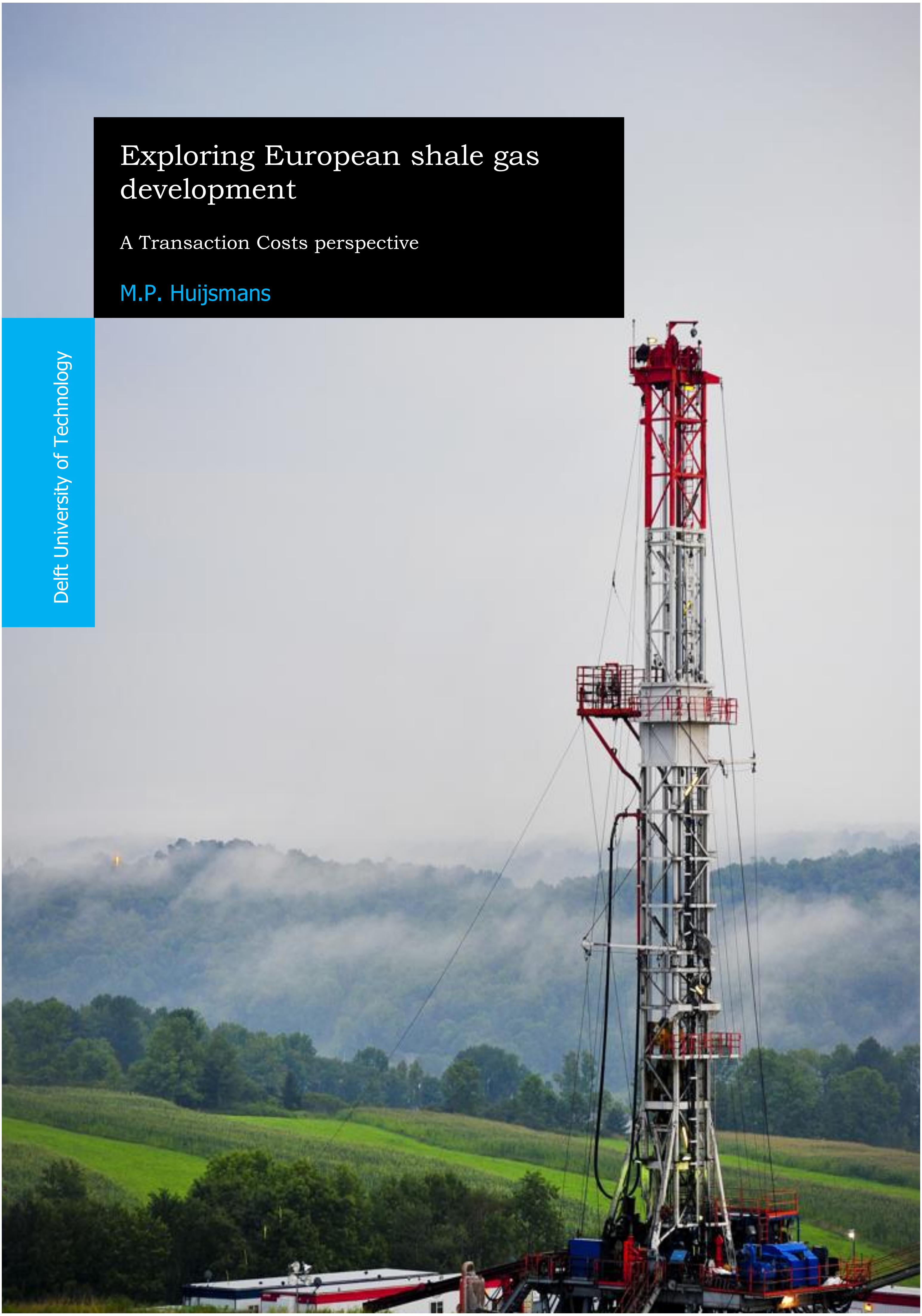

Exploring European shale gas development

A Transaction Costs perspective

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A Transaction Costs perspective

Den Haag, June 6 2016

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Preface

This research was conducted as final course of the Master's degree programme Systems Engineering, Policy Analysis and Management of the Delft University of Technology. The purpose of this thesis was to apply theory of both general courses and domain specific knowledge to a specific project. It was a great opportunity to apply the derived knowledge in this complex research problem. Combining technical and institutional aspects proved to be both challenging and interesting. The feasibility of European shale gas development under future European gas market design is a relatively unexplored research topic. During this thesis I gained a great insight into future challenges of European shale gas development, which contributed to my enthusiasm for the research topic from the first to the final day of writing.

I would like to thank my supervisor Aad Correljé for his excellent guidance and support during the process. Especially his expertise on European gas markets and shale gas in particular, provided me with valuable feedback. In-depth discussions during scheduled and non-scheduled meetings helped me structure and further explore the research problem.

Finally, I would like to thank my family and friends for debating research ideas and issues and for always supporting me during my studies.

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Abstract

The rise of shale gas production, has been the greatest revolution in the U.S. energy landscape since WWII and it is argued that market governance facilitated the process. This study analyses the feasibility of EU shale gas development. The publicly available shale gas analyses are inconclusive about the impact of future market design on shale gas feasibility. As the current EU governance structures are expected to change under influence of the GTM, it is interesting to examine whether they fit the prospect of EU shale gas development. The aim of this thesis is to gain a better understanding regarding the feasibility under EU future gas market design, by analysing the alignment of shale gas transactions and GTM governance structures.

TCE identifies the transaction attributes of EU shale gas exploitation and GTM governance structures by looking at technical characteristics and by analysing GTM key characteristics. These transaction attributes, together with GTM governance structures form the basis of the alignment analysis. A desk research is performed that applies TCE theory and compares the EU gas market developments with the U.S. and U.K. market conditions. By analysing, the degree of (mis)alignment of the shale gas transaction attributes with the characteristics of the future market design (GTM), the limiting and/or enabling factors for EU shale gas development are clarified. A synthesis of these factors provides an indication of EU shale gas cost efficiency (feasibility).

Specific shale gas transactions are characterized by a stochastic production profile. This leads to the requirement of flexible and transparent trading and more complexity that needs to be bridged by balancing mechanisms. The EU gas grid is extensive and storage facilities are numerous, so required shale gas infrastructure investments are minimal. Possible new investments are characterized by high asset specificity, high costs and hold up problems. The analysis of governance structures shows that the GTM combines market governance forms to create and connect markets, with hybrid governance forms to realize security of supply and infrastructure investments. This provides trade flexibility but limits infrastructure investments.

EU shale gas development has the potential to be feasible depending on the requirement of infrastructure investments and the way infrastructure investments are organized. With minimal required infrastructure investments, the most likely scenario given extensive EU gas infrastructure, shale gas can be developed and subsequently flexibly traded at European gas markets. However, if infrastructure investments are required, it is expected that shale gas producers will be hampered in exploitation, as a consequence of the hybrid GTM infrastructure investment mechanism that results in inefficient expensive long-term contracts. A deeper analysis of the required infrastructure investments (potential locations) and a better understanding of the way infrastructure investments are organized (extent of hierarchy), contributes to a robuster conclusion on European shale gas feasibility under EU future gas market design.

Keywords:
European shale gas development, Gas Target Model (GTM), Transaction Cost Economics (TCE), Desk research, Alignment

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List of abbreviations

Abbreviation Explanation

- **ACER** Agency for the Cooperation of Energy Regulators
- **CEER** Council of the European Energy Regulators
- **CEETR** Central and Eastern European Trading Region
- **CEGH** Central European Gas Hub
- **EA** Environmental Agency
- **EC** European Commission
- **ETC** Enhanced Trading Conditions
- **GOG** Gas-on-Gas Competition
- **GPL** Gaspool
- **GTM** Gas Target Model
- **GTS** Gasunie Transport Services
- **IOC** International Oil Company
- **LNG** Liquefied Natural Gas
- **MECOS** Market Enabling, COnnecting and Securing
- **NBP** National Balancing Point
- **NCG** NetConnect Germany
- **NIE** New Institutional Economics
- **NOC** National Oil Company
- **NRA** National Regulatory Authority
- **OPE** Oil Price Escalation
- **OTC** Over-The-Counter trade
- **PEG** Point d'Echange de Gaz
- **PSV** Punto di Scambio Virtuale
- **RSI** Residual Supply Index
- **TCE** Transaction Cost Economics
- **TPA** Third Party Access
- **TSO** Transmission System Operator
- **TTF** Title Transfer Facility
- **VP** Virtual trading Point
- **ZEE** Zeebrugge Hub

1 Introduction

1.1 European shale gas development

U.S. shale gas revolution and European feasiblity

The rise of unconventional gas production, and in particular shale gas, has been the greatest revolution in the U.S. energy landscape since the Second World War. It is argued that U.S. market governance facilitated the transformation of U.S. requirement for LNG imports (and hence global LNG trade) to export potential. This study analyses the possible feasibility of European shale gas development, by looking at the EU future gas market design, analysing the suggested GTM governance structures and their alignment with shale gas transactions.

Literature analyses

Most of the publicly available shale gas analyses focus their attention on either the macro-economic and the energy market impacts, or on the potential technological cost of European shale gas development (Weijermars, 2013).

European shale gas expensive

Gény performed an analysis of European shale gas focusing on the success factors behind the U.S. shale gas revolution, and the challenges to be faced by the European gas industry in replicating this U.S. revolution (2010). The conclusion was that costs of developing shale gas plays in Poland and Germany is at least two to three times higher than in the U.S. and that it is expensive compared to conventional gas in Europe.

European shale gas economics marginal

Other analyses focus on the environmental issues (MacKay & Stone, 2013) or political and geopolitical implications (Polish Institute of International Affairs, 2011). De Jong et al. (2014) looked into the effects of the U.S. shale gas revolution on the stability of Europe's traditional energy suppliers. Other publications (Kuhn & Umbach, (2011); Johnson & Boersma (2013); Bellelli & Genderen (2013); Spencer, Sartor, & Iddri (2014)) have focused on the context of European environmental regulation, public acceptance, gas market regulation and energy security. The U.S. shale gas revolution has also been extrapolated to other regions like China (Tian, Wang, Krupnick, & Liu, 2014). The conclusions of these analyses are that the economics of shale gas in Europe are marginal, and its economics are further negatively influenced by environmental and other constraints (Chyong & Reiner, 2015).

Effective future market design shale gas feasibility?

However, no studies have focused yet on the impact of future market design on shale gas feasibility. It is expected that by developing European shale gas, Europe could lower its import dependency and secure its future supply (Weijermars et al., 2011). It promises to decrease the ability of Russia to impose, oil-indexed gas prices in most of the European markets, especially in Central and Eastern Europe, where countries have almost no other source of supply. In short, shale gas proponents argue that it would allow Europeans to have more influence on their own energy destiny (Buchan, 2013). In order to ensure security of supply Europe should focus on a diverse gas suppliers portfolio, combined with an effective European shale gas extraction policy (Flues, Löschel, Massier, & Wölfing, 2013).

European gas markets developments

The question is whether the future governance structures of European gas markets allow for shale gas development. In comparison with the U.S. hub-based system that has free-floating prices, the European situation is less flexible. It is constrained by long-term contracts with the absence of a unified market, not as much transnational joint-ventures, and a carbon market price that fluctuates (Clemente, 2012). In the last two decades the EU gas industry is opened to forces of the market and some activities have been reorganised under decentralised processes. Moreover, the regulatory approach that defines the use of gas networks is characterized by entry/exit capacity contracts and tariffs, in combination with local balancing zones and virtual hubs. This liberalisation process of the European gas industry aims at an integrated market via legislative and regulatory reforms. The Third European Energy Package (2009 Directive) supports this process by providing a guideline to design EU-wide network codes, with the aim of facilitating and organising trade across EU countries.

Gas Target Model

The design of new governance structures in line with the Third European Energy Package resulted in the development of The Gas Target Model (GTM), which is under development since 2011. The GTM is a guiding top-down framework of principles that provides a description of expected gas market development, and focuses on investments in future interconnectors (connecting European markets) in combination with efficient usage of the gas infrastructure. It serves as a tool for the guidance and assessment of the on going process of developing the framework guidelines, that provide the foundations of the specific European network codes (Glachant, Hallack, & Vazquez, 2013).

Shale gas transaction attributes fit with GTM governance structures?

As the current governance structures are expected to change under influence of the GTM, it is interesting to examine whether they fit the prospect of European shale gas development. This requires a well-aligned GTM and forms of coordination, so that requirements imposed by the technical functions of shale gas exploration on the one hand (transaction attributes), fit with the rights and rules embedded by the GTM (governance structures) on the different institutional levels on the other hand (Maltby, 2013).

1.2 Research problem

Alignment effiency of governance structures and transactions

Evaluating these developments, the prospect of feasible European shale gas development will require an analysis of the future gas market design based on GTM governance structures. The changes caused by the GTM raise questions on the alignment efficiency of governance structures and transactions (Glachant et al., 2013). A crucial question is to what extent the regulatory framework (GTM) establishes adequate conditions for European shale gas development within its total gas market design. The theory of Transaction Cost Economics (TCE), which is further explained in paragraph 2.1, provides effective methods to analyse the governance structures and transaction attributes, and will therefore be applied in order to assess this alignment.

Selecting right form of governance; spot-markets, hybrids and hierarchies

TCE looks at the broader perspective regarding vertical integration, going beyond the principle of conduct structure performance, in which market structure has direct influence on the firm's market performance. It considers the structures of firms, contracts and markets as alternative methods of internal and market governance to allocate the risk involved in transactions. The parties involved in a transaction can, by selecting the right form of governance for a transaction, ranging from spot-markets to a contract or a vertical integrated structure, minimize its transaction costs and the exposure to ex post risks. If ex ante, is identified that these costs are not manageable, the transaction will not take place. The efficiency of arrangements and thus the overall cost of a transaction, is influenced by the attributes of transactions in markets between buyers, sellers and the environment.

Transaction attributes; asset specificity, uncertainty, frequency

This means that the alignment (efficiency of arrangements) of shale gas transaction attributes with future market design governance structures, will influence shale gas development in European gas markets. A misalignment could hamper European shale gas feasibility. The main attributes of transactions within this research involve; asset specificity, uncertainty and frequency. These attributes of shale gas transactions will be defined within the context of its upstream (and resulting midstream) value chain by applying TCE. Expected involved aspects are:

- Exploration (quality differences in shale gas layers)
- Production (profile flexibility regarding demand)
- Processing (treatment/blending)

Limiting and/or eneabling factors determine feasibility

By analysing, the degree of (mis)alignment of the shale gas transaction attributes with the characteristics of the future market design (GTM), the limiting and/or enabling factors for European shale gas development become clear. Subsequently a synthesis of these factors provides an indication of European shale gas cost efficiency (feasibility). See paragraph 1.5 for the research outline.

1.3 Contribution

Better understanding of feasibility

The objective of the research is to gain a better understanding regarding the feasibility of European shale gas development, by looking at the EU future gas market design, under GTM governance structures and their alignment with shale gas transactions. The study will be based on the conceptual framework introduced in paragraph 1.4. It is expected that the feasibility depends on the required midstream infrastructure and form of market organization.

Testing the use of TCE

The scientific objective of the research is testing the use of TCE within the research scope, and the discovery of new insights regarding the alignment of governance structures and transactions in European gas markets dynamics.

Alignment efficiency knowledge gap

A similar analysis for the European electricity market was performed by Eva Niesten (2009), however with more focus on the adaptation process of new governance structures as result of restructuring (1996-2008), while this research focuses on the alignment process regarding shale gas attributes and future market design. In addition to Niesten, Neumann et al. (2015) looked into long-term contracts of the natural gas industry. They conclude that long-term contracts are important for all economic activity and crucial for comprehending economic structures. According to Neumann et al. future research can improve understanding the impact of changing investment conditions and institutional environment, on choosing more or less centralized governance in the value chain. This research analyses how imposed governance structures within a changing institutional environment, influence the degree of their alignment with shale gas specific transaction attributes. According to Chyong & Reiner (2015) a liquid competitive internal gas market is essential, because of the random production nature of shale gas and its fast decline rate. If Europe wants to develop shale gas, it is not enough to have public and political support because of security of supply. Europe should focus on effective future market design that focuses on liquid, deregulated and easy entry gas markets. However, Europe is not the U.S. and has different attributes. This research aims to fill in the alignment efficiency knowledge gap, by analyzing specific shale gas transaction attributes in the European context and future market design under GTM governance structures, resulting in a better understanding of possible alignment regarding European shale gas development feasibility.

