology, to involve these marginal interests in the next round policy making. As the above elaborates, the stakeholder map is a complex adaptive system. To fully understand how each stakeholder reacts to each other and how they influence the whole system, agent based modelling on the stakeholder ecosystem could be carried out.

4.3 Power-Interest of the Stakeholders

The Stakeholder Map in the previous paragraph gives an overview of the various stakeholders involved in the political debate on shale gas in the Netherlands. They all play a role in the decision-making, however, their power to influence the debate is diverse. For example, the Dutch residents have high interests, but are unlikely to have direct power over it. Figure 4.2 shows a Stakeholder Power-Interest Diagram, which classifies the various stakeholders by their power and by their interest in the shale gas debate.

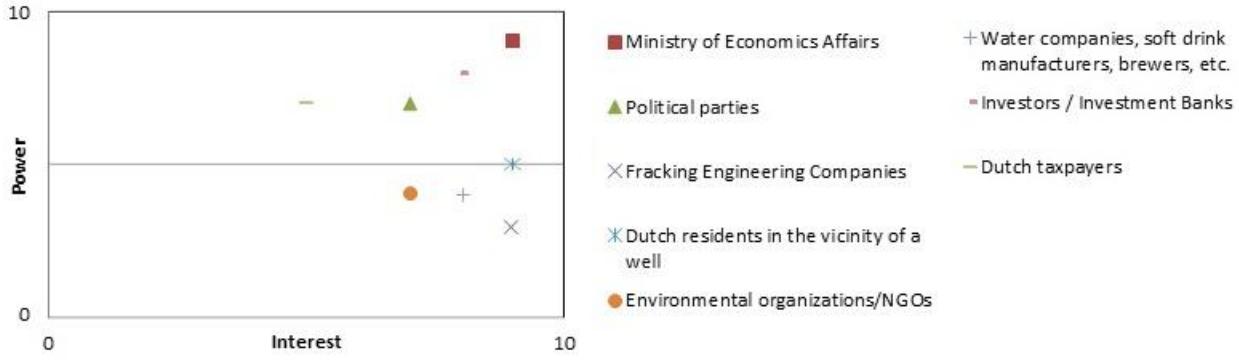

Figure 4.2: Stakeholder Power-Interest Diagram

Chapter 5

Theoretical Analysis

In this chapter the theoretical analysis of the interaction between different domains concerning the discussed debate will be described . In chapter 4 it becomes evident that a lot of stakeholders from different domains participate in this debate. It is therefore necessary to analyze the interaction between these domains to get a full understanding of the developments in the ongoing debate.
In chapter 1 a short description of a "wicked" issue was given and firstly this wickedness will be analysed and explained in section 5.1. After that the interaction between two specific domains will be discussed in section 5.2, namely between the political and scientific domain, which is also referred to as the boundary work. This chapter will contribute to a better understanding of interaction and communication between different domains.

5.1 The wickedness of shale gas production in the Netherlands

Shale gas production is a salient manifestation of complex issues that transcends the boundaries among technology, ethics, politics, economy, environment, safety and society. This kind of problem is generally identified as "wicked problem". Rittel and Webber first coined the term in the context of problems of social policy, an arena in which a purely scientific-rational approach cannot be applied because there is no consensus of the clear definition of problem, no agreement on the relevant knowledge and the norms and values at stake due to differing perspectives of stakeholders (Rittel & Webber, 1973). Wicked problem is described as a problem that is difficult, if not impossible, to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize. The term wicked does not mean evil but rather addresses the complexity of problem and resistance to resolution (Commission, 25 October 2007). Besides, due to the complex interdependency of various aspects of the problem, the effort to solve the problem from one aspect or one domain might raise feedbacks or side effects thus create another problem in other aspects or domains.

The theory of "wicked problem" dates back to a 1969 paper written by two urban planners, Horst Rittel and Melvin Webber. They framed the concept in terms of social policy and planning, and suggested that wicked problems occur in any domain involving stakeholders with differing perspectives (Conklin, 2006). The shale gas case particularly bears the characteristic of conflict interests and worldviews of different stakeholders. This is sometimes resembled by paradox of goals from various institutional domains. Moreover, within each domain, there exists contradictions of stakes at different levels, different scales, or inconsistency between future and now. Besides, shale gas production causes various environmental and ecological impact. However, most environmental and ecological problems are unstructured or complex as the nature is a complex adaptive system. Human ecology is another sphere involved in the complex human-nature system which add one