1.4 Conceptual framework and research questions

Based on the research problem, the following conceptual framework of the European gas markets is applied, to guide (see parts chapters/colours Figure 1) the research questions and forms the basis for the research outline.

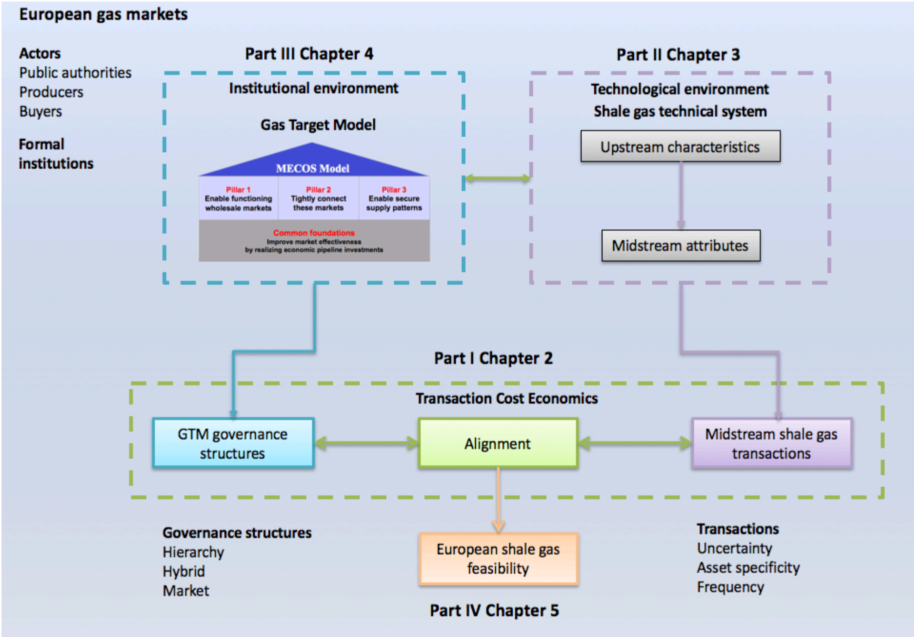

Figure 1 Conceptual framework

Conceptual framework; alignment knowledge gap regarding alignment

The main focus within the framework is on the alignment between the assumed GTM governance structures and midstream shale gas transactions, and their influence on the feasibility of European shale gas development. The GTM governance structures result from the institutional environment, in which the GTM is embedded and address the midstream section of the gas value chain. Therefore, in order to allow for effective comparison of the transactions and governance structures, the focus is on midstream shale gas transactions. Specific midstream shale gas transactions result from the technological environment and follow from the upstream technical characteristics. As Figure 1 illustrates, the institutional environment consists of sector structure, regulation and competition policy. The technological environment consists of the upstream shale gas value chain components, defining the midstream attributes. The focus of this thesis is on the sector structure, within the scope of aligning future GTM governance structures and shale gas transactions. The following questions are formulated following from the research problem within the conceptual framework:

<u>Main research question</u>

Main research question; feasibility European shale gas development

What is the influence of future European gas market design on the feasibility of European shale gas development?

The main research question originates directly from the conceptual model. Insight in the effects of interaction between the institutional environment and the technological environment, can provide insight into the feasibility of European shale gas development.

Sub research question 1; operationalisation TCE

Sub research question 1

How can the theory of transaction costs economics be operationalised for gas markets and shale gas exploitation?

In order to gain a better understanding of the future market design and its governance structures, a TCE perspective analysis is required as the research problem in paragraph 1.2 indicated. Therefore, the theory of TCE must first be operationalised for gas markets and specifically shale gas.

Sub research question 2; transaction attributes shale gas

Sub research question 2

What are the transaction attributes of shale gas exploitation derived from technical (and market) characteristics?

Subsequently, it is possible to analyse shale gas specific transactions by applying the operationalised TCE theory. This will provide insight into the shale gas transactions concept in the conceptual framework and identify its attributes, by addressing the upstream phase of the shale gas value chain and the resulting production and investment profiles for midstream. This requires the analysis of the listed aspects in paragraph 1.2:

- Supply and production profile flexibility regarding demand
- Quality differences in shale gas layers and transport requirements
- Local blending/spiking or clustered

Sub research question 3; Expected GTM governance structures

Sub research question 3

What are the expected governance structures of the European gas markets under the GTM?

The next step is identifying the expected governance structures under the GTM. This will be performed by taking the defined shale gas transaction attributes into account, as they will provide a clear and guided approach to analyse shale gas relevant GTM aspects.

Sub research question 4; Limitations and/or possibilities

Sub research question 4

How do these expected governance structures limit and/or enable European shale gas development?

The final step in order to answer the main research question, is analysing the alignment efficiency between the midstream shale gas transaction attributes and relevant GTM governance structures, by defining limitations and possibilities that influence feasibility.

1.5 Research outline and methodology

Figure 2 below graphically presents the structure and outline of this research. It describes four parts, segmented in five chapters as listed below in which the research questions are guiding. The colours of the research questions and corresponding chapters, match with the colours from the related concepts in the conceptual framework.

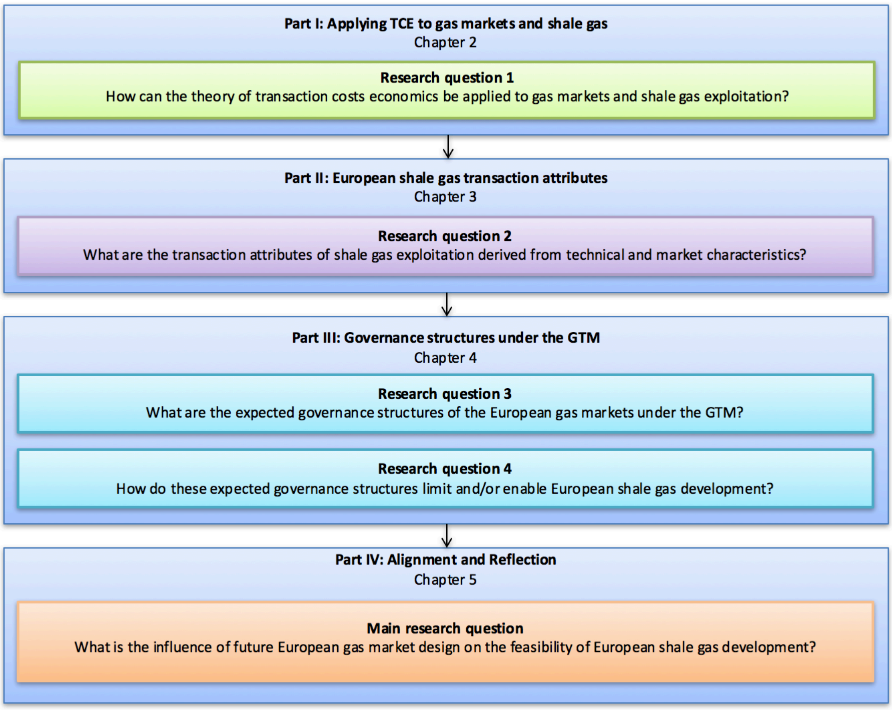

Figure 2 Research outline

Research outline

In order to gain a better understanding of the future market design and its governance structures, a TCE perspective analysis is useful as the research problem in paragraph 1.2 indicated. Therefore, in Part I, the theory of TCE must first be operationalised for gas markets and specifically shale gas. The various concepts of the conceptual TCE framework and their qualitative attributes will be defined. Subsequently, it is possible in Part II to define shale gas specific transactions and GTM expected governance structures in Part III by carrying out a literature study that focuses on U.S. and U.K. shale gas characteristics and European future market design. The final step in order to answer the main research question, is scoring the quantitative data of the alignment between the shale gas transactions and GTM governance structures. This is also done in Part III, by defining limitations and possibilities via Williamson's discriminating alignment hypothesis (Williamson, 1996: 12). Insight into the limiting and enabling consequences of the GTM governance structures for European shale gas development, will provide an indication of European shale gas development feasibility in Part IV.

Methodology and time frame

In order to answer the five research questions, a policy orientated descriptive desk research will be performed by applying TCE theory, and analysing the European gas market developments based on the

U.S. and U.K. market conditions. The theory of TCE provides the required methods to identify shale gas transaction attributes and GTM governance structures. Subsequently via its discriminating alignment hypothesis (see paragraph 2.4) it is possible to analyze the degree of (mis)alignment between the transaction attributes (shale gas market properties) and governance structures (future GTM market design). Based on the conceptual framework, a selection of TCE, European gas markets developments and shale gas development literature will be made that contributes to the answering of each sub- and eventually main research question. Academic papers, proceedings of conferences, books and reports will be used as sources for empirical refinement. The time period for which the changes are studied in the European gas markets range from the implementation of the 2009 third EC gas directive into the national laws and regulations, until the GTM standard of 2020.

Limitations desk research and TCE

The limitations of desk research are that data often is not presented in a way that exactly meets the researchers needs. The data may not be accurate, be old and out of date and the sample may be too small. Therefore, it is important to critically evaluate the validity and reliability. There are several examples from literature that discuss TCE limitations as Foss and Klein show in their 'Critiques of transaction costs economics' (Foss & Klein, 2010). 'One of the main limitations is the relatively static and equilibrium-oriented approach that cannot explain the dynamic efficiency issues of governance structures such as learning, capability, and innovation' (Hodgson, 2010: 4). Efficiency in the short-term may not always be efficient in the long-term. According to Hodgson as result of uncertainty, dynamic efficiency is essentially about learning and innovation and cannot be reduced to static terms. The consideration of static rather than dynamic efficiency is rooted in the comparative statics of Williamson and Coase (Lee & Liu, 2003). This however will not limit this research. The comparative and static element of TCE, in which two or more institutional set-ups are compared, corresponds with the research focus of studying the alignment in long-term future predetermined GTM conditions. This rules out the requirement for short-term dynamic efficiency. Furthermore, the long-term predetermined GTM conditions are an evolution of their environment and actor interactions, that follow from the current short-term market conditions.

Part I
Operationalisation of theory

This part of the research will address the operationalisation of the Transaction Costs Economics theory for gas markets and shale gas exploitation.

2 Operationalisation Transaction Cost Economics theory for gas markets and shale gas

The conceptual framework introduced in paragraph 1.3 requires further operationalisation in order for TCE to be applied on gas markets. The various concepts of the conceptual framework and their attributes will be defined in this chapter. First the TCE theory is described (2.1, 2.2, 2.3 and 2.4) and subsequently operationalised for gas markets and shale gas exploitation (2.5) by filling in the conceptual framework. Chapter 2 answers the first sub research question:

How can the theory of transaction costs economics be operationalised for gas markets and shale gas exploitation?

2.1 Describing Transaction Cost Economics

New Institutional Economics

This paragraph will describe the various components of TCE with emphasis on the theories of Oliver Williamson and Claude Ménard. The concept of transaction costs is part of the New Institutional Economics (NIE) and focuses on Level 3.

Level 1	**Informal institutions:**	***Broad values, norms, technological and physical characteristics***	Broad (energy) policy objectives and balance between: SoS, market and environment
Level 2	**Formal institutional environment:**	***Laws and constitutions***	Regulatory models and market 'design'
Level 3	**Institutional arrangements:**	***organisations, contracts and hybrids like PPPs***	- Actual regulatory instruments and decision; - Forms of PP cooperation - Firms tariff structures and trading practices; - Public and private evaluation and sharing of risk, profit, market, etc.
Level 4	**(market) behaviour**	***Interactions by actors with different objectives, strategies***	Market strategies, investments, lobbying, R&D, cooperation and conflict

Figure 3 The socio-political embedment of regulation (Correljé & Groenewegen, 2005: 12)

Figure 3 shows the position of NIE in Williamson's four-layer model. It illustrates how the governance structure is embedded in informal and formal institutions, and the related institutional arrangements and how it influences the behavior of market actors.

Levels of institutional analysis

Level 1 exists of society specific beliefs, values and general objectives. For instance: The environment, energy independence and scarcity. These principles vary in different countries and are the result of other factors like economic development and the political culture. They materialize in the formal institutional framework of Level 2, such as EU directives (for instance 'Gasdirective') and national laws (for instance 'Gaswet') and constitutions that define elements of market design. The formal laws are operationalized in arrangements such as contracts, network codes and tariffs and get a value and purpose in Level 3. At Level 4, the outcome of the other levels drives the interaction of market actors regarding their objectives and strategies, influencing buying and selling, investments and other behavior. The model usually works from the top downwards, but it is also possible that bottom up processes influence higher levels. The informal institutions of Level 1 and formal institutional environment of Level 2, are not addressed by NIE and are considered exogenous within this research, as the focus (getting the governance structure right) is on the institutional arrangements of Level 3 that is addressed by TCE.

Bounded rationality and ex-post dependencies

The theory of TCE states that the optimal form of governance depends on the efficieny effectiveness of coordinating institutional arrangements, that depend on the attributes of the transaction. Economic actors are bound in rationality and possibly behave opportunistic (self interest seeking), capturing the investment made by others. A simple example is claiming sunglasses from a travel insurance, when they are not lost at all, as it is expected that the insurer will not investigate such small claims. Another example addresses the buyer/seller relationship. The party that has not invested may take possession of some of the invested value by threatening to walk away from the relationship. Uncertainty about future developments leads to incomplete contracts that do not account for all the risks. When there is market competition with sufficient demand and supply, there is minimal uncertainty as a consequence of incomplete contracts. However, ex-post dependencies because of investments in specific assets, allow for opportunistic behavior that leads to transaction risks (influencing firms and market performance). This can be minimized by aligned forms of governance structures (Ruester, 2010).

Complementing TCE with technology

According to Ménard (2014), Williamson captures the essence of NIE emphasizing on transaction cost economics, he argues that it can be enriched with the integration of technology. TCE is strongly biased towards neglecting the role of technology as it switched its attention to a non-technical representation of attributes and organizational arrangements. Complementing TCE with a focus on technology would benefit this research given the analysis of the technical shale gas system.

Interaction technical operation and organizational arrangements

Criticality provides a method to identify the interaction between institutions, organizational requirements and technology. Criticality indicates that transactions must be organized in such a way, that they meet technical requirements in order for network infrastructures to deliver the expected services at highest quality and the lowest costs. This has a direct impact on the organization of transactions in and between different components of the system (value chain) and on the costs. The requirements resulting from the technical functions, should fit with the rights and rules at the different institutional levels (Ménard, 2014). This is the alignment between institutions and technology (see Figure 1).

Alignment transactions

Ménard extends Williamson's TCE analysis by making the transactions conditional on their alignment with specific technical characteristics. The contribution of the theory of Ménard regarding the interaction between technology and institutions is limited to the focus on the alignment, and does not emphasize critical transactions. The alignment in this research focuses on the transactions between technical operation (shale gas value chain) and organizational arrangements (governance structures). Levels 1 (Global Embeddedness) and 2 (Sector Governance) are considered exogenous, as indicated earlier.

2.2 Transactions

Uncertainty, frequency and asset specificity

'The basic unit of TCE is the transaction which takes place when a good or service is transferred across a technologically separable interface as one stage of activity terminates and another one begins' (Williamson, 1985: 1). Williamson indicates three main attribute categories of a transaction:

- The uncertainty to which a transaction is subject and that could affect transactions originating from opportunism (in addition to general uncertainty).
- The frequency with which the transaction occurs that is relevant regarding the reputation effect and governance costs. Reputation between contracting parties becomes more imporant when the frequency of transactions increase. Increased frequency allows for an easier recovery of specialized governance structures costs.
- The asset specificity of assets that are specific to the transaction, which has a central role in TCE. It refers to 'the degree to which an asset can be redeployed to alternative uses and by alternative users without sacrifice of its value' (Williamson, 1996: 59). There are five types of asset specificity (Williamson, 1985): (1) site-specificity, focusing on the location of similar activities in order to optimize inventory and transportation expenses; (2) physical asset specificity, referring to specialized systems designed for a single purpose; (3) human asset specificity in which highly specialized human skills develop in a learning by expierence method; (4) dedicated assets represent a discrete investment in production activities that cannot be used for other purposes; and (5) time-specificty in which there is a window of opportunity for the asset's value to reach the user within a specified time.

2.3 Governance structures

Forms of governance

The assumptions of bounded rationality and opportunism, introduced in 2.1, lead to the focus of TCE on the governance of incomplete contracts. Governance structures aim to safeguard against the hazards of opportunistic behaviour and to economize on bounded rationality. 'Governance structures are the organizational constructions that coordinate transactions between economic actors (in incomplete contracts), enabling the contractual implementation and enforcement' (Niesten, 2009: 28). There are three basic forms of governance:

- The market,
- The hybrid
- The hierarchy

Attributes

These can be categorized by three attributes (Williamson, 1991):

- Incentive intensity that is measured by the extent to which a technologically separable stage of economic activity appropriates its net profits.
- Administrative control which has a bearing on autonomy in both operating and investment respects as well as on procedural controls (routines, accounting procedures).
- Contract law regime that can be identified as classical (non flexible, short-term and most complete), neoclassical (more flexible and short-term) and forbearance (high flexibility and long-term).

Forms of governance and attributes combined

The attributes of governance are summarized in Table 1 and have a consistent relation to one another. Low administrative control and a classical contract law regime are consistent with a high incentive intensity.

Governance forms	**Incentive intensity**	**Administrative control**	**Contract law regime**
Markets	High	Low	Classical
Hybrids	Intermediate	Intermediate	Neoclassical
Hierarchies	Low	High	Forbearance

Table 1 Governance attributes related to governance forms

2.4 Descriminating alignment hypothesis

TCE alignment of governance structures and transactions

Central in TCE is the hypothesis that contracting parties have organizational arrangements (governance structures) that minimize transaction costs. This is called the discriminating alignment hypothesis and is described by Williamson accordingly (1998: 12): 'Transactions, which differ in their attributes, are aligned with governance structures, which differ in their cost and competence, so as to effect a discriminating mainly a transaction cost economizing result'. Each form of governance (explained in paragraph 2.3 Table 1) in the comparative institutional analysis of transaction cost economics, that is dependent on the attributes of the transaction has an efficiency place. This is shown in Figure 4.

<table>
<tr><td colspan="2"></td><td colspan="3">Asset-specificity:</td></tr>
<tr><td colspan="2"></td><td>Non-specific</td><td>Mixed</td><td>Idiosyncratic</td></tr>
<tr><td colspan="2"></td><td colspan="3">Uncertainty:</td></tr>
<tr><td colspan="2"></td><td></td><td>Intermediate</td><td>High</td></tr>
<tr><td rowspan="2">Frequency:</td><td>Occasional</td><td rowspan="2">Market governance</td><td colspan="2">Trilateral governance</td></tr>
<tr><td>Recurrent</td><td>Bilateral governance</td><td>Unified governance</td></tr>
</table>

Figure 4 Discriminating alignment of transaction attributes to governance forms (Williamson, 1985: 79)

Matching governance structures and transactions according to hypothesis

The market (spot market) is best suited for occasional/recurrent and non-specific standardized transactions. The hybrid form (long-term contracts) of governance suits best with mixed or idiosyncratic assets and intermediate or high uncertainty, as it supports the contractual relation and guards for opportunistic behavior. The difference between bilateral and trilateral governance is that in trilateral governance the contracting parties are assisted by a third party (a relatively independent expert that determines the contract content-form, such as a regulator or court commission for complaints), while in bilateral governance the contracting parties focus on a specialized structure for their transactions. The costs of this specialized governance structure requires a recurrent transaction frequency to be recovered. High uncertainty and idiosyncratic assets require the unified (hierarchical) governance structure, because decisions can be taken fast by authorative order and risk is shared. When governance structures are aligned with transactions as described above, the inefficiencies are expected to be minimal. However, governance structures can become misaligned to transactions because of severeal reasons. For instance, contracting parties can change transaction attributes by investing (more or less) in specific assets during contract implementation, which leads to higher or lower asset specificity. This results in less or more alignment efficiency of the governance structure. Exogenous changes can also influence the comparative efficiency of governance structures, as the effect of governance structures could change under influence of a changing institutional environment. A change of technology could also lead to misaligned governance strucutures and transactions, i.e. from natural gas to shale gas. This research focuses on the expected change of governance structures under the GTM.

2.5 Operationalisation of concepts

With the TCE theory described in the previous paragraphs, it is possible to operationalize the conceptual model that was introduced in paragraph 1.4 (Figure 1) for European gas markets and shale gas exploitation. Each concept will be defined in this section by following this conceptual framework.

Institutional environment and technological environment

The institutional and technological environment are both considered exogenous within this research, as the focus is on the alignment of governance structures with transactions. The institutional environment consists of the GTM (introduced in paragraph 1.1 and specified in paragraph 4.2) that will be analysed according to its governance structures. The technological environment consists of the shale gas value chain that will be analysed according to its transactions.

2.5.1 Transactions

Transaction attributes

Transactions will be operationalised by deriving the attributes of shale gas transactions from its most important technical characteristics in the shale gas value chain. The types of transaction that are studied in this thesis are those of the upstream and the midstream European gas markets and comprise the trade of natural gas with its shale gas exploitation related investment and transmission related components. The transactions in this thesis will be operationalised according to their attributes:

- Frequency (one-time, occasional, recurrent)
- Asset specificity (non-specific, mixed, idiosyncratic)
- Uncertainty (low, high)

When which frequency?

The frequency is one-time when the transaction occurs only once over the contractual period, for instance the acquiring of an exploration permit (sale of concession) in the natural gas upstream phase. It is occasional when the transaction does not happen very often over the contractual period, for instance the realization of midstream pipeline infrastructure with corresponding maintenance and components renewal transactions. It is recurrent when the transaction occurs more often over the contractual period, and follows a fixed pattern between the contracting parties, such as midstream gas trading. In the natural gas sector, transaction frequencies depend on the specific characteristics of each phase of the value chain (Ruester & Neumann, 2009).

When which asset specificity?

Asset specificity is non-specific when assets can be easily applied to to other transactions and alternative uses without great costs (no asset specificity). Asset specificity is idiosyncratic when asset investments are made specifically to enable a particular transaction. 'These idiosyncratic assets, which are specific to a transaction, are put to alternative uses only at great loss of economic value' (Williamson, 1996: 59). Asset specificity is mixed when both non-specific and idiosyncratic assets are involved. The idiosyncratic operationalized asset specificity is listed below using some examples from the natural gassector (U.S. Department of Energy, 2012):

- Site-specificity, focusing on the location of value chain activities in order to optimize inventory and transportation expenses;
  Pipeline immobility leads to site specificity, as it becomes almost impossbile to relocate once the investment in pipes is made. The relocation will be very expensive and therefore there are no economic gains to be made when demolishing the infrastructure. Site specificity is also characterized by where the gas is located in the ground (Glachant & Hallack, 2010).
- Physical asset specificity, referring to specialized systems designed for a single purpose;
  Upstream drilling infrastructure can only be used for the purpose of drilling and has no other use (Ivanenko, 2012).
- Human asset specificity in which highly specialized human skills develop in a learning by experience method;
  Drilling crews and infrastructure constructors develop highly specialized skills that can only be used for its specific purpose (Kefferpütz, 2010).
- Dedicated assets represent a discrete investment in production activities that cannot be used for other purposes;
  Natural gas pipelines, compression units and treatment and storage facilities, cannot be used for other purposes (without expensive investments) than the transportation of gas in a specific region. The remuneration for transport investments in upcoming markets is therefore dependent on a small number of players, meaning that the assets are dedicated to a small number of transactions (Glachant & Hallack, 2010).
- Time-specificity in which there is a window of opportunity for the asset's value to reach the user within a specified time.
  Investments in the value chain need to be synchronised with each other for optimal efficiency. Transport infrastructure investments are constrained by investments in upstream activities and vice versa (Rious, 2007).

When which uncertainty?

Behavioural uncertainty is hard to scale given the ambiguity of contracting parties that blurs degrees of uncertainty and the assessment of performance. 'It is difficult to ascertain performance when responsibility for performance is shared between the contracting parties, when there are no readily observable indicators of what is meant by performance' (Anderson, 1985: 239). In this thesis, gas related transactions will be characterized by either low or high behavioral uncertainty. When parties to a contractual relation are able to align their incentives there is low behavioral uncertainty. Incentives are considered aligned when both parties to the contractual relation provide the other party with accurate information, with the aim of increasing their own income. These transactions do not require any form of protective governance structure according to TCE. An example of such a low uncertainty transaction within the natural gassector is the trading of gas on liquid spot markets that has sufficient buyers and sellers, with no volume risk (Vazquez, Hallack, & Glachant, 2012a). When parties to a transaction are not able to align their incentives and the behavioral attribute of opportunism is assumed to present, it will lead to a transaction with high uncertainty. This is when the contracting parties have an incentive to distort and disguise, in order to increase their own income. Contracting parties strategically distorting or disguising information can for instance occur due to hold-up. The hold-up problem is a situation where two parties may be able to work most efficiently by cooperating, but refrain from doing so due to concerns that they may give the other party increased bargaining power, and thereby reduce their own profits. An example of such a high uncertainty transaction within the natural gas sector is the realization of transit pipeline interconnection infrastructure between different markets (countries), given the high asset specificity. 'If some countries cannot commit to grant access to pipelines on agreed terms, recontracting after the completion of the investment is anticipated, and investment may be distorted (regulatory uncertainty) to gain leverage in the bargaining process, the hold up problem arises' (Hubert & Suleymanova, 2008: 2).

2.5.2 Governance structures

Governance structures attributes

The governance structures (hierarchy, hybrid and market) will be operationalised according to their attributes:

- Incentive intensity (high, medium, low)
- Administrative control (extensive, medium, low)
- Contract law regime (classical, neoclassic, forbearance)

When which incentive intensity?

The incentive intensity is high when the efforts of an economic actor directly result in a higher remuneration for this actor. High incentive intensity is related to markets and can for instance be observed in gas markets with high liquidity with sufficient buyers to react on the efforts of the economic actor (shipper). It is low when efforts of an economic actor do not result directly in a higher remuneration, only after a longer period of time or has to be shared with other economic actors that contributed to the higher remuneration. Low incentive intensity is related to hierarchies and can for instance be observed in pipeline infrastructure realization, which is caused by its high asset specificity and expenses resulting in long return on investment and possible shared investment. A medium incentive intensity is characterized by an economic actor that cannot influence a part of the remuneration or when the transaction does indirectly lead to remuneration via a future required transaction, for instance, when gas traders cannot directly influence their revenues as tariffs are regulated but costs decreasing can influence their profits in a 'delayed' way. Medium incentive intensity is related to hybrids (Niesten, 2009).

When which administrative control?

The administrative control is extensive when there are penalties and the monitoring is strict. Extensive control is related to hierarchies and can for instance be observed in the realization of pipeline infrastructure given the high expenses and asset specificity. The regulator (such as the UK Competition and Markets Authority) has some instruments at her disposal to stimulate contracting parties to live up to their contractual argreements, e.g. binding instructions or the obligation to pay a fine when they do not comply with regulation (UtilityWeek, 2015). It is medium when there is information disclosure and verification mechanisms. Medium control is related to hybrids and can for instance be observed in balancing the gas flows of the gas transport network. The balancing relies on a combination of system operator regulatory intervention and self organized control by shippers. It is low when there is less strict monitoring and control is self organized. Low control is related to markets and can for instance be observed in the self controlled (organized) trading of natural gas via spot-markets (Haase, 2009).

When which contract law regime?

The contract law regime is classical, when the contracts are most complete, but are short-term and non-flexible (almost complete) and can for instance be observed in the trading of gas. Classical contract law is related to markets and disputes are not solved (contract will be ended) or ultimately in court.
The contract law regime is neoclassical when the contracts are medium-term and more open and flexible (not complete). Neoclassical contract law is related to hybrids and disputes are solved via a third party, for instance arbitration (private instead of public via court).
The contract law regime is forebearance ('holding back') when the contracts are even more flexible and long-term with internal dispute settlement by use of authoritive power. Forebearance contract law is related to hierarchies. Both neoclassical and forebearance contract law can for instance be observed in the realization of upstream and midstream gas infrastructure with high asset specificity, requiring flexibility (contract evaluation) because of large investments and possible medium term to long term construction periods (Neumann et al., 2015).

2.5.3 Alignment

When (mis)aligned? Technological operation and institutional environment

A misalignment between governance structures and transactions can occur when the attributes of the transaction change while the governance structure remains unaltered, or when an exogenous factor makes the governance factors change while the attributes of the transactions remain unchanged or a combination of both. This misalignment will lead to inefficiencies and transaction costs increase. An alignment occurs when governance structures and transactions are matched in the most efficient way according to TCE (see Figure 4). The alignment concerns the comparison of GTM governance structures with the midstream shale gas transactions, that originate from their technological upstream characteristics of the value chain. These upstream technological characteristics concern the shale gas exploration, production and processing from which transaction requirements (attributes) follow. As the research problem identified, it is a crucial question to what extent the regulatory framework (GTM), establishes transaction cost efficient conditions for European shale gas development within components of its total gas market design. When analyzing the alignment it is important to understand that shale gas is a partial element of the total European gas industry and that the GTM cannot focus on shale gas only. The degree of alignment within the GTM addresses the possibilities and limitations regarding European shale gas development, in the scope of the derived preconditions from its value chain analysis.

2.6 Conclusion

Operationalized conceptual framework forms basis for subsequent chapters

This chapter discussed the operationalisation of transaction costs economics theory for gas markets and shale gas exploitation. It indicated and translated the most important aspects of TCE to the conceptual framework with focus on the discriminating alignment hypothesis. The operationalized conceptual framework (GTM governance structures, shale gas transactions and alignment) will form the basis for the subsequent chapters and their corresponding sub research questions. Chapter 3 will identify the transaction attributes of European shale gas exploitation by looking at technical (and possible resulting market) characteristics. These transaction attributes, together with GTM governance structures (Chapter 4), will form the basis of the GTM alignment influence analysis (Chapter 5).

Part II

European shale gas transaction attributes

This part of the research will focus on the attributes of shale gas transactions by looking at technical and possible resulting market characteristics.

3 European shale gas transaction attributes

This chapter derives the attributes of shale gas transactions from its most important upstream technical (and possible resulting market) characteristics by addressing the upstream shale gas value chain illustrated in Figure 5. Subsequently with the characteristics of the shale gas value chain upstream elements identified, it is possible to define the European shale gas midstream transaction (market) attributes, that follow from the upstream characteristics. This will be done by applying the operationalised transaction attributes from paragraph 2.5.

Analyzing technical shale gas characteristics for upstream (3.1), derives the resulting specific midstream (market) transactions and their attributes that differ from conventional gas exploitation (3.2), answering the second sub-question (3.3).

What are the transaction attributes of shale gas exploitation derived from technical and market characteristics?

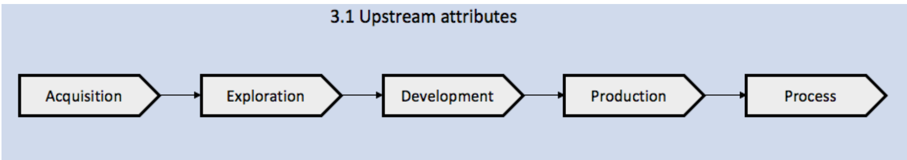

Figure 5 Shale gas upstream value chain (Ernst & Young, 2014: 13)

Emphasis on aspects that differ from conventional gas

Shale gas development differs in several aspects from conventional gas development. First the analysis will be performed by following the upstream shale gas value chain components, emphasizing the differences with conventional gas. Subsequently the resulting transactions and attributes for the market (midstream), will be defined. The foundation of this analysis is mainly based on research by EY on UK shale gas development (Ernst & Young, 2014), as this research targets European shale gas development. Furthermore, a variety of articles that focus on U.S. shale gas aspects regarding European gas market conditions are used for technical and market insights, such as Gény (2010) and Chyong & Reiner (2015).

3.1 Upstream attributes

3.1.1 Acquisition

Extensive permit application process, environmental concerns

The first phase (combined with geological studies and preliminary test drilling that are similar to conventional gas acquisition) in the shale gas value chain, consists of acquiring environmental and regulatory approvals, including land leasing permits when a possible shale gas location is identified for explorative test drilling. Given the environmental concerns about shale gas fracking (see paragraph 3.1.3) Development), the permit application process is more extensive than the process for conventional gas and requires extra details from the operators, such as the proximity to nearby environmentally sensitive areas including watersreservoirs and biodiversity areas. When the Environmental Agency (EA) has reviewed and approved the operator's spatial planning against a fee, the exploration can be initialised.

UK fast track government support

In order to overcome this extenstive permit application process, the UK government declared in August 2015 to introduce measure to fast track oil and gas planning applications in the regions, including the threat that local authorities who are overdue in applications in their areas will have the decision taken from them and decided by the central government's Secretary of State for communities and local government instead. Furthermore, the government declared that gas would form a central role in the country's future power generation and urged the drilling of a number of exploratory wells. The UK looks like to lead the way as six wells are expected to be drilled in 2016 (Mainwaring, 2016).