more layer of complexity. Environmental and ecological problems are complex and not fully understood by our science domain yet. Sometimes, primary effect of a pollutant can be the cause of several secondary effects and subsequent consequences which even cross institutional domains. For example, the shale gas production might cause groundwater pollution and earthquake which decrease safety in the neighbourhood residence area and further lower the value of local property thus degrade the local economy. This kind of causal chain has transcend institutional domains from one to another and does not stop. Environmental impacts could be normally categorized into resource use, human health and ecological consequences (Baumann & Tillman, 2004). Safety issues has close relationship with human health and thus could generate huge decisive power towards whether a project could be implemented or not, especially when stakeholders like local residents are involved into participatory decision making processes.

Thus the sustainability issue of shale gas production pose challenges to engineers, policy makers and civil society at large. The wickedness and complexity of the shale gas production lays at the following aspects which ignited fiery political debates.

1. Confrontation of interests of different domains.
2. Dilemma and Paradox of short-term benefit and long-term planning.
3. Stakeholders have different world views and interests.
4. Difficulty of aligning the stakes of People, Profit, Planet.
5. International character increases complexity.

Thus, the following paragraphs provide a further elaboration on each of the five paradoxes listed above.

5.1.1 Confrontation of interests of different domains

While looking at Table 5.1 of pros and cons of shale gas production, one could easily conclude that there are positive and negative opinions in each aspect itself. This is the basic element of complexity. Above that, more importantly, the institutional domains sometimes clash with each other in their sustainability articulations. For example, the energy industry might claim that shale gas is a more efficient energy source with less emission of CO2 comparing with coal or oil. While the articulation sounds plausible from the carbon footprint consideration, the water footprint and water pollution of shale gas production might disappoint local residents due to the potential of large scale groundwater contamination. Since there are more global ambitious targets on reducing CO2 emission thus more specific articulations on carbon impact such as Kyoto protocol and European 2020 Goals, but relatively less international treaties regarding to groundwater especially when the pollution is within a local scale. Thus the political pressure on environmental impacts might lay more emphasis on CO2 issues. The relative environmental gains might be considered to be larger than environmental lost. The political pressure of the government facing different environmental impacts determines their priority of policy agenda.

Besides, there is also confrontations from economy domain and political domain. There is a more stringent trend of liberalizing gas markets on the policy agenda of European Union (Belin, 2009). However, energy is still some member states national interests. In the European context, there is a challenge of liberalizing gas market without severe collapse of gas supply from Russia. Its concluded that liberalization of the energy market induces short-term thinking and system fragmentation. This will further results in decline of mutual trust and decrease of long-binding opportunities between Western European gas companies and the Russian gas company Gazprom (Westphal, 2012; Pesch, 2012). While the shale gas production in the Netherlands might strengthen the international negotiation power of the country and increase international political importance. The business long-binding agreements would dramatically decrease and once the

	For	Against
Energy	• Shale gas production contributes to the countrys energy supply • Shale gas can support other forms of energy production	• Shale gas production hinders the transition to renewable energy
Environment	• Shale gas production and use are relatively environmental friendly • Domestic shale gas production increases control over environmental impact of energy production	• Shale gas production harms the environment in terms of groundwater pollution, methane emission and chemical leakage • Shale gas production restricts space and disturbs tranquillity
Safety	• Shale gas can be produced safely	• Shale gas production is a hazard to employees and residents
Economy	• Shale gas production strengthens the national economy • Shale gas production is financially profitable for the country • Shale gas production boosts the local economy	• Shale gas production is expensive and its profitability is unclear • Shale gas production may lower the value of property • Large scale shale gas production may weaken the national economy in the long term
Politics	• Shale gas production strengthens the political position of the country	• Shale gas production can lead to domestic political tensions • Shale gas production requires amendments to existing law and legislation • Shale gas production can create international tensions

Table 5.1: Positive and Negative perceptions on shale gas production in the Netherlands

shale gas production cost increase due to economic recession or national currency increase, the domestic shale gas companies would suffer.

In the Dutch context, the CPB (Netherlands Institutes for Economic Policy Advice) might be in favor of the shale gas production as this spurs national economy in a short period. However, the PBL (Netherlands Environmental Assessment Agency) might be very cautious on drawing any conclusion on the sustainability of shale gas production due to the potential of groundwater pollution and methane emission. An empirical observation is that the CPB might have more political power than the PBL so that the political debates between CPB and PBL would represent the conflicting interests from different domains (Economy vs Environment).