Land access

Land access in Europe is a challenge because there are no fininacial incentives for landowners, as the mineral rights belong to the state (Gény, 2010). The land access in the most parts of U.S. is arranged in a different way with no state ownership (but private) and the ability to lease land (mineral rights) at a low price. This was a powerful incentive for the U.S. shale gas revolution. However, state ownership of mineral rights can provide operators with blocks of land that allows for more efficient exploitation (Wang & Krupnick, 2015). The companies that have been awarded a concession (concession operators) take the risk by investing in the required exploration, drilling the wells and preparing the site for production. Operators can combine their activities, by investing together in a single concession, for instance the cooperation between an international oil company (IOC) or national oil company (NOC) with an independent smaller oil company, sharing the cost risks (higher for shale gas exploration than for conventional gas, (see paragraph 3.1.4 Production) and potential profits (Kowalski, 2015).

3.1.2 Exploration

Variety in geological characteristics of the deep underground per location and within shale play

The exploration phase consists of soil surveys to indicate the location of the shale gas play (shale gas area) and is followed by a site drilling planning and preparation. This is a complicated process, because the geology within a shale gas play can vary significantly. This will require constant evaluation via drilling in order to identify sweet spots and maintain optimal production flows. The exploration will be performed by companies hired by the operator (if not specialized), which are specialized in geophysical services and independently conduct seismic exploration (Ivanenko, 2012). European shale gas plays can be characterized as more scattered in comparison with U.S. plays, which results in quality differences due to the variety in geological characteristics of the deep underground.

Because of the occasional exploratory and appraisal (commercial viability) drilling requirements during exploitation (generally fifteen to thirty wells over a period as long as nine months' depending on location characteristics), shale gas developments have a continuous capital investment profile, so constant capital investment is needed. This investment profile in combination with the short optimal production capacity and long decline, indicates that shale gas requires longer production periods (maximizing output of all identified areas around the sweet spots) than conventional plays in order to be commercial viable. Conventional development is characterized by a shorter investment profile (large initial cash sink), followed by continuous production for a long period without significant further investment (Baker & McKenzie, 2014). The combination of these factors indicates higher exploration costs for shale gas than conventional gas (with a different exploration pattern).

Occasional exploration and appraisal drilling to indicate location and predict viability

3.1.3 Development

With the exploration phase started, and under the condition that shale gas is found of required quality and volumes, the site (well pad) can be developed. A well pad is a location in which several wells are located (see Figure 6). The benefit of a well pad is that multiple wells can be drilled in a shorter time than with only one well per site and the surface disruption is minimized (U.S. Energy Information Administration, 2012).

Site (well pad) development

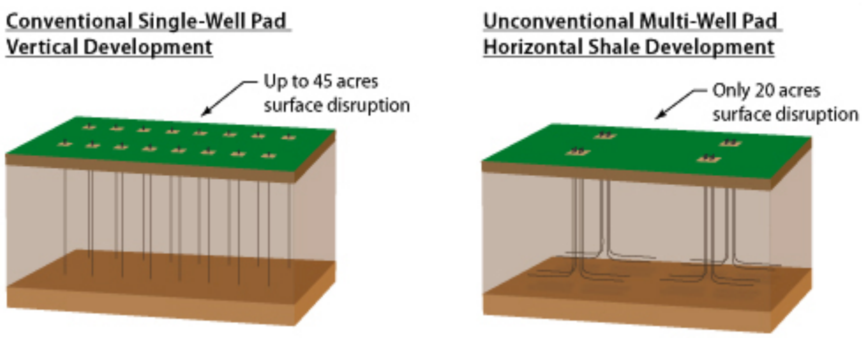

Figure 6 Conventional gas single-well pad vs. shale gas multi-well pad (U.S. Energy Information Administration, 2012: 3)

Relocating a drilling rig from one well site to another well site, previously involved the disassembling and reassembling of the rig, even if the new location was nearby. Nowadays when a well is drilled, the complete rig can be lifted and moved to the next well location via hydraulic lifting systems. This creates more drilling flexibility and reduces costs (U.S. Energy Information Administration, 2012). When the drilling rig is relocated a long-term permanent wellhead is installed for constant development, after which hydraulic fracturing equipment is placed. A well pad hase five to ten wells that are located close together at the surface and are horizontally drilled in different directions. In horizontal drilling, the first drilling distance is vertically, like a conventional gas well, and reinforced with cement to prevent leakage of fracturing fluids. When the drilling reaches the target depth, where the shale gas formation is

Drilling mobility, horizontal drilling located, the drilling is redirected horizontally in order to maximize the number of fractures via hydraulic fracturing, which provide a way out for gas that is surrounded by shale (see Figure 7).

Hydraulic fracturing, treatment and reuse

The technology of hydraulic fracturing has been used for over 60 years and has helped to safely produce more than 600 trillion cubic feet of natural gas. Shale gas hydraulic fracturing consists of injecting fluids (mostly water) in combination with chemicals (acid, lead, benzene) under pressure to fracture shale formations (and keep them open) and release the natural gas. Sand is pumped in with the fluids to keep the fractures open. The type, composition and volume of the used fluids is dependend on the clay shale structure, required pressure, the geological location and production target for a well. 20% of the used water flows back to the surface via the well, and after treatment, is reused for subsequent hydraulic fracturing, which significantly reduces the volume of waste water and required fracturing fluids which reduces costs (U.S. Department of Energy, 2012).

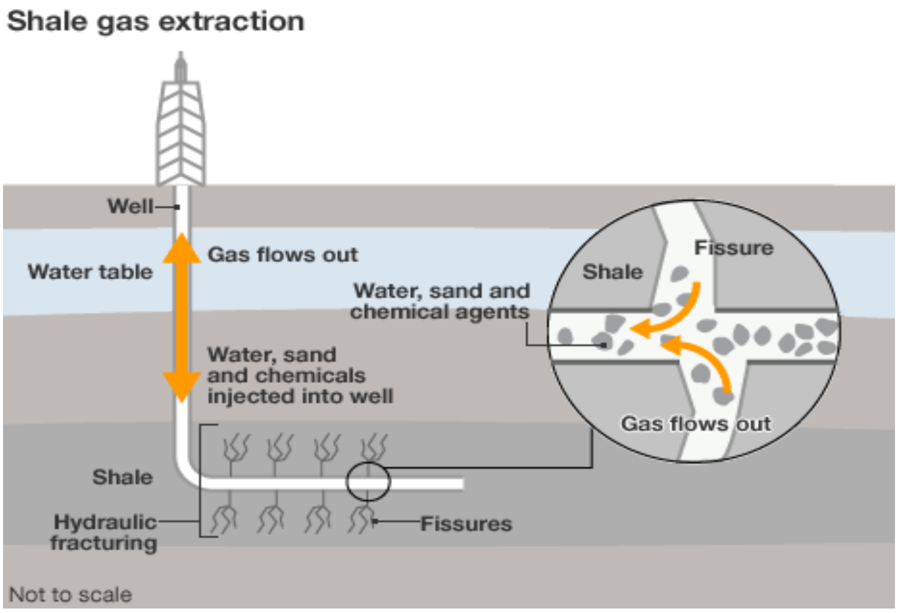

Figure 7 Shale gas extraction (BBC, 2015: 1)

Drilling equipment and drilling crew hire

The development of the site and design of the well pad (drilling mobility) allows for multiple drills in the area, identified by the exploration drill, minimizing time and reducing costs. Capital investments are required according to the amount of drilling and hydraulic fracturing, resulting in higher costs than conventional gas exploitation (see paragraph 3.1.4 Production). In Europe there is a relative shortage of onshore drilling rigs and drilling crews for possible commercial shale gas exploitation (2220 rigs in the U.S. and 98 rigs in Europe (Niemiec, Jessen, Gooch, & Zimmer, 2014)). These rigs and crews need to be hired (via competitive bidding) by the operators from a small number (approximately 20 in the UK) of specialized subcontractors and form about 25% of the total development costs (Fracking for Gas, 2016). The role of the crew consists of drilling services, casing and cement services (casing the well), taking care of drilling waste disposal, and logistics management. The hydraulic fracturing equipment (pumps, trucks, blenders and chemicals) and fracking crews also need to be hired (via competitive bidding) from subcontractors, as the equipment and expertise (mixing of chemicals, pressure pumping, perforation operations, microseismic services and waste management) are specialized and not widely available in Europe (resulting in waiting time), as most of the knowledge and equipment is U.S. based. The hiring costs of these services form 62% of the total development costs and are only partially provided from inside Europe by third parties (Ernst & Young, 2014).

3.1.4 Production

Production flexibility, Operating costs

The development phase is followed by the production phase, in which first the predicted viability of the well (in the exploration phase) is confirmed before surface facilities and transportation infrastructure is installed. The biggest difference with conventional gas production, which requires a relevant constant production rate throughout the year (because it is economically not viable to provide high levels of seasonal flexibility, exception to this is the Dutch Groningen gas field), is the shale gas production (seasonal) flexibility. As the most of the shale gas costs are dependent on the amount of produced gas (operating costs) because of low upfront costs and drilling rig mobility, it is possible to shift (increase or decrease) the production profile relatively easily to maximum or minimum levels (80%) of total production capacity, without loosing commercial viability (Joode, Plomp, & Özdemir, 2012). Exploitation costs are divided in fixed and variable costs. Fixed costs are not dependent on the amount of produced gas, such as the costs of obtaining a lease and hiring drilling equipment or expertise. Variable costs are dependent on the amount of gas that is produced, such as taxes (Continental Economics, 2012). Most of the shale gas costs are therefore variable costs.

Viability confirmation

It is important for the producers to confirm the viability of the wells before the production commences, and the volume contracts with suppliers are signed, in which production flexibility provides security in fluctuating market circumstances.

Stochastic production nature, Steep decline rate, Joint-ventures, Short term market access

Other differences with conventional gas production are the great variety of well productivity (see Figure 8), even within the same shale gas formation, and the steep deceline rate of production (Acker, 2014). This stochastic nature of shale gas production results in higher risks in comparison with conventional production, which attracts smaller exploration and production companies with greater flexibility and risk preference than larger companies. However, these smaller companies require funding for their operations (and gathering pipeline infrastructure investments) and therefore cooperate (joint-ventures) with larger (NOC or IOC) companies for investment purposes (PWC, 2015). ‘Small to mid-size independent operators are the main players currently active in the UK onshore oil and gas sector. Typically, they do not have the balance sheet strength or financial flexibility of the majors. The high level of uncertainty around the UK's shale potential and pace of development makes it challenging for these smaller companies to access funds needed to train up crews and purchase equipment, some of which may require significant levels of investment' (Teasdale, 2015). These smaller companies are unlikely to lock themselves into traditional long term contracts, because it is too risky for shalegas producers to guarantee fixed stream of gas flows for longer periods of time (longer than five years) due to uncertainties in well production and rapid decline rates. They therefore require financial hedge instruments, such as gas forwards and futures via liquid wholesale markets. 'Since their risk profile is concentrated on production and traditional hedging such as moving along the value chain (e.g., downstream) to safeguard their position would destroy their competitive advantage relative to integrated oil and gas majors. Hence, they would require financial hedging tools to shield their production positions. The stochastic production characteristics, imply that shale gas producers would require short term easy access to networks and markets to monetize their supplies and hedge risks' (Chyong & Reiner, 2015).

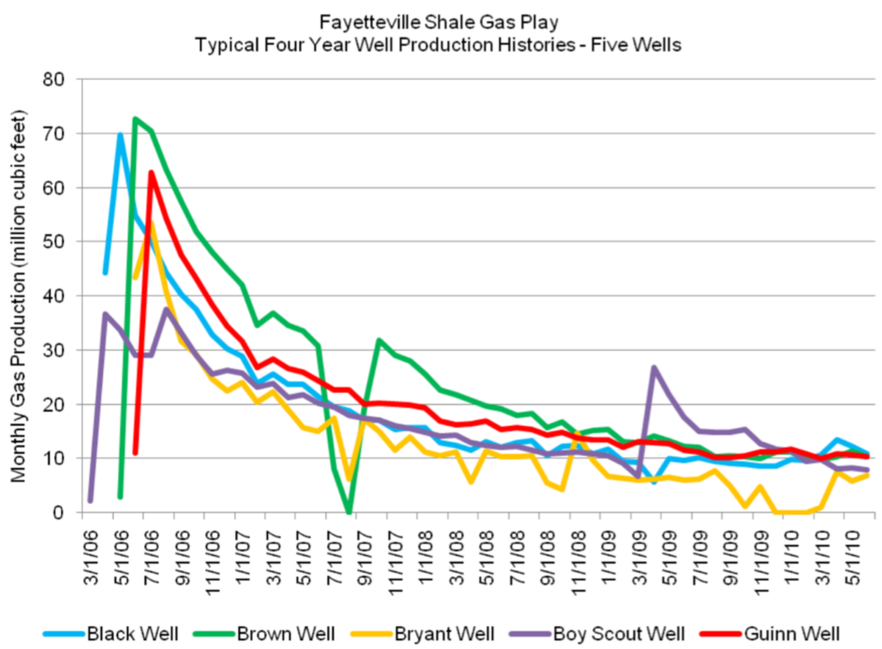

Figure 8 Four year gas production histories for five relatively high production gas wells in the U.S. Fayetteville shale gas play (Mason, 2011: 10)

3.1.5 Processing

Meet calorific and quality standard, construction new facilities required, possible facility sharing

The produced shale gas will have to meet calorific value and gas quality standards. Given the great diversity of shale gas quality, as result of the scattered locations and variety throughout the plays, the calorific values and the Wobbe index are adjusted to the desired level, by the injection of nitrogen or by mixing gas flows. The processing phase is essential in complying with the required gas quality standards in the transmission grid for transport and usage.

Possible construction new facilities required, facility sharing

Some of this processing can be done at the wellhead, but the complete processing takes place at a processing facility that is located in a region where shale gas is produced. A network of gathering pipelines (small-diameter and low-pressure) transports the shale gas to these processing facilities (NaturalGas, 2013). The processing facilities purify (and filter valuable hydro liquid carbon byproducts) the 'wet' gas that contains fracking liquids and requires treatment to comply with transmission tolerances (Ernst & Young, 2014). Although Europe has processing plants in place close to existing industrial sites, possible new facilities need to be constructed given the scattered shale gas locations. In addition, treatment plants for the flow-back fracking fluid are required. Dependent on the requirement to build new processing and treatment plants (upstream operators investments) and the extent to which the shale gas locations are scattered, smaller plants could be shared (according to their capacity) by upstream operators on a regional level (regional access), providing scale economies via single connection points to the network and shared processing operations. These shared operations are based on a partnership with one of the operators running the treatment plant. Another option for the operators is to sell the gas directly from the wellhead wich makes the buyer responsible for the gas treatment (Ivanenko, 2012).

3.2 Midstream transaction attributes

The midstream transaction attributes of the shale gas value chain will now be described according to its characteristics for trade and transport/storage, that follow from the shale gas upstream characteristics (paragraph 3.1). There will be attention for the elements of trade and transport/storage including aspects such as; infrastructure, conditions and tariffs network access and trading and balancing costs. Describing the midstream transaction attributes is the first required step in the alignment analysis of midstream shale gas transactions with GTM governance structures (see Figure 1 conceptual framework).

3.2.1 Trade and transport/storage

Upstream shale gas characteristics that influence midstream characteristics

Looking at the upstream chacarteristics described in paragraph 3.1, shale gas requires an extensive permit application process, as result of the environmental concerns about shale gas exploration and the state land ownership. The producers permit review and approval by the applicable Environmental Agency approving the land lease, differs per member state (Weijermars, 2010). If possible permits are granted, then European shale gas development will lead to a more distributed and local supply of gas, as result of the scattered shale gas plays across the member states and the stochastic shale gas production profile.

Distributed local supply and stochastic production profile leads to more trade and transport/storage complexity

This distributed supply and stochastic production profile increases midstream network complexity in comparison to the current conventional supply flows, and will require a more flexible and transparent form of trading and transport, in order for shale gas to compete with conventional gas and match the timing of supply and demand (Buchan, 2013). The stochastic production characteristics, imply that shale gas producers would require short term easy access to networks and markets to monetize their supplies (Chyong & Reiner, 2015). The increased complexity leads to a larger gap between the (simplified non physical entry/exit zones) commercial network (virtual trading hub) and the physical network (piping infrastructure). This gap needs to be bridged by balancing mechanisms (based on transparency) in order to arrange the gas flows (Glachant et al., 2013). It is important that the gas network is in balance to safely and effectively transport gas. Balance means that the network remains at the correct pressure, and that the overall volume of extracted gas matches the volume entering the network.