5.1.2 Dilemma and Paradox of short-term benefit and long-term planning

While the shale gas production benefits the national economy by contributes to the countrys energy supply and reduce the imports of gas and other energy resources. The large scale implementation of the production might cause a paradox and impede the economy growth in longer term. One impressive argumentation is that the shale gas investment might hinder the transition to renewable energy system (Geels, n.d.). Under the European 2020 goal landscape, government of the Netherlands has also put the country on the course of achieving the EU 2020 goal: An annual energy saving of 2%, an increase in the share of renewable energy to 20% by 2020 and a 30% reduction in greenhouse gas emissions, preferably at European level, by 2020 relative to 1990. Thus the large

investment on shale gas production might cause short budget which decrease the investment on renewable energy and lose the best time of energy transition. The Dutch government might use the budget to invest renewable energy directly to accelerate transition phase. Shale gas increases the energy supply and thus could decrease the urgency of switching to renewable energy and degrade the political and economic ambition in developing renewable energy. This could be considered as a moral hazard just like geoengineering is considered as moral hazard as it loosen peoples cautiousness of climate change impacts. Moreover, the shale gas production reduces the fossil fuel energy prices and makes renewable energy even more expensive. The economic competitiveness of cheap shale gas might even eradicate current existing companies dedicated to renewable energy. Thus while the shale gas production might bring instant benefit in terms of cheap energy supply, it might hinder the countrys energy system transition and fundamentally impede the Netherlands progress of achieving the EU 2020 targets. The failure of switching to renewable energy in time might cause the Netherlands lag behind of other member states in renewable energy industry and market. Thus the final result might be the loss of political and economic power in the end. The short-term economic benefit might dramatically decrease the opportunity of achieving future benefits. This pattern of development would be considered as unsustainable.

Moreover, the transition towards a renewable energy industry is a technology system transition. Technological Transitions (TT) are defined as major technological transformations in the way societal functions are fulfilled. Technological transitions do not only involve technological changes, but also changes in elements such as user practices, regulation, industrial networks, infrastructure, and symbolic meaning (TNO, 2012). A transition normally refers to a system innovation which contains changes from different domains, such as economy, institution, technology, behaviour, culture, ecology and belief systems, that reinforce each other and lead to a radical systemic changes. The energy transition to a renewable energy supply is also a system change which includes both production and consumption sides. To achieve a sustainable production and consumption, changes in various domains such as regulations, business, science, social norms such as user practice are all needed. Physical energy infrastructure system also need to adapt to new energy production and transport demands. The transition process requires enormous monetary investment and decades of time to complete. The longer we wait, the more difficult it would be to achieve a system change. Thus the shale gas production might dramatically hinder the system change. Just like the Chinese proverb says : "If we do not change our direction, we are likely to end up where we are headed".

5.1.3 Stakeholders have different world views and interests

In the stakeholder analysis, various stakeholders have been identified including: Ministry of Economic Affairs, political parties; fracking engineering companies, Dutch residents in the vicinity of a well; environmental organizations/NGOs; Water companies, soft drink manufacturers, brewers etc., investors/investment banks; Dutch taxpayers. These different stakeholders uphold different world views and thus their opinion towards shale gas production are not all aligned. Among them, Ministry of Economic Affairs, political parties and investors might have high interest and power at the planning phase and beginning of the implementation phase as they make plans and steer the direction of national economy. Fracking Engineering Companies also have strong interests in shale gas production projects and might compete with each other when the government announced a project to be implemented. Dutch residents in the vicinity of the well is highly influenced by nearby production projects, especially when the project caused groundwater contamination or triggers earth quakes. Thus residents are easily becoming victims once severe environmental impact occurs. However, residents in the vicinity of a well are this kind of actors: they are scattered across the whole country; Individual has no power to change the whole energy system; they are only influenced by local impact and local projects in the vicinity of their house; their interests and rights are easily influenced but they need to defend themselves; residents living in different places normally have no contacts and can rarely unit each other, etc. Thus residents are considered as marginal stakeholders who are directly vulnerable to the negative impacts of the shale gas projects.