Gas trading, High costs, Flexible production, Increase in GOG

'While the U.S. market hub-based system for natural gas trading has exchanges and free-floating prices, the situation in Europe is less flexible, despite the presence of spot hubs, the markets are constrained by long-term contracts, the absence of a unified market, few transnational ventures, and a fluctuating carbon market price' (Clemente, 2012: 5). Given the combination of high shale gas costs (exploration, development and processing) and its flexible production profile, the question is whether European trading provides for economical feasible shale gas exploration (Gény, 2010). There are two major price formation mechanisms in Europe: short term Gas-on-Gas Competition (GOG) and long term OPE (Oil Price Escalation) oil linked prices. In GOG the price is determined by the interaction of supply and demand in gas-on-gas competition and is traded in different periods (daily, monthly and annually). European shale gas production will require an increase of the share of GOG, as it offers the flexible and transparent trading mechanisms to overcome its stochastic production profile and increased network complexity, to compete with conventional gas supplies (International Gas Union, 2014).

Transporation and storage capacity, OPE return on investment, TSO investment required

Shale gas producers require access to the infrastructure that will transport the gas to consumers. If the shale site is situated close to an existing entry point, the connection to the transmission system and gas distribution network should not be complex. If a site is located further away from existing pipeline infrastructure, additional pipelines are required (Ernst & Young, 2014). Transmission infrastructure however will most likely not be a significant issue, as the gas grid in Europe is extensive with sufficient capacity (Taylor, Lewis, & Byles, 2014). This is also applicable on storage facilities which are, in addition to line packing (temporary storage in pipelines), numerous in Europe and require minimal future investments, given the flexible production profile of shale gas compared to conventional gas (KPMG, 2012). The flexibility reduces the storage requirement, because of the possibility to shift down (decrease) production if required. Possible investments in pipeline and storage infrastructure are characterized by regulated longer term contracts that guarantee return on investment. As the smaller shale gas companies are unlikely to lock themselves into traditional long term contracts (see paragraph 3.1.4 Production), infrastructure investments by only themselves are too risky and expensive, therefore requiring TSO (Transmission System Operator) support (Teasdale, 2015).

Infrastructure competition vs. investments, Third Party Access exemption

In order to have effective gas market competition, the operators of transmission networks must allow shale gas shippers non-discriminatory access to the transmission network and storage facilities to supply customers. This is arranged via the third party access (TPA) principle. The risks of free competition and private investments incentives (when not performed by TSO's) in shale gas infrastructure may not always be aligned. New infrastructures can be particularly susceptible to this dilemma, as investors often prefer limited investment risks. The European regulatory framework aims to create a balance by demanding access for third parties, while at the same time enabling an exemption (shielding investors from market risks by no TPA) for new infrastructures from this requirement if certain conditions have been met (Zillman, Roggenkamp, Barrera Hernandez, & del Guayo, 2012). Mostly these requirements (total network capacity, diversification, the security of supply and level of competition) are met, as an increase in capacity also improves the required factors, which stimulates shale gas transportation and storage infrastructure private investments when performed by the market (Vijver, 2008).

Conditions and tariffs network access, entry exit capacity, virtual trading point

National regulatory authorities regulate the conditions and tariffs of access to the networks (Gasunie, 2012). The main conditions are defined in the Tariff Structure and Network Codes. Gas transmission takes place based on an agreement by the producer with the network operator of the national grid. This means that the operator of the national grid accepts gas offered at an entry point to the national grid and makes it available at an exit point. The transmission takes place by using the entry (right to inject a quantity of gas per hour into the national grid at an entry point) and exit (right to extract a quantity of gas per hour from the national grid at an exit point) capacity services, that can be contracted independently of each other as there is no linked contract path. This capacity is contracted and allocated on a first come first served principle (Gasunie, 2014). Network users do not need to specify a specific transmission path and distance, but only the network points they intend to use for system entry and exit. A virtual trading point (VP) or hub, allows for virtual trade and independent entry and exit points (gas entered can be delivered at any exit point). A network user that contracted entry capacity, could sell gas at the virtual trading point, while network users that have exit capacity, could buy this gas. They could also resell this capacity to other network users. The VP is not tied to physical point in the system and the network users have free access to the virtual point from the entry and exit points. This is indicated with the blue arrows in Figure 9. A VP/hub allows title transfer (trading) of gas via spot markets.

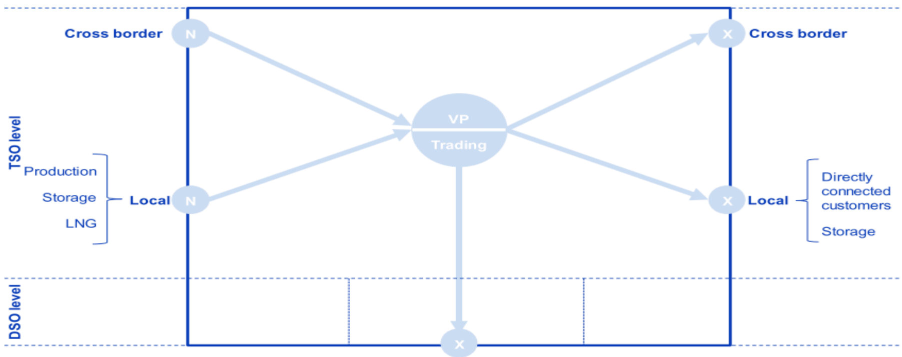

Figure 9 Schematic representation of an entry/exit system (Kiewiet, Petrov, & Vos, 2013: 2)

Trading and balancing costs, imbalance consequences

Conditions for free access to the VP are that the actual flows may not exceed this (entry and exit) capacity (overshoot margins are charged) and that the network points need to be within the same entry/exit zone (defined area of entry and exit points). The network user's costs depend on the total amount of entry and/or exit capacity booked and the associated tariffs. These tariffs may differ between the different entry and exit points and depend on the cost allocation methodology applied by the TSO (Kiewiet et al., 2013). Each shipper is responsible for the quantity of gas it removes from or feeds into the grid, which means that the shippers also share responsibility for maintaining the balance of the transport network. The shippers know their own position at all times and can contribute to keeping the transport network in balance. If this action is not sufficient and the imbalance gets too big, the TSO buys or sells the gas and the responsible shipper pays the costs of the imbalance resolvement (Gasunie, 2016).

3.2.2 The Trade and transport/storage transaction attributes

With the characteristics for trade and transport/storage described, it is possible to discuss its midstream transaction attributes of the shale gas value chain (operationalized in chapter 2), that forms the first required step in the alignment analysis of midstream shale gas transactions, which will be compared with GTM governance structures in chapter 4 (see Figure 1 Conceptual Framework).

The trade transaction consists of the trading of gas volumes (capacity) between shale gas producers and shippers and between shippers and shippers (resell of capacity) via a VP/hub. More distributed and local supply of gas (scattered across Europe) with a stochastic production profile, which increases complexity of transactions due to unpredictable production, requires a more flexible form of trading to efficiently arrange trade (timing of supply and demand) and handle the great variety of shifting gas flows. Balancing is part of the trading mechanism and is therefore linked to the trade transaction, so that shippers and producers can balance their trading portfolios by feeding gas into the system or removing it from the system with a market focused correction mechanism as final resort.

The transport/storage transaction consists of regulated investments in gas infrastructures (including interconnector pipelines and storage facilities), performed by TSO's who realize return on investment via shipper tariffs for infrastructure usage. Pipeline construction investements may be necessary to facilitate shale gas transport from remote production locations.

Idiosyncratic asset specificity transport/storage, non-specific asset specificity trade

The attributes of both transactions will now be discussed. *Asset specificity* can be characterized as physical asset specificity, because transmission and storage infrastructure can only be used for its specific purposes of transporting gas (conventional gas, shale gas, LNG). There is site specificity, as it becomes almost impossible to relocate once the investment in the transport infrastructrure is made. The relocation will be very expensive and therefore there are no economic gains to be made when demolishing the infrastructure. Furthermore, there is dedicated asset specificity as the TSO dedicates (locked in) his infrastructure investments (when not performed by the market, only seldom with large supply interconnector) to specific contracting parties (shippers). Certain shippers terminating or not complying with their part of the deal (capacity bookings), leads to return on investment difficulties for the investing TSO (Peel Gas and Oil Ltd, 2015). Time specificity plays a role because of the need to synchronise infrastructure investments with preceeding and subsequent stages of the value chain in order to maximize asset value. Trade and balancing has non-specific asset specificity as no significant investments are required. If the system is out of balance (peak cap) and the TSO has to intervene, the costs are for the shippers that were unable to correct their imbalance.

High uncertainty transport/storage, low uncertainty trade

Uncertainty can be characterized as high for the transport/storage transaction, as there is an incentive regarding infrastructure investment for contracting parties to strategically distort or disguise information, due to hold up problems resulting in under investments. 'The essence of hold up is that investments may be obstructed if an investor doubts the credibility of a (future) regulatory policy. Policy becomes incredible when a regulator's actions are time incostistent, i.e., when a regulator can not credibly commit ex post to a regulatory rule, this rule becomes incredible ex ante. Regulatory uncertainty results in inefficient investments (Spanjer, 2008: 2)'. Large initial sunk costs, low variable costs and locked in asset specificity, in combination with a long return on investment period are the conditions for such hold up problems. EU competition policy for pipeline and storage investments, aims to facilitate investments and overcome the hold up problem via TPA exemptions that minimize regulatory uncertainty (Hubert & Suleymanova, 2008).
Trade and balancing are characterized by low uncertainty, as the trade transactions do not allow for increased opportunities to behave opportunistically, given the size (traded total volume) of the European gas markets with sufficient liquidity, depending on the region (Lowe, 2015). Even the smaller markets in the Danube region such as the Czech Republic, Slovakia, Austria and Poland are integrating (cross-border interconnections) towards a central trading

region with sufficient liquidity to overcome uncertainty (Danube Region Strategy Energy, 2014). Regarding balancing, the responsible parties have an incentive to provide accurate information because of imbalance charges. The transmission system operator wishes to receive accurate information because it enables him to better balance supply and demand. The incentives between these contracting parties have thus been aligned ex-ante, which results in low uncertainty (Miriello & Polo, 2015).

frequency occasional transport/storage, frequency recurrent trade

Frequency is occasional for pipeline and storage investments (planned infrastructure development) that does not happen very often and recurrent for trade and balancing, because of daily (and monthly and annual fixed patterns) basis trading and balancing.

3.3 Conclusion

Extensive exploration phase, development and production flexibility, gas quality variety

This chapter looked into the technical (and possible resulting market) characteristics of shale gas exploitation that differ from conventional gas exploitation, following the upstream shale gas value chain. Subsequently with the characteristics of the upstream shale gas value chain identified, it was possible to define the European shale gas market (midstream) attributes, by taking into account the upstream characteristics and applying the operationalised transaction attributes from chapter 2. Specific shale gas transactions can mainly be characterized by an extensive acquisition and exploration phase (except for the UK with the government's fast track of oil and gas planning applications) given environmental concerns and variety in geological characteristics of the deep underground, followed by an unpredictable and flexible development and production phase in which stochastic production profiles, mobile drilling rigs and shifting production rates play a key role. As result of the production unpredictability, mobility and flexibility, in comparison to conventional gas exploitation, the upfront costs are low and operational costs are high. The subsequent processing phase is defined by the need of constructing new treatment facilities, as result of the differing shale gas characteristics (quality) per location. The clustering of processing facilities depends on the proximity of shale gas exploration locations and could provide scale economies.

The upstream shale gas characteristics lead to the following midstream shale gas trade and transport/storage transactions conclusions:

Flexible and transparent trading

Due to scattered exploration locations across Europe and stochastic with steep decline production profile in combination with high operational costs, shale gas will require a more flexible (timing of supply and demand) and transparent accessible form of trading and efficient transport/storage, in order for shale gas to compete with conventional gas.

Balancing mechanisms

More complexity leads to a larger gap between the commercial network (virtual trading point/hub) and the physical network, that needs to be bridged by balancing mechanisms.

Sufficient transport and storage capacity, TSO investments

The European gas grid is extensive and storage facilities are numerous, so required infrastructure investments are minimal. Clustering of processing facilities minimizes the requirement of pipeline connections. Possible new transport investments are characterized by high asset specificity and hold up problems and therefore require minimal regulatory uncertainty. These investments will most likely be performed by TSO's as the costs and risks for smaller shale gas companies are too high. Gathering pipeline transport investments will most likely be performed by shale gas companies in joint ventures, to overcome costs and risks.

Based on these findings the midstream attributes (asset specificity, uncertainty and frequency) for the trade and transport/storage transactions were defined and are summarized in Table 2. The recurrent trade transaction is characterized by no asset specificity and low uncertainty while the occasional transport/storage transaction is characterized by high asset specificity and high uncertainty. By applying the combination of attributes and governance structures of Williamson (see Figure 4 chapter 2) to Table 2, the required governance structures for European shale gas development are listed in Table 3.

Transaction Attributes	**Trade and transport/storage Midstream**
Asset specificity	Non–specific (Trade) Idiosyncratic (Transport/storage)
Uncertainty	Low (Trade) High (Transport/storage)
Frequency	Recurrent (Trade) Occasional (Transport/storage)

Table 2 Shale gas midstream transaction attributes

	Trade and transport/storage Midstream
Governance structure	Market (Trade) Hierarchy (Transport/storage)
Involved actors	Producers Shippers and TSO
Covering	Entry/exit point capacity contract (Trade) Reselling capacity contract (Trade) Balancing contract (Trade) Infrastructure investments (Transport/storage)

Table 3 Required shale gas midstream governance structures

The next chapter will analyse the future MECOS GTM and identify its governance structures. Subsequently these will be compared with the required governance structures of Table 3, indicating the alignment.

Part III

Governance structures under the GTM

This part of the research focuses on the expected governance structures under the future GTM. An analytical confrontation based on the results of the analysis taking the transaction attributes of shale gas exploitation of chapter 3 into account, defines the degree of (mis)alignment under the GTM that limits and/or enables European shale gas development.

4 Governance structures under the Gas Target Model

In order to analyse the expected European gas markets governance structures, this chapter first looks at the current market design (gas hub), with special attention for recent developments such as the Dutch TTF (Title Transfer Facility), as this one of the leading European markets (4.1). The Gas Target Model (GTM) serves as a tool for guiding and assessing the on-going process of developing framework guidelines, which should be used as the foundations of the broader network codes under the Third Energy Package. The GTM defines the key characteristics of gas transactions and their institutional framework. It strongly interacts with how transmission capacity should be allocated in the medium and short-terms, and how it should be built into the long-term (Glachant et al., 2013). MECOS (**M**arket **E**nabling, **CO**nnecting and **S**ecuring) GTM is a non-binding top-down framework of principles and characteristics providing a description of how the European gas market is possibly expected to develop (Glachant et al., 2013). The shale gas transactions from chapter 3, provide an upstream and midstream shale gas specific approach for the GTM analysis.

The key characteristics of MECOS will be described (4.2) according to its three pillars and common foundations (see Figure 11). The next step is to identify (4.3) the MECOS governance structures. This answers the third sub research question:

What are the expected governance structures of the European gas markets under the GTM?

Subsequently, the required midstream shale gas governance structures (Table 3), will be compared with the expected GTM governance structures, addressing the alignment between chapter 3 shale gas midstream transactions and chapter 4 GTM governance structures. This answers the fourth sub research question, that focuses on the limitations and possibilities (4.4) of future GTM governance structures regarding shale gas transactions:

How do these expected governance structures limit and/or enable European shale gas development?

4.1 Current European gas trading

Connected to the same and functioning wholesale market, Examples are TTF and NBP s

The MECOS GTM follows from current market developments. The aim is that all European end-users are linked to a functioning wholesale market and connected to the same EU wholesale market. Prices across wholesale markets are to be aligned as much as possible with the aim of gas being traded in the EU at competitive spot market price. Currently there are two leading gas hubs in hub based trading and they both contribute to European price alignment; the Dutch TTF and British NBP (National Balancing Point). Figure 10 shows the European gas hubs and exchanges. A better understanding of the current European gas hub developments, contributes to the analysis and defining of MECOS GTM governance structures. Exchanges (allow for gas trading without it physically changing hands) contribute through anonymous and arranged market places to the growth of gas hubs and merely have a supportive role in relation to gas hubs.

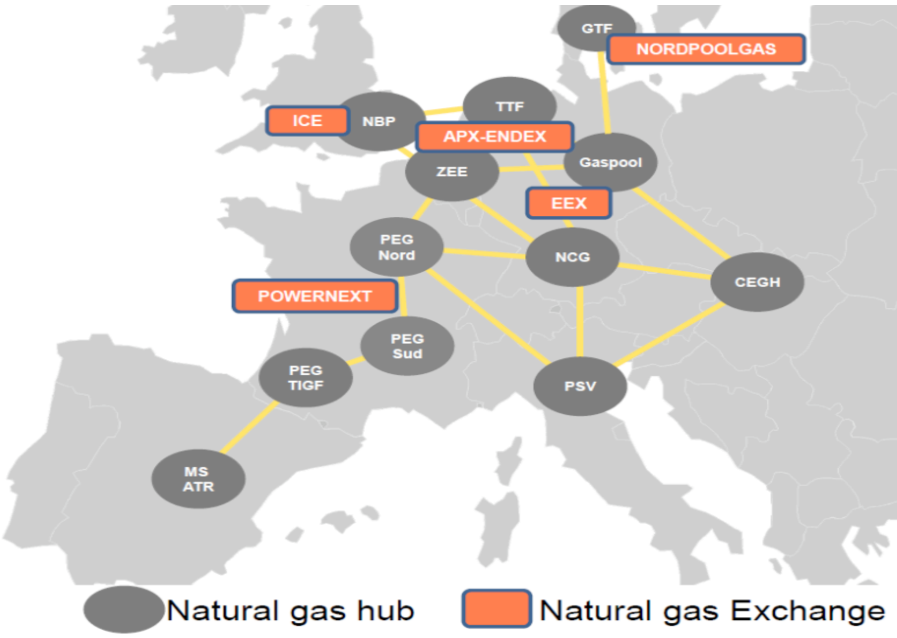

Figure 10 European Gas Hubs and Exchanges (Heather, 2012: 4)

Virtual points, open and easy access, large number and great variety of participants, transit hubs, transition hubs

The comparable TTF and NBP are considered leading trading hubs as they have reached a certain level of maturity and fully implemented the entry/exit zone model (see paragraph 3.2 for entry/exit model). They are virtual trading points, are open and provide easy access to trade to a large number and great variety of market participants via common carrier contracts (explained in paragraph 4.2.3 Pillar 3). Furthermore, they have good transparency and have proven to be reliable markets. The other (secondary) hubs can be considered transit and transition hubs. Transit hubs (ZEE and CEGH) are actual physical points, where market participants can trade gas. However, their primary role is to facilitate the routing (transit) of large quantities of gas for further transportation towards TTF, NBP and transition hubs. Transition hubs (GPL, NCG, PEGs and PSV) are based on a virtual trading point but have not yet reached a mature level. They are attracting more gas volumes each year and are becoming a price-marker for their national market. Already these transition hubs are being used as balancing markets for shippers. However, there are doubts whether they will develop to become more than just national markets (Heather, 2012).

4.1.1 Title Transfer Facility

Virtual gas trading, Increased liquidity entry/exit

The TTF has been created in 2002 as a natural gas virtual trading point for Gasunie's entry/exit system operated by GTS (Gasunie Transportservices) in the Netherlands. Initially it was only used for the physical trading of gas. This is no longer a requirement under the Gaswet of 2011, as it is also permitted to trade on the TTF without gas actually physically changing hands. It involves several products under which gas is supplied days, weeks, months or even a year later. This way it has become viable for financial and trading organisations to trade at the TTF, which increased liquidity. As explained in paragraph 3.2.1, given the virtual character of the trading points, trading does not have to relate directly to the traded volumes of gas being fed into or extracted from the network at Dutch gas entry/exit points. Gas fed into an entry point on the national transmission network, could well be traded several times before it is withdrawn or exported at an exit point. In order to trade, gas buyers and purchasers have to be shippers on the TTF. These shippers include oil and gas companies, large-scale industrial gas consumers and utility companies (GasTerra, 2015b).

4.1.2 TTF pricing and developments

Price based on supply and demand, Benchmark across Europe, System responsibility, Imbalance costs

Products traded on the TTF are standardised (OTC) to simplify their trading. Over-The-Counter trade (OTC) means that parties do business with each other directly via standardized 'off the shelf' products. Gas prices are formed by supply and demand (directly bilateral, via a broker or via the gas exchange in MW/hour (see paragraph 3.2) and are not linked to those of petroleum and/or petroleum-based products like OPE as explained in paragraph 3.2.1. The gas price of the TTF is an important benchmark for gas transactions across Europe. Pricing differences between the TTF and other virtual trading points in Europe have reduced in recent years, which is an indication of gas market integration with price formation based on supply and demand (GasTerra, 2015b).

Biggest traded gas volume 2014, OTC, High churn rate, No long-term impacts

In 2014 the trading at the TTF increased to a record high with a volume of almost 1400 billion cubic metres taking over the lead position of the NBP regarding OTC trade (see Figure 11). The TTF churn rate (total traded volume divided by the physical traded volume) increased also in 2014, indicating higher liquidity. The Ukraine and Russia crisis had no long term impact on the pricing and only influenced volatility. The growth level of the TTF and NBP gradually periodically levelled of, given the challenging global developments on gas and oil markets. However both showed strong growth, with total traded volume in 2015 increasing with 25% (Natural Gas Europe, 2016).

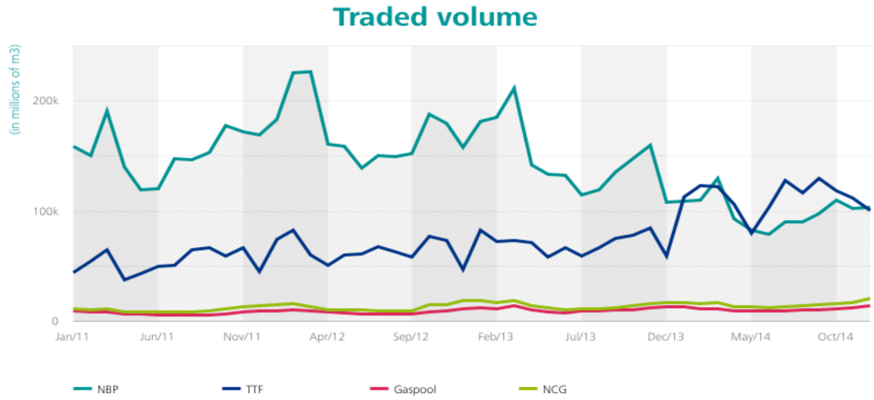

Figure 11 Virtual hubs traded volume (GasTerra, 2015a: 16)

MECOS follows hub (TTF) developments, Price alignment

Although other European trading points, like the German NCC and Gaspool, are also developing towards more liquidity, transparency and short-term contracting, the TTF remains the most important price marker for long-term contracts and for gas on the other trading points in continental Europe (GasTerra, 2015a). A liquid integrated EU market is on its way but there are still steps to be taken given the diversity of European gas markets. Given this diversity and in line with and building on the TTF developments, MECOS aims at aligned prices across wholesale markets, with gas being traded at all European trading at competitive spot market price. The key characteristics of MECOS GTM will now be discussed. This allows for the identification of its governance structures that forms the second required step in the alignment analysis with midstream shale gas transactions.

4.2 MECOS key characteristics

Easy access for customers, Entry/exit zones combination with hubs, Efficient infrastructure use, Market integration, Combination of short- and long-term contracts

MECOS (Glachant et al., 2013) was the first sketch for the gas target model published by the Florence School of Regulation in June 2011 and builds on prior market developments, such as the Third Energy Package (CEER, 2011). It is a '**M**arket **E**nabling, **CO**nnecting and **S**ecuring' model that describes the possible European gas market over time (2020) and is developed with CEER (Council of the European Energy Regulators). It aims at the creation of a number of functioning wholesale markets within the EU, together enabling easy access to all European final customers. The 2011 GTM prescribes a combination of entry-exit zones with virtual hubs in order to achieve competitive European gas markets. The development of competition should be based on the creation of liquid trading hubs (national or cross-border) in Europe. Efficient use (balanced zones with minimal congestion) of infrastructures should support market integration so that gas can be shipped between market areas and respond to price signals. The GTM has to facilitate sufficient infrastructure investment, in order to overcome physical congestions that could hamper market integration. Shippers need both short- and long-term capacity as gas may be traded both short-term and long-term (ACER, 2015b). 'Long-term contracts will continue to be used despite the increase in short-term contracts and transactions all along the value chain as well as spot trading. They will be used where significant infrastructure investments are required and/or where both parties have a strong interest in establishing a long-term relationship because of strategic or security of supply considerations for instance' (DNV KEMA and COWI, 2013).

The GTM (see Figure 12) focuses on three aspects:

- 'Short-term coordination of the entry/exit system to bridge the gap between the commercial network flows and physical network flows via specific mechanisms (enable functioning markets).
- Long-term coordination to connect the several EU market zones is required via mechanisms that allocate and expand network interconnection capacity (tightly connect these markets).
- Investment and security of supply in order to support market connection with supply regions (enable secure supply patterns and improve market effectiveness by realizing economic pipeline investments)' (Ascari, Glachant, Vazquez, & Hallack, 2011: 2).

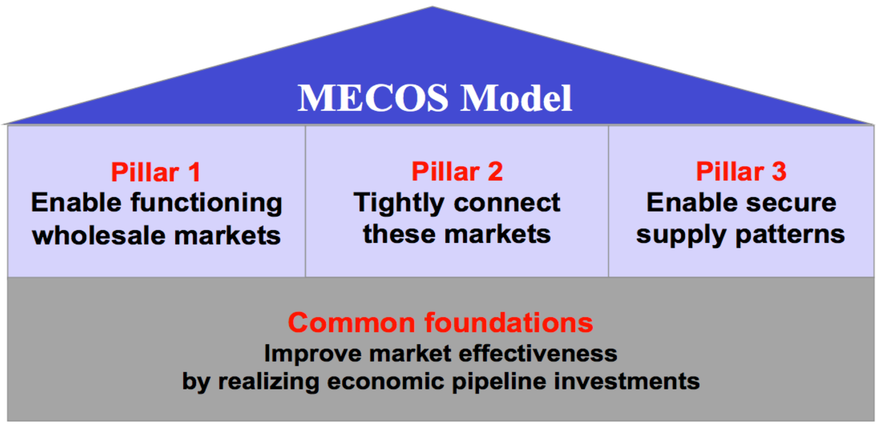

Figure 12 MECOS GTM three pillars proposal (Ascari et al., 2011: 6)

ACER 2015 MECOS update

The GTM was developed with the possibility to be evaluated and updated according to the ongoing work on Network Codes, taking future developments into account. ACER (Agency for the Cooperation of Energy Regulators) reviewed and updated the Target Model as required without changing the fundamentals of the gas market vision outlined above. In January 2015 the renewed MECOS model was introduced, which updates the original model developed by CEER in 2011 (ACER, 2015b). The update emphasizes the importance of gas supplies, as the costs of dependence on a single supplier have again been made clear. The characteristics of the MECOS GTM will now be discussed following the three pillars and common foundations.

4.2.1 Pillar 1 Enable functioning wholesale markets

Network size, Minimum traded volume, Frequency of trade, Number of gas suppliers, Two models

Functioning wholesale markets are crucial in order to support supply competition and efficient use of gas assets. The size of the network, the minimum volume traded, the frequency of trade and the number of gas suppliers define the sufficient size of a functioning market. MECOS creates conditions for functioning markets via entry/exit-pricing zones, which have to be large enough for a number of suppliers (minimum of 20 bcm). These zones also have to be well connected to other markets and to a minimum of three different gas supply sources. Sufficient size well connected markets with entry/exit-pricing zones are enabled through Market Areas (market merger) or Trading Regions.

Entry/exit zones, Market Areas, Integrated balancing

'In the case of a market merger, two neighbouring gas market areas (A, B) fully merge their balancing zones into one unified cross-border balancing zone (underpinned by an integrated cross-border entry/exit-system) and consequently also merge their virtual points (since one balancing zone can have only one virtual point)' (ACER, 2015a: 5). See Figure 13. Market Areas can be organised national (if functioning national wholesale markets can be achieved) or cross-border (if other markets are required to achieve a functioning wholesale market with 20 bcm volume and three gas sources).

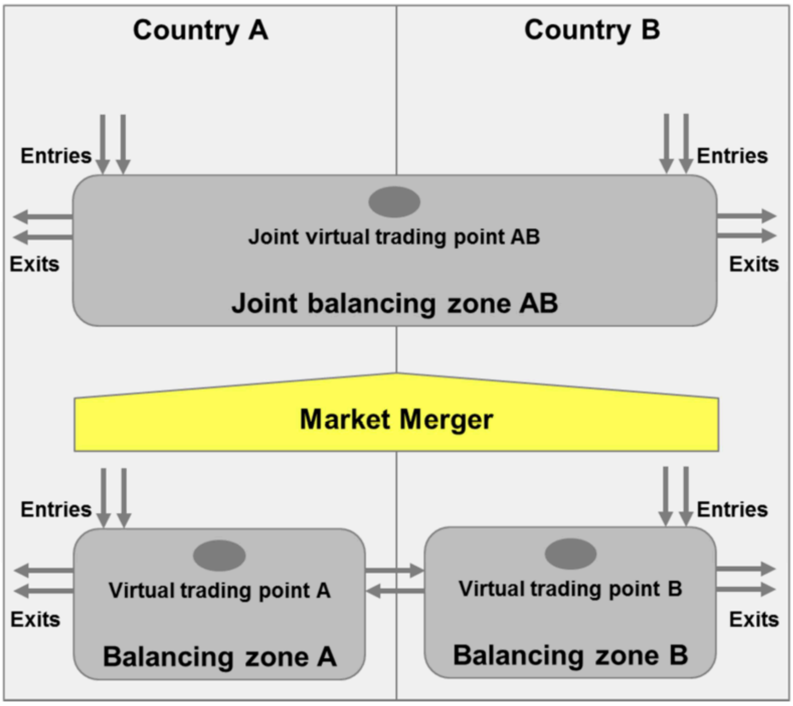

Figure 13 Market Area (Market Merger) with integrated balancing zones (ACER, 2015a: 6)

German market mergers, BeLux project

Examples are German market mergers in which Market Areas and balancing zones including several TSO's, can be formed without merging the TSO's. This was possible because all affected Market Areas had corresponding jurisdiction, which made harmonisation easier than in a cross border context. An upcoming cross border project example is the BeLux project, that merges the Belgian (high calorific) gas market with the Luxembourgian gas market.

Entry/exit zones, Trading Regions, Separate balancing

'In the case of a trading region, two neighbouring gas market areas (A, B) merge their virtual points, creating an integrated gas wholesale market, but refrain from fully merging their national end user (load) balancing systems'(ACER, 2015a: 8). See Figure 14.

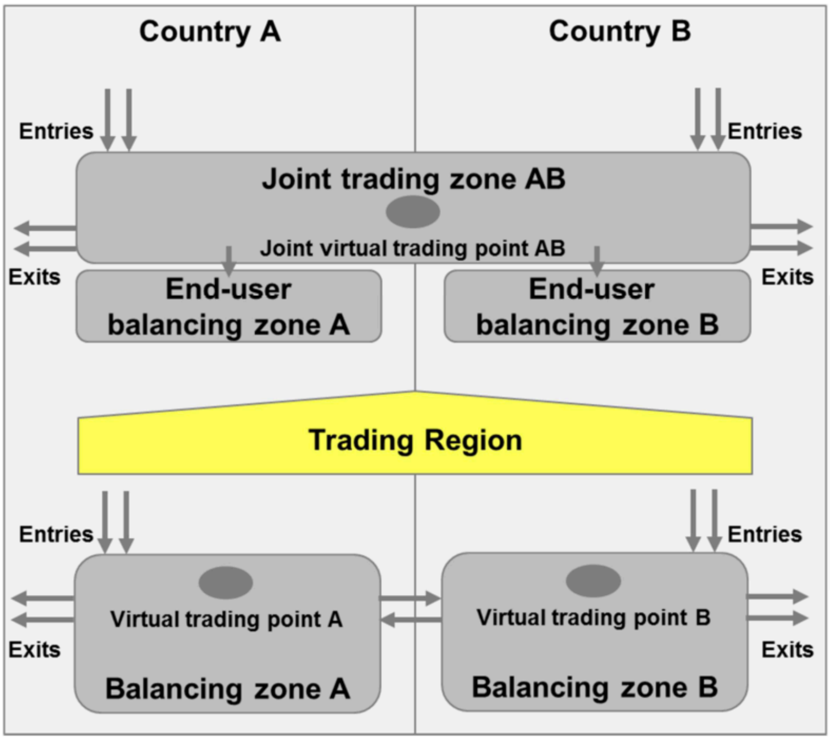

Figure 14 Trading Regions with separate balancing zones (ACER, 2015a: 8)

CEETR project

An example where the Trading Region concept is applied, is the Central Eastern Europe Trading Region (CEETR) project. In this Trading Region the gas wholesale markets of Austria, the Czech Republic and the Slovak Republic are integrated (Wagner Elbing and Company, 2012). The project is currently in post feasibility status.