Nevertheless, these marginal stakeholders rarely have the opportunity to partake in the policy making and decision making process. However these stakeholders are normally tax payers, their interests should be well defended. Stakeholder dialogues are thus recommended as a means to tackle complex ecological and environmental problems. Stakeholder dialogues could thus enhance mutual learning by generating and evaluating divergent knowledge claims and viewpoints (Cuppen, Breukers, Hisschemoller, & Bergsma, 2010). For example, in the Netherlands stakeholder dialogue was carried out to collect stakeholders opinion on biomass as energy option using Q methodology (Cuppen et al., 2010). Its thus recommended to organize a similar stakeholder dialogue for shale gas production. Otherwise, an severe environmental impact could results in public resistance on shale gas production and even political upheaval.

5.1.4 Difficulty of aligning the stakes of People, Profit, Planet

To warrant sustainable development, its vital to achieve the balance among the stakes of three Ps (People, Profit, Planet), which is also commonly concluded as triple bottom line (Pesch & Cuppen, 2013). Economic, ecological, and social realms are three pillars of the society and should evolve in a coherent way without gaining one while losing another. Only a harmonized development of People, Profit and Planet could lead us to the EU 2020 targets. However, while the shale gas production has various benefits and potentials, there still exists some barriers on the alignment of the three Ps. The economic benefits should be carefully reaped without harming human health and safety. Domestic and international environmental impacts should also be minimized. Among them, people are vital in terms of stakes. The environmental impact such as groundwater contamination of shale gas production is normally local impact, not a global environmental problem. However, the local impacts might be overlooked or neglected by national authorities / developers while its the local people really suffer from it. Its not to say shale gas production is a problem that should be removed from our policy agenda. But cautious balance of stakes of People, Profit and Planet should be thoroughly considered and described in detail in future policy regarding shale gas projects.

5.1.5 International character increases complexity

The shale gas production in the Netherlands could cause international impact and particularly influence neighbour countries such as Germany. The emissions and groundwater contamination thus could cause negative environmental and safety impact in neighbouring countries. Thus sectors in the governments who support shale gas production must confront with both domestic political opponents and foreign pressures. Especially cross-border environmental problems are tricky and difficult to quantify the impact. An example could be demonstrated by a coevolutionary revision of decision making process of the port extensions in Germany, Belgium and the Netherlands (Gerrits, 2012). The cross-border international environmental problem will add one more layer of complexity to the issue.

5.2 Boundary Work

An important link in the process of a “wicked issue” is the interaction between science and politics, the so called boundary work. This boundary work is defined as followed in the reader (Pesch & Cuppen, 2013):

> The description of the interaction between policymakers and scientific experts as a continuous process of negotiation and coordination

When a decision has to be made in the political domain, arguments and objective information are needed to convince others and to come to a decision. In this paragraph this interaction will be described and analysed.

In this case of the debate on test drillings in the Netherlands a lot of interaction at this boundary can be found. When TNO was asked by the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) in 2009 to investigate the feasibility of fracking for shale gas, the results led to a license for exploratory drillings. This grant led to resistance from the opponents of the (exploratory) drillings for shale gas. After that a new research took place to investigate the prospective risks and effects of fracking and drilling for shale gas in the Dutch subsurface. Besides the TNO research, some reports and conclusions of other scientific researches were published. These results however did not give a decisive answer on which a decision could be made. Figure 5.1 shows this interaction between the two different domains, as is discussed in the reader (Pesch & Cuppen, 2013).

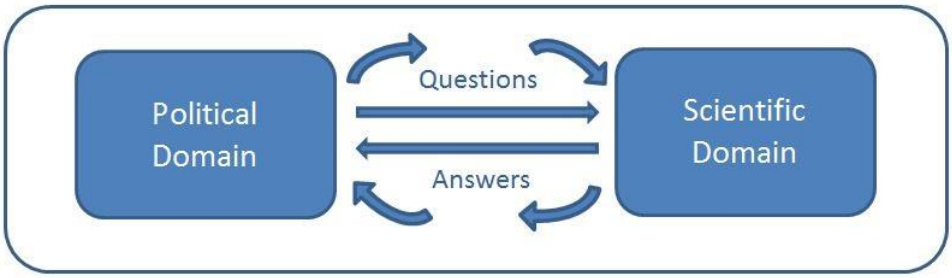

Figure 5.1: Interaction between political domain and scientific domain

The boundary work can be seen as a circular process which consists of a lot of forward and backward communication. This process is visible in this particular case. Science and research could not, however, rule out all the risks and prospective negative effects of the drillings that caused the resistance of part of the parliament and also of the local residents of the areas concerned. Because of this, more specific research was done, for example on the risks of earthquakes.
During the interview (Peters, 2013), Rene Peters pointed out that the opinion of a lot of people is based on perceptions and unfounded arguments. The continuous interaction between the scientific experts and policymakers contributed to a broad sheet of known knowns as Donald Rumsfeld, secretary of Defense in the Bush administration called them (Pesch & Cuppen, 2013):

> Known knowns; things we know we know.