Required 20 bcm and three gas sources are exception, Trading Regions more considered

Both models are based on entry/exit-zones to create cross-border markets. The two models can be used simultaneously in Europe according to country specific characteristics. The Market Area model is more attractive for larger member states, while the Trading Region has more benefits for smaller member states, that require cross-border cooperation in order to achieve sufficient market size and gas sources. According to ACER 2015 GTM update, in many markets the current characteristics do not allow for full competition, as functioning European gas markets, which meet the requirement of 20 bcm and three gas sources, are more the exception rather than the rule in 2014 (ACER, 2015b). Trading Regions are therefore currently more considered by National Regulatory Authorities. However, the decision for either Market Areas or trading Regions should be sensitive to, and appropriate for, the specifics of the market area under consideration.

4.2.2 Pillar 2 Tightly connect these markets

Hub-to-hub products

Making sure that the interconnection infrastructure is used efficiently results in tight connection of markets. The existing capacity is used efficiently when shippings from lower price markets to higher price markets are realized until either there is no more price differential between those markets (shippers having no more interest in shipping additional amounts of gas), or the available capacity is fully used (this sets a technical limit to shippings from lower price to higher price markets). Suffiecient interconnection capacity and efficient use will lead to price alignment between markets, which will unify them via cross-border optimization.

ETC

Tightly connecting markets is realized by the implementation of hub-to-hub transport products (traded at the spotmarkets) and several cross-market trade harmonisation measures by ETC (Enhanced Trading Conditions) for suppliers and shippers. These ETC make cross-border supply and trading easier and are to be implemented in the European network codes regarding areas of: capacity allocation, congestion management, balancing, tariffs and gas quality. The hub-to-hub products (transport capacity) will be auctioned for the mid-term (months) and short-term (weeks) markets and will be allocated via the first come first serve principle for the intra-day (daily) market (see Figure 15).

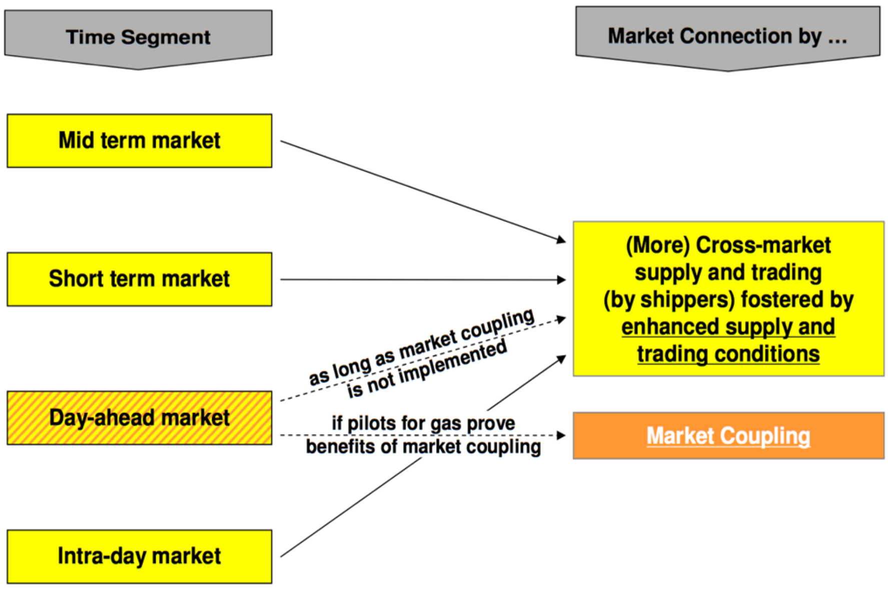

Figure 15 MECOS methods for connecting markets (CEER, 2012b: 31)

Market Coupling

These hub-to-hub products are possibly supported (if pilots prove benefits) by Market Coupling (see Figure 16) for day-ahead trading (possibly intra day), in which the allocation of cross-border capacity (first come first served) is tied to the continuous trading processes in the neighbouring spot market (Glachant & Vazquez, 2011). Day ahead spot markets (exchanges on the virtual point) are connected by an administrative process in which gas is bought by shippers in the cheaper market and sold in the pricier market, within the capacity limits of the interconnection capacity available to the Market Coupling process that possible involves several member states at once (Glachant & Ascari, 2011).

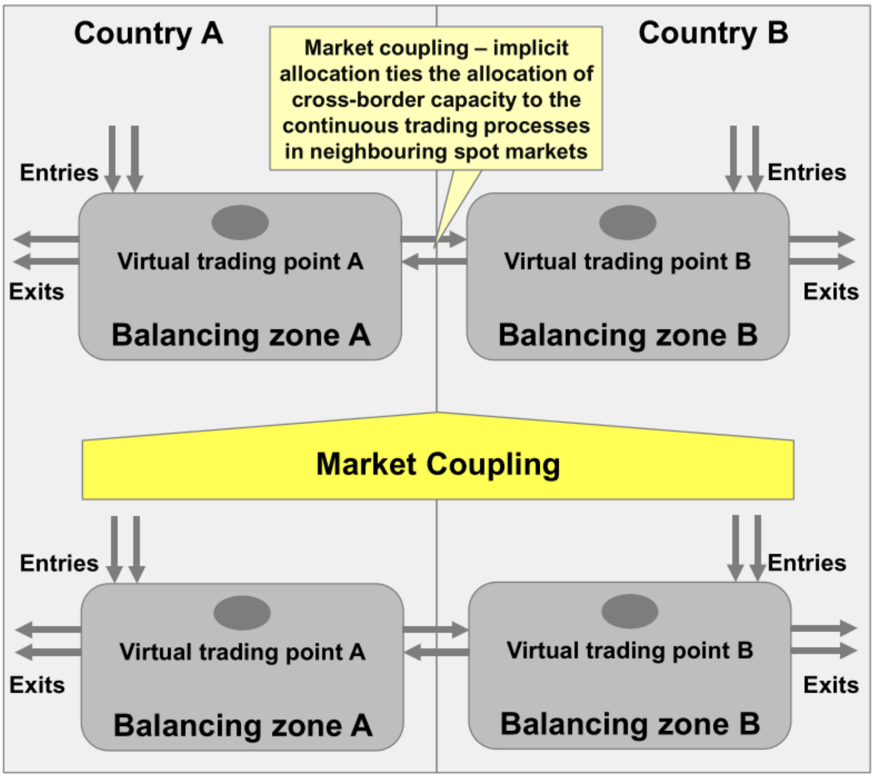

Figure 16 Market Coupling with implicit allocation (ACER, 2015a: 14)

4.2.3 Pillar 3 Enable secure supply patterns

GTM criteria, RSI 110%

According to ACER (2015) the recent crisis in Ukraine and the potential threat to the availability of gas from Russia lead to concerns about the European security of gas supply. CEER proposed that all member states should try to achieve a Residual Supply Index (RSI) of 110% exceeding their demand (2011). The RSI is the most important criterium as the other criteria are direct results of security of supply. Many member states currently do not have the level of security of gas supply they would like to have (see Figure 17).

Member state	Churn rate	Zone size (TWh/year)	Number of sources	HHI	RSI
Austria	3	105	3	7,500	143%
Belgium	6	197	8	1,709	279%
Bulgaria		39	2	7,587	13%
Croatia		535	5	5,987	125%
Czech Republic		95	3	9,051	159%
Denmark		45	2	2,570	22%
Estonia		9	1	10,000	0%
Finland		36	1	10,000	0%
France	3	485	13	1,240	137%
Germany	4	438	4	1,982	116%
Greece		49	9	5,181	131%
Hungary		113	4	3,198	60%
Ireland		52	2	1,215	8%
Italy	3	799	12	2,093	108%
Latvia		15	1	10,000	0%
Lithuania		39	1	10,000	0%
Luxembourg		12	4	3,185	0%
Netherlands	7	424	6	2,488	189%
Poland		193	3	4,550	56%
Portugal		55	6	2,821	93%
Romania		157	4	3,270	104%
Slovakia		70	2	9,595	369%
Slovenia		12	5	5,027	74%
Spain		365	12	2,000	159%
Sweden		13	1	2,766	0%
United Kingdom	15	910	11	950	142%
GTM target	≥ 8	≥ 215	≥ 3	< 2,000	≥ 110

Churn rate
- Volume of gas traded relative to physical volume

Market zone size
- Consumption of gas by consumers within a market zone

Number of supply sources
- Interpreted to be the number of countries imports are originating from

HHI (Herfindahl Hirschman Index)
- Measure of concentration amongst suppliers based on energy measured by firm

RSI (Residual Supply Index)
- Share of consumption which can be met without largest supplier based on supply capability, i.e. capacity (again on firm level)

Figure 17 Overall GTM criteria results (ACER, 2015b: 26)

Security of supply problems, Physical reverse flow

Thirteen member states do not meet the RSI target by CEER, of which most are all Eastern European member states that are reliant on supply from Russia. However, there are also Western European states that are vulnerable. The RSI of Italy is less than 110% and Germany and France only meet the target because demand has decreased. Furthermore, not all countries with an RSI higher than 110% have guaranteed security of gas supply. Countries like Austria, the Czech Republic and Slovakia have a high RSI because of the interconnection capacities between them, while they all depend on the same source of Russian gas. European LNG import capacity could contribute to the security of gas supply. Most of the EU gas supply sources are outside the EU like Russia, Norway and Algeria. This could change when more LNG production comes on stream (Australia and the U.S.) and as result of the Japanese nuclear power plants restart. However, pipeline capacities limit the extent to which areas far removed from LNG terminals can be supplied. The realization of physical reverse flow capability at interconnection points in Europe's current transmission system (especially eastern Europe), will play an important role in improving the extent, to which all areas of the EU can benefit from the security offered by both spare capacity (at LNG import terminals) and flexibility in other sources of gas. Physical reverse flow is not expected to be a total solution to all security of gas supply problems, given the minimal amount of gas sources (ACER, 2015b). ACER is convinced that well-functioning and competitive wholesale gas markets improve security of gas supply. Possible interventions to overcome supply interruptions and achieve adequate supply security, such as ramping up specific LNG imports, should be justified by a costs-benefit analysis to distort the market little as possible.

Long-term supply and long-distance transport contracts, Open season, Capacity expanding investments, Link-chain products

By creating the conditions for long-term supply and long-distance transport contracts, pillar 3 aims to enable secure supply patterns for European gas markets. Currently more than 30% of all European gas crosses multiple border points (Glachant et al., 2013). Furthermore, it aims to provide a market based solution for realizing transport security of supply when collaboration with neighbouring markets is required. The security of supply is realized (if demanded by shippers) through new long-term transport contracts. The shippers can periodically demand, in an open season style process, these contracts for a term of for instance 15 years. If the cumulated demand of all shippers for long-term capacity is higher than the available capacity, economical feasible investments are required to expand capacity (see paragraph 4.3.4) Common Foundations for more details about the open season procedure). The lead time for allocating long-term transport capacity should at least take as long as required for expanding capacity, in order to allow for investments. This way the capacity can always be expanded, so that long-term capacity is not a scarce good anymore and auctioning of capacity is no longer required. Long-distance shipper transport is arranged via link-chain products, which are packages of hub-to-hub transport products (see paragraph 4.2.2 Pillar 2). These packages allow for long-distance transport crossing multiple border points, on a continuous route linking the hub-to-hub products between multiple markets. The link chain products are homogeneous common carrier. This means that every shipper has the same rights and duties and pays the same socialized tariffs (flat services) under the obligation of having the same kind of network service flow. In contrast, the U.S. pipelines the delivery points and the period of injection and withdrawal are heterogeneous, allocating costs and resources heterogeneously among shippers. This means that shippers with different characteristics negotiate (with the TSO) how flexible the network services are. The U.S. tariff also depends on how many service units are required by the shipper (flexible services require more units than flat services) (Hallack & Vazquez, 2014). The U.S. link chain products therefore provide more flexibility compared with Europe.

Fall-back capacity

The other instrument in order to improve security of supply, is fall-back capacity. It provides a means for member states to secure sufficient capacity in a neighbouring market when not enough gas can be delivered through its usual supply lines. With a fall-back capacity contract, a TSO (A) of the member state in need of redundant transport capacity, books the required capacity long-term with a neighbouring TSO (B). B charges A only that part of the capacity, that is not booked by shippers (redundant) with B. This is why its called a fall-back contract, if shippers provide all the capacity (booked under the fall-back contract between both TSO's) on the same route (B to A), then there are no costs. However, if they do not, then A pays for the redundant booked capacity with B. This way A has improved security of supply as there is always capacity, even when not booked by shippers. A allocates the cost for this security measure to its market customers (Glachant & Vazquez, 2011). See Figure 18.

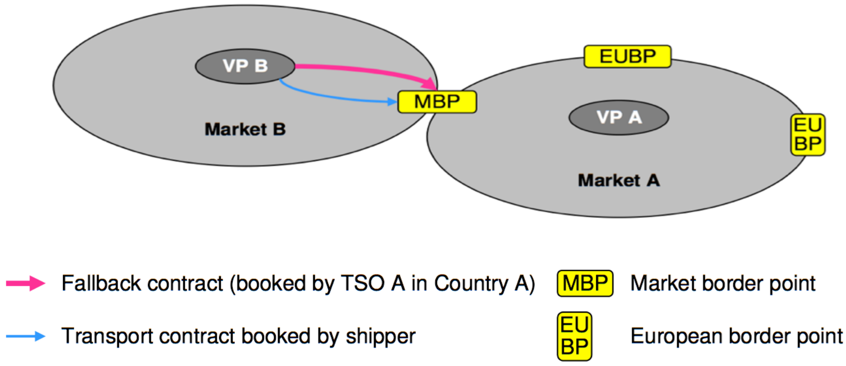

Figure 18 Fall-back capacity (Glachant & Ascari, 2011: 17)

4.2.4 Common foundations realizing economic pipeline investments

Interconnections, Intraconnections

The three pillars of MECOS aim at realizing investment between (interconnections to connect) and within (intraconnections to minimize congestion) markets. The investments support other pillars in their goals via interconnections, such as the creation of functioning wholesale markets, price alignment between markets and security of supply.

Pre-set evaluation criteria, TSO

The interconnection investments are realized by TSO's and supervised by NRA's through open seasons in which shippers can periodically demand for capacity. These open seasons are based on pre-set evaluation criteria (such as a mimimal capacity percentage per booking) for the acceptance of capacity booking biddings by market parties (shippers). Additionally, TSO's have the option to add more capacity for security of supply or openness of the market. Intraconnections within markets need to be evaluated against the congestion costs and are also performed by TSO's (ACER, 2015b). According to MECOS, National Regulatory Authorities (NRA's) are the main players supervising (via investment criteria that differ in European countries) TSO's in deciding on the locations and amount of intraconnections within national/regional markets. The NRA's hold the TSO's accountable for their investments in order to ensure efficient investments. This means that if the TSO decides to invest and the benefits of the investment do not outweigh the costs, the TSO is accountable (has to pay) and is not allowed to socialize the costs among the network users (CEER, 2012a). If TSO's can/will not invest, the project will be tendered to the market, in which the pipeline would be build and financed by a market parties (possibly producers that identify investment potential of a specific location) against a long-term yearly fee. As indicated earlier, these market based investments seldom occur. Once the pipeline is constructed, it will be integrated into the operational responsibility of the respective TSO.

Economic appraisal, Tariffs, Long-term contracts

The economic appraisal (cost benefit analysis performed by TSO's) of investments takes into account the return from long-term contracts and the expected value, as result of market connection price alignment. The TSO's could accept to take on a share of the constructing risk, in exchange for a higher rate of return on that part of pipeline investment via tariffs. The cost of constructing for mid-term and short-term markets are recovered by tariffs or long-term contracts (Glachant & Vazquez, 2011).

4.3 Identifying MECOS GTM governance structures

Based on MECOS key characteristics discussed in paragraph 4.2, it is possible to identify its expected governance structures (market, hybrid or hierarchy) for the shale gas midstream phase. This will be done according to the governance structures attributes operationalised in paragraph 2.5 (incentive intensity, administrative control and contract law regime).