But there also remained some questions that could not be answered, which are the known un-knowns;

> Known unknowns; things we know we don't know.

Because of this the boundary work is a cycle of questions to the scientific domain and formulated answers and information to the political domain. This process is currently still in progress.
There seems to be a dimension in this debate that keeps popping up while analyzing this debate. This factor was also raised by Rene Peters: He made clear that test drills really are necessary to support arguments pro or against the method of fracking for shale gas. The issue however is the fact that the general conception on actual fracking for shale gas keeps preventing the exploratory drillings. Right now it is not clear how strong the arguments presented in the argument map are. For the debate and effective boundary work, explicit questions should be presented from the politic domain but this dynamic has changed in this debate because of the strong perspective and influence of the citizens of the cities and surroundings involved.

Chapter 6

Interview

The director of gas technology and initiator of the EU Member States' version of the Argument Map, Dr.ir. M.C.A.M. Peters (TNO), was interviewed. He confirmed an interview on April 30th. The reason we chose him for this interview was his position and the position of TNO in the debate about shale gas and exploratory drillings. Because TNO is an independent research organization they look at the case objectively. Three of us have met with him at his office. The interview was recorded and we received a lot of useful information. A summery of this interview is presented here, which does not consist of his exact words but is the same in essence and context. The summary below is a translated version from Dutch. The information of this interview is furthermore processed in the report and did contribute to answering the subquestions and research question.

6.1 Summary of the Interview

1. TNO is one of the initiators to identify the advantages and disadvantages of the production of shale gas in the Netherlands in a so-called argument map. This map has been developed in cooperation with different stakeholders from the public and private sector, government, NGOs and research organizations. Could you briefly explain the role between TNO and these various stakeholders with respect to shale gas production?

   TNO is an independent research organisation with facts and knowledge as a basis. The research of the production of shale gas was done in cooperation with the universities Delft, Utrecht and Groningen, department geo-sciences, and also international institutes. The research is not based on expectations or perspectives and the goal is to get impartial objective information for both sides, and making this information available for everyone. It is important that this information is also available for the citizens, to decide on their own opinion. TNO's role is to explain what is going on and to give information. Right now research is done to look for alternatives and the impact of using shale gas. The research of TNO is always independent research. In the end general information is given to make it understandable for everyone. Besides that also more complex results and information are provided for the decisionmaking process. For citizens it is frightening to hear about plans to make use of shale gas because it involves working with 'dangerous' liquids and solids. Peters introduced us to his argumentation map and told us it is also used in the political debate to see if all the arguments are already used from all the different points of view.

2. In particular, the technique of fracking to produce shale gas is a topic that is relatively new to both national and local governments. Henk Kamp, minister of economic affairs, has issued various research organizations to investigate all possible risks and consequences of this technique. How do you think scientific research can contribute in the political debate?

Peters thinks it is a good thing all the pro's and con's are now researched and analysed. Producing gas always comes with taking risks, and the question is whether the risks are controllable and acceptable. And also íf the foreseen risks will occur, do we have a solution ready to solve the problems? Scientific research is used to analyse whether the risks can be eliminated or reduced. The process of fracking brings risks, and at the moment research is done to check if risks can be reduced by using different chemicals, or using other liquids than water, like LPG for the fracking process. Right now water is used to frack the layers, but there are a lot of countries water is not a sufficient available source. Scientific research contributes to finding alternatives for these problems. Collaboration is important, to combine different results and researches.
In the political debate there is not much opportunity or time to bring forward very extended arguments so mostly short statements and slogans are used. Scientific research takes time, and in this case years. Technology is always developing and for the Shale Gas discussion it will play an important role in the decisionmaking. Peters says the next few years are used to investigate the alternatives and possibilities even further. Because of this the scientific research plays an important role in the political debate.
This is also the case at the current debate about the earthquakes in Groningen. Now people are scared because of the earthquakes without exactly knowing what is going on. With technology can be shown what the actual risks are - how severe the earthquakes will be - and why they occur. After that a good consideration can be made.
There is a difference between the national discussion and the discussion on smaller scale. For the national discussion other arguments are decisive and important than for the discussion on smaller scale. On national scale however, also the local arguments are of importance. Public acceptation is very important, when a big national decision has to be made. In the argument-map, all arguments, on every scale, are shown. If the production of Shale Gas can produce local benefits for the area where the fracking will take place, this may contribute to the general acceptation of the production by the citizens. A very good example of this is the initiative for a compression generator in an area with a dense population. This generator caused a lot of noise and nuisance for the people. To compensate, the heat the generator produced, was used to heat a local swimming pool. Because of this measurement the initiative was accepted.

3. Is TNO one of these organizations? Why, or why not? What specific research (and with what motivation) is done by TNO that could assist in the political debate on shale gas? Are geological models part of your research?

TNO is an advisor of the Ministry of Economic Affairs. And they also provide licences for technical cases. TNO can therefore not be involved in projects where gas-companies will ask for a license to TNO. After the research is done for the ministry, TNO will be asked for advice on how to use the results of the research that is done by Witteveen+Bos in cooperation with some other companies. Right now current results are analysed and reference-projects are used. This is more an analysis of current knowledge than new results but if it is concluded that more research is necessary, additional scientific research can be a possibility, parallel to test drillings.
Now Peters emphasizes the difference between test drills and the real drilling for shale gas. When using test drills, samples are taken to research the properties of the ground conditions and after that some conclusions on perceived risks can be made. In Boxtel there is persistence against test drillings. The licenses are permitted but as soon as the citizens heard about the possible testdrills, they protested. Because of this the testdrills were not executed. The testdrills are, however, very important in the decisionmaking-process. The results give a solid base on which the decision for actual shale gas production can be made. Without these testdrills it is more speculation and discussing than a good grounded decision. Right now there are a lot of arguments pro and against drilling for shale gas, but it is only after the test drills we know how relevant these arguments really are. Exploratory drilling can tell us

how much gas the layer contains, how easily we can extract it and how much profit we can make from it. In England this was the case; Cuadrilla did exploratory drills and earthquakes occurred. Afterwards research made clear the earthquakes were caused because of hitting a natural crack. There was a lot of shale gas in the layer and eventually they decided it would be profitable to extract the shale gas. At the moment they are in the process of starting with extracting shale gas.

4. Do you have information on such a similar test drilling that was performed abroad? If so, what was the outcome and how was this used in the political debate? What do you think will be the result of a test drilling in the Netherlands and will this automatically have consequences for shale gas production?

   The results from England can partly say something about the Dutch case. We know we have similar underground, but we dont know if there is as much shale gas to extract as in England. There is a good chance it would be profitable in the Netherlands as well. In Poland however, it was expected there was a lot of shale gas but from 100 testdrills only 25 were positive. Test drilling in The Netherlands is really needed for the decisionmaking, this can be either positive or negative.
   The difference between conventional gas and shale gas is that for extraction of conventional gas only one well is needed per source. The gas diffuses to the well and the extraction can take place from this one point. This is different with shale gas extraction. Per frackingpoint only a small area can be extracted because the gas does not move in the direction of the frackingpoint. Because of this a lot of wells are needed. It also means that the efficiency of one well will decrease rapidly. Finding a good extraction point for conventional gas is more difficult than for shale gas, but the process of extracting is much easier.

5. The most frequently mentioned risks are groundwater contamination and earth tremors and are raised by local municipalities and brewing groups such as Heineken, Grolsch and Bavaria. Are these concerns justified and to what extend can new fracking techniques (or geological models) minimize these risks?

   The chemicals that are used, are also used in other products. Its the perception of the citizens that causes the tumult. Its all about perception and expectation. That, again, is the reason why the citizens should be well informed, to take away wrong ideas about drilling for Shale gas. The most important thing is to analyse what the cause is when something goes wrong. There is always a small risk that something goes wrong. It is important to learn from the mistakes and to make sure it will not happen again. If the cause of a failure is found, a new risk-analysis for following projects will be more accurate.

6. How is the political debate in the Netherlands different compared to other EU countries? Are our current gas regulations an obstruction for shale gas fracking? And furthermore, does our relative dense population hinder the actual drilling process?

   Our current gas regulations ar not an obstruction for fracking. Fracking is also used with conventional gas winnings. It is already sometimes used for not very porous groundlayers. It is already legally allowed, only additional licences are needed. The dense population is thé cause of all the issues around fracking. The 'not in my backyard'-attitude is the reason of all the risks and effects are because of the dense population. In the United States for example, there are wide areas where no people live. In the Netherlands there can be made wells, but they only reach up to a couple of kilometers from the source. Because of this, sources can be used less effective when there is a dense population. When there is not a very dense population, areas in The Netherlands are often protected or nature, that is why fracking is no option there. Because of these reasons a lot of areas are unreachable in The Netherlands.

Chapter 7

Conclusion

In this chapter the main findings of this research paper are presented and an answer is given to the main research question:

> What is the role of geological models in the political debate on exploratory drillings for shale gas in the Netherlands?

This question is answered in Section 7.2 and is based on the conclusions of the subquestions that are answered in Section 7.1.

7.1 Answers to the Research Questions

Based on the information provided in the previous chapters, the subquestions are answered below and provide a brief summary of the total research paper.

1. What is shale gas and what is the political debate about? Is it a wicked issue?

   An initial exploratory study by TNO for Energie Beheer Nederland in 2009 revealed that the Dutch subsurface probably contains significant quantities of shale gas. Shale gas is natural gas contained in layers of clay (shales) in the subsurface. The layers are compact and hard to penetrate. This shale gas is produced by using a technique called fracking. This technique creates fractures in the shales in order to let the gas out. To produce shale gas more water and chemicals are required than for producing conventional gasses.

   The political debate is about whether the Dutch government should grant approval of exploratory fracking activities for shale gas in the Netherlands. An initial exploratory drilling with fracking is not only a test drilling for the specific project concerned but also a check on the effectiveness of the existing technology for shale gas in the Netherlands in general.

   The wickedness and complexity of the shale gas production lays at the following aspects which ignited fiery political debates.

   i. Confrontation of interests of different domains.
   ii. Dilemma and Paradox of short-term benefit and long-term planning.
   iii. Stakeholders have different world views and interests.
   iv. Difficulty of aligning the stakes of People, Profit, Planet.
   v. International character increases complexity.
   vi. Since the discussion is about exploratory drillings, there are no exact data and results from research in the Netherlands available yet.

2. Which stakeholders are involved in the debate on shale gas and what positions do they take?

   In the stakeholder analysis, various stakeholders have been identified including: Ministry of Economic Affairs, political parties, fracking engineering companies, Dutch residents in the vicinity of a well, environmental organizations/NGOs, water companies, soft drink manufacturers, brewers etc. and the Dutch taxpayers. These different stakeholders uphold different world views and thus their opinion towards shale gas production are not all aligned.

   TNO is one of the initiators to identify the advantages and disadvantages of the production of shale gas in the Netherlands in a so-called argument map. This map has been developed in cooperation with different stakeholders and gives an overview of the wide range of arguments that can be used in the debate on shale gas. We interviewed Rene Peters (TNO), director of gas technology and initiator of the EU Member States' version of the Argument Map (Peters, 2013).

3. What are the models used for the exploration and production?

   Geological models provide detailed knowledge about the Dutch subsurface. The Geological Survey of the Netherlands (GDN), part of TNO, keeps the results of research in databases. GDN has developed several models of the Dutch subsurface, such as the DGM, REGIS-II, GeoTOP and NL3D model. Excisions can be made from the models for specific purposes, like the possible effects of shale gas production.

   By using existing data from the geological models, a first evaluation from TNO confirmed high potential for shale gas in the Netherlands, although estimates were presented with strong uncertainties. TNO currently works on refining shale gas estimates based on additional data collection and an integrated multidisciplinary approach. Besides reserve estimations, TNO researches methods and technologies relevant to possible future shale gas exploitation. This research includes the minimization of surface footprint, monitoring and simulating of hydraulic fracturing, and looking at alternatives to stimulation.

4. How are the results of the geological models used by the various stakeholders to strengthen their arguments?

   The various stakeholders use the scientific research and models in different ways. The research itself is commissioned by some of the stakeholders, like the Ministry of Economic Affairs and Energie Beheer Nederland. TNO developed different models for the exploration and production of shale gas and tries to get impartial objective information for both supporters and opponents of shale gas production in the Netherlands. Several investigations have been carried out by engineering and consulting firms like Royal Haskoning, Witteveen+Bos, Arcadis, etc.. Their research is based on the models developed by TNO. So the results of the geological models play a prominent role in the debate.

   However, due to the strong uncertainties in gas-in-place estimates, opinion on the potential for shale gas in the Netherlands is divided. Rene Peters emphasized in the interview (Peters, 2013) that test drillings are very important in the decision-making process. Right now there are a lot of arguments pro and against drilling for shale gas, but it is only after the test drills we know how relevant these arguments really are. Exploratory drilling can tell us how much gas the layer contains, how easily we can extract it and how much profit we can make from it. But opponents of shale gas production fear that once approval of exploratory drillings is granted, this will automatically lead to approval of shale gas production.

7.2 Main Findings

The political debate on whether exploratory drillings for shale gas should take place has been a typical example where scientific models play an important role in a wicked issue. However the debate is relatively new, such that the effects of these models on the discussion are not always that noticeable. Also, the research that will be most decisive for the outcome of the debate is not finished yet. Moreover, most parties involved with the research that is due on July 1st are not willing to comment on shale gas in general. This does not make the debate fully transparent either.

The wickedness of the debate was immediately clear. The local and national stakeholders involved have very distinct but different notions of the political debate. And furthermore, there is no consensus on the potential effects of an exploratory drilling for shale gas. Therefore, this particular political debate provided to be an interesting case study.

However, the way specific scientific models have played a role in the debate was not that evident. Since the described geological models of TNO do not contain specific information on shale layers with respect to gas production, one could argue that the scientific model would be developed once the first exploratory drilling will take place. And thus proponents of shale gas production use this argumentation that we need such an exploratory drilling. However, opponents often use geological models from the US or UK to empower their arguments against shale gas. This has led to a new type of boundary work for this debate. As indicated in the interview with Peters from TNO, convincing (local) opponents of the validity of exploratory drillings is often not done by arguments as outcome of mathematical research (Peters, 2013).

In conclusion, the mathematical models play an important role in the decision by Minister Kamp on whether exploratory drillings will take place. And arguments pro or against this decision are founded by these mathematical models. But apart from mathematical science, also social science is used to closely identify the resistance of local residents and governments opposing to shale gas exploration. Regardless of the different views of stakeholders on the geological consequences, social studies can be used to convince opponents by beneficial secondary consequences of exploration in their neighborhood.
Furthermore, the outcome of this debate will immediately start another. If exploratory drillings are necessary to acquire more scientific information, the debate on the potential profitability or risks of full-scale production remains.

Chapter 8

Discussion and Reflection

As mentioned in the Conclusion it was not quite clear what mathematical models have been used in the debate on shale gas exploration. Initially we therefore struggled with finding the correct model that would be (most) decisive in this debate. Also the level of detail in which the technicality of the chosen models would contribute to our research was a bit indistinct. Although the geological models are not solely responsible for the outcome of the debate, its information and impact is now presented such that it supports this research paper.

Our interviewee, Rene Peters from TNO, has been very helpful in pointing us to suitable models. Furthermore he has been a great source of information for general information on shale gas, but also on the perspective of both sides of the debate. TNO as organization and also as initiator of the argument map has taken a neutral role in the debate to provide information on the level that suits the various stakeholders. We would like to thank Peters for his assistance and the information he has provided for our report (Peters, 2013).
If we had to interview a different stakeholder, the provided information would be more biased towards one side of the debate. Nonetheless, interesting candidates for an interview would be Cuadrilla, the Ministry of Economic Affairs, Witeveen+Bos, schaliegasvrij Nederland or one of the municipalities involved. However, since the research issued by the Ministry of Economic Affairs is not finished yet, some of these stakeholders do not want to respond to questions regarding shale gas exploration.

The confidentiality has been imposed by the Ministry to the stakeholders involved in this research. But furthermore, this confidentiality also applies to the members of an established Sounding Board on the contents of a concept report on the conducted research. This has been understood by several members as an obstruction of the transparency in the debate on shale gas. And therefore the municipalities Noordoostpolder and Boxtel, the provinces North Brabant, Limburg and Zeeland, and Milieudefensie withdrew from the Sounding Board. Because the withdrawal of these stakeholders damaged the representation of our society, the viability of the Sounding Board is questioned (NOS, 2013b)
This development occurred one week before the outcome of the research would be introduced to this board. Also, contemporary to this news a group of 54 Dutch professors on environmental and sustainable development signed a manifest against shale gas (NOS, 2013a). Both these events show that the shale gas discussion is unfinished and that there is much recent development. Unfortunately these recent developments caused that the overview of the entire debate is somewhat incomplete, and therefore future research reports on the same topic could have a very different outcome.

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