4.3.1 Pillar 1 Enable functioning wholesale markets attributes

Market, High incentive intensity

The way to organize functioning wholesale markets according to MECOS, is by applying a *market* form of governance, in which virtual hubs play a key role. Shippers and suppliers are directly remunerated for their efforts via the spot-market mechanism of virtual hubs with entry/exit zones, which indicates a *high incentive intensity*.

Low/medium administrative control

Current market liquidity and number of gas sources define the applied market form of Market Areas or Trading Regions, which both have *low administrative control* given the self-controlling market principle of transparent spot-market auctioning (ACER, 2015a). Balancing combined with the entry/exit zone (Market Areas) or left apart (Trading Region) requires *medium administrative control* as shippers and TSO are both responsible for network balance. Shippers are corrected by a market focused correction mechanism in which the TSO buys or sells additional gas when their balancing actions are insufficient (to be recovered from ouot of balance shippers).

Classical contract law, Non flexible short-term

The virtual hub contracts are *non flexible classical short-term,* with no dispute settlement (contract will be ended) or ultimate settlement in court (Gasunie, 2016).

4.3.2 Pillar 2 Tightly connect these markets attributes

Market, High incentive intensity

According to MECOS, the market connection is organized through a *market* form of governance, which makes sure that the interconnection infrastructure is used efficiently with the aim of optimizing supply and demand resulting in price alignment. Hub-to-hub transport products and market harmonisation measures (ETC), make sure that cross-border supply and trading is optimized. This leads to *high incentive intensity* as shippers (volume) and TSO's (capacity) are directly remunerated for cross market trading via hub-to-hub products (no more delayed remuneration as result of 'pancaking' entry/exit charges at each system border) (ACER, 2015b).

Low adminstrative control

The market connection requires *low administrative control* by TSO, as hub-to-hub products (auctioned at spot markets) supported by market harmonisation measures, possibly combined with market coupling, are all self organized via market based trading of volume between shippers and suppliers and of capacity between shippers and TSO or shippers and shippers (CEER, 2012b).

Classical contract law, Non flexible short-term

The contracts for hub-to-hub products, under influence of market harmonisation measures and possible market coupling, are *non flexible classical short-term,* with no dispute settlement (contract will be ended) or ultimate settlement in court.

4.3.3 Pillar 3 Enable secure supply patterns attributes

Hybrid, Medium incentive intensity

The way MECOS enables secure supply patterns, is by a hybrid form of governance, that mixes market aspects (long term supply and long-distance transport contracts) with TSO institutional influence (TSO fall-back contracts). There is *medium incentive intensity* for shippers given the open season process for possible capacity expanding investments, which results in long-term capacity not being a scarce good anymore. The obligation (TSO's should build more capacity than the demanded bid) to keep short term capacity available, decreases shipper's incentives to make long term commitments via open seasons (ENTSOG, 2012). Shippers prefer to wait by not bidding in open seasons and buy short term capacity so the open season bid does not reflect the actual required capacity of the shippers. In addition they book less long term capacity (higher risk) as the risks and uncertainties for short term capacity are lower (Vazquez, Hallack, & Glachant, 2012b). The aim is to create more liquid markets by under-using the physical network capacity (more short term available). This increases liquidity inside the entry/exit zone but also increases costs for cross-border trade. Less capacity allocated within the entry/exit zone means also less capacity allocated at the border entry/exit points. This leads to inefficient capacity allocation and higher costs for the shippers, as there is more capacity required so the investment costs are higher (Colomer, 2012). Furthermore, the tariffs for (long-distance) transport capacity (link-chain) are regulated (socialised tariffs within entry/exit zones via homogeneous common carrier), only costs decreasing can influence their profits in a delayed way (Hallack & Vazquez, 2014). The TSO fall-back contracts influence the shipper's revenues as the costs to the TSO for the redundant capacity are socialized among the shippers.

Medium adminstrative control

Medium administrative control by TSO is required to verify the open season process, i.e. setting and checking the pre-set evalutation criteria and monitoring the second binding phase for shipper bids (Eijkel & Moraga-Gonzalez, 2014). The organization of the link-chain products and the fall-back contracts between neighbouring markets also requires medium administrative control by TSO. The tariffs for spot market link chain products are socialised to the shippers and the costs for the fall-back security measure are allocated to its respective market by the TSO (Glachant & Vazquez, 2011).

The supply and transport contracts are *open and flexible neoclassical medium-term*, given the term of 15 years (Glachant et al., 2013). This allows, if required (for instance unexpected developments), for contract alteration and dispute settlement via arbitration (Niesten, 2009).

Neoclassical contract law, Open flexible medium-term

4.3.4 Common foundations realizing economic pipeline investments attributes

According to MECOS economic pipeline investments are realized through a *hybrid* form of governance, that combines market and government aspects. The open seasons have pre-set objective criteria (see paragraph 4.2.4 Common Foundations) in regard of the booking capacity by market parties (shippers) defined by TSO's and supervised by NRA's (Eijkel & Moraga-Gonzalez, 2014). There is *medium incentive intensity* for shippers, as the open season process prescribes for TSO support if not sufficient capacity is booked, in order to secure supply or achieve more market openness. For the same reasons mentioned under pillar 3, shippers cannot influence a part of their expenses (and revenues) due to regulated and socialized transport and service tariffs. These regulated tariffs realize economical feasible pipeline investments by TSO's within entry/exit zones. Costs decreasing can influence their profits in a delayed way (Vazquez et al., 2012b).

Hybrid, Medium incentive intensity

Medium administrative control by TSO is required, which verifies and monitors the second phase of binding bids of the open season process for interconnections and the TSO organized (if the TSO is not willing to invest, then tendered to market) intraconnections (see paragraph 4.2.4 Common Foundations).

Medium adminstrative control

The *open and flexible neoclassical medium-term* contracts, allow for TSO's to react to market developments (such as increased demand or supply requiring more capacity) and adjust (add or reduce) planned future capacity. Dispute settlement takes place via National Regulatory Authority arbitration (for instance not complying with pre-set open season evalution criteria) (ERGEG, 2007).

Neoclassical contract law, Open flexible medium-term

Based on these governance structures attributes and by applying Table 1 of chapter 2, Table 4 provides an overview of the defined MECOS governance structures and answers sub research question 3.

Key characteristics	**MECOS**
Pillar 1 Enable functioning wholesale markets	Market
Pillar 2 Tightly connect these markets	Market
Pillar 3 Enable secure supply patterns	Hybrid
Common foundations realizing economic pipeline investments	Hybrid

Table 4 Governance structures MECOS

The next step is to compare the MECOS governance structures with the required shale gas midstream governance structures that were identified in chapter 3 (Table 3) This will address the alignment between chapter 3 shale gas transactions (and resulting required governance structures) with chapter 4 GTM governance structures.

4.4 Comparing future GTM governance structures with shale gas transaction attributes

Linking GTM MECOS to midstream shale gas transaction attributes (required governance structures)

Comparing the governance structures from Table 4 with the required shale gas transactions governance structures defined in Table 3 chapter 3, answers the fourth sub research question regarding the alignment (enabling and limiting factors) of future GTM governance structures and shale gas transactions. The shale gas transactions (midstream shale gas phase) consists of 'Trade' and 'Transport/storage', which both correspond with different pillars of MECOS GTM. Trade corresponds with pillar 1 and pillar 2, as these pillars create the required trading conditions. Transport/storage corresponds with pillar 3 and common foundations, as these two facilitate the required transport capacity and connections. These correspondences and their alignment will now be discussed.

Governance structures	Trade and Transport/storage midstream phase
Required shale gas governance structures	Market (Trade)
	Hierarchy (Transport/storage)
MECOS GTM expected governance structures	Market (Pillar 1) Market (Pillar 2)
	Hybrid (Pillar 3) Hybrid (Common Foundations)

Table 5 Required shale gas and expected GTM governance structures (green=aligned, red=not aligned)

4.4.1 Shale gas enabling and limiting governance structures

Only Pillar 1 and Pillar 2 align with shale gas required governance structures for trade

Looking at shale gas 'Trade and transport/storage' (market and hierarchy governance structures required), all three pillars and common foundations are of influence, from which two align with the required market governance form (pillar 1 and pillar 2), see Table 5. MECOS Pillar 1 'enabling functioning wholesale markets' (market) and Pillar 2 'connecting wholesale markets' (market), both correspond with the trading of shale gas, while Pillar 3 'enabling of secure supply patterns' (hybrid) and Common foundations 'realizing economic pipeline investments' (hybrid), both correspond with the transport and storage of shale gas. First the alignment of trade will be discussed, followed by transport/storage.

4.4.2 Trade

MECOS enables the required trade flexibility by following current market characteristics

The required market governance structure for shale gas trade, aligns with the market MECOS governance structures of pillar 1 and 2. The scattered shale gas locations across Europe and stochastic production profile will lead to more supply volatility and more system complexity. This requires more system flexibility and results in a larger gap between the commercial and physical network as explained in paragraph 3.2.1. This gap needs to be bridged by means of balancing mechanisms. In addition, the larger the entry/exit zone (single entry/exit zone), the larger the required flexibility (under-use of physical network capacity to provide balancing flexibility) and the gap between the commercial and physical network (DNV KEMA and COWI, 2013). Transport tariffs are expected to be higher in a complex and larger entry/exit zone, as the costs of the transmission infrastructure are socialized among the shippers. Short term hub based spot markets can provide the required trading and balancing flexibility for shale gas. Because of its more stochastic production profile and steep decline rate, producers prefer short term contracts and easy market access, to effectively match their stochastic supply with demand. Shale gas producers can not guarantee a fixed stream of gas flows for longer periods of time (Chyong & Reiner, 2015). This makes the currently often used take or pay contracts (buyers agree to take a certain amount of gas and to pay a penalty if they take less) not compatible as these contracts are based on longer periods of time.

Short term liquid hubs and market based connected

These flexiblity and balancing requirements indicate, that shale gas exploitation requires a market based approach to efficiently develop and connect market hubs. MECOS aligns with this via its hub development (enable functioning wholesale markets), which follows from the current market characteristics (RSI 110% and three different gas sources). The hubs have different sizes and relative importance, depending on the development of current market characteristics. Furthermore, the regulatory role of MECOS focuses on the harmonization of market rules (enhanced trading conditions ETC) possibly combined with market coupling, to tightly connect these markets, stimulating hub-to-hub market based products. Liquid trading hubs that are formed efficiently by market forces, contribute to the economical feasibility of shale gas development providing easy market access (Glachant et al., 2013). MECOS Market Areas or Trading Regions, create these liquid trading hubs via efficient entry/exit zones, and provide the mechanisms (combined balancing with entry/exit zone or single balancing zones) to balance the gas flows within network.

4.4.3 Transport/storage

MECOS limits the investments in transport/storage infrastructure by relying too much on market forces within its hybrid approach

The required hierarchy governance structure for shale gas transport/storage development, does not align with the hybrid GTM MECOS governance structures of pillar 3 and foundations. Without adequate transport/storage facilitation, shale gas cannot be traded effectively. The hybrid governance structure for organizing long-term transport and storage contracts via open seasons, does not align with the required hierarchy governance structure. This is the consequence of the entry/exit system not providing clear capacity signals to the TSO's via the open seasons, which also influences the fall-back capacity. There are three main reasons for this failure (Colomer, 2012):

- The lack of cost reflectivity in tariffs
- The reserved capacity for short term allocation (and balancing)
- The inefficiencies of capacity allocation

Cross-subsidising

Firstly, the lack of cost reflectivity in tariffs. The TSO organized entry/exit rights, socialize a major part of the transmission infrastructure costs. The tariffs paid for buying capacity through entry/exit tariffs, do not reflect the individual costs of shipper network usage. Buying transport entry capacity comes with a bundle of homogeneous transmission services like in the U.S. (flat point to point services or flexible services between regions and line pack storage), which leads to a distortion of network user incentives (Hallack & Vazquez, 2014). These common carrier homogeneous transmission services do not allow for price negotiation; all shippers pay the same tariff in contrast to the more flexible heterogeneous transmission services, in which shippers are allowed to negotiate their preference for flat or flexible services (contract carrier). As the network users (shippers) do not buy these transmission services separately, the TSO cannot identify the real user demand for the services it delivers, and therefore costs are socialized. Moreover, the open season mechanism (required for shale gas transport/storage investments) creates distortions by relying on these established fixed tariffs via shipper capacity bids. They are cross-subsidising and result in network users with less extensive and cheaper transmission services requirements, demanding below their efficient capacity level. Network users with extensive and costlier transmission service requirements (for instance due to remote shale gas locations), demand above their efficient capacity level. This leads to a distortion on the network services demand side (followed by the supply side), as the costs of usage are not accurately reflected.

Short term capacity more attractive

Secondly, the reserved capacity for short term allocation. As there is short term capacity available (obligation for the TSO's), the shippers have decreased incentive to make long term commitments. The TSO's are required to build more capacity than required by shippers, which stimulates the shippers to wait and buy short term (lower risk and uncertainty) capacity, instead of bidding long term via the open seasons (Hallack & Vazquez, 2014). This way the open season does not reflect the real capacity preference of the shippers.

Expensive investments as result of flexibility

Thirdly, the inefficiencies of capacity allocation via the aim of providing flexibility (and balancing) by not fully using the physical network capacity. The advantage of this flexibility (improving liquidity) is however only within the entry/exit zone, and increases the costs for cross-zone trade. Not fully allocating the network capacity means also less capacity in the border entry points of the system (DNV KEMA and COWI, 2013). The open season process addresses these border entry points and therefore the investment costs to offer more capacity are higher.

More hierarchical form required

The result of these three factors is inefficient expensive long-term contracts (Vazquez et al., 2012b). This could limit possible investments for shale gas transportation and storage, which requires a clearer hierarchical approach, with a larger top down role for TSO's regarding the planning of transportation/storage capacity, in order to effective realize sufficient investments. This role should focus on clearer market signals via for instance the implementation of binding open seasons. Open seasons start with a non-binding phase in which shippers are asked to indicate their commercial interest in a new infrastructure. This allows the TSO to identify the future needs of the market (non-binding open seasons). Some open seasons have a second phase in which shippers are asked to submit binding bids for infrastructure usage (binding open seaons) (Eijkel & Moraga-Gonzalez, 2014).

4.5 Conclusion

Market and Hybrid governance forms combination, Midstream trading is enabled, Midstream transport/storage is limited

This chapter looked into the current European gas trading and hub and exchange landscape developments. This indicated that the MECOS GTM follows from, and builds on current market characteristics. The analysis of GTM governance structures showed that MECOS combines market and hybrid governance forms to create and connect markets (market form), and realize security of supply and infrastructure investments (hybrid form). The market approach to midstream shale gas trade enables the required trade flexibility, by following current market characteristics. The hybrid approach however limits the investments in transport/storage infrastructure (which requires a hierarchical form of governance with possibly a larger top down role for TSO's), by relying too much on market forces within its hybrid approach. This could negatively influence shale gas supporting transport and storage investments. Chapter 5 will conclude on the influence of the limiting and enabling factors, on the feasibility of European shale gas development.

Part IV
Conclusions and recommendations

The final part of the research will combine and build on the previous parts with the aim of providing insight into the influence of future European gas markets design on European shale gas feasibility.

5 Conclusions alignment influence on shale gas feasibility and recommendations

The study was set out to explore the feasiblity of European shale gas development. Most of the publicly available shale gas analyses focus their attention on either the macro-economic and the energy market impacts, or on the potential technological cost of European shale gas development. However, these studies are inconclusive about the impact of future market design on shale gas feasibility. This study sought to understand the influence of future European gas markets design on the feasibility of European shale gas development, by applying TCE and has identified the shale gas transaction attributes and the GTM governance structures. It adressed the extent of their alignment as to identify the enabling and limiting factors for European shale gas development answering the main research question.

What is the influence of future European gas market design on the feasibility of European shale gas development?

The synthesis (5.1) will discuss the study findings with respect to the individual research questions and provide synthesis of arguments to show how these converge to answer the main research question. This is followed by a reflection on the results and discussion of the limitations (5.2). Subsequently the recommendations for future research are discussed (5.3). The study is concluded with a personal reflection (5.4).

5.1 Synthesis

The main findings are chapter specific and were summarized within the respective chapters: 3 European shale gas attributes and 4 Governance structures under the Gas Target Model. This section will synthesize the sub questions findings to answer the main research question.

What are the transaction attributes of shale gas exploitation derived from technical (and market) characteristics?

By indicating the specific technical (and possible resulting market) characteristics of shale gas exploitation, it was possible to identify the operationalised transaction attributes (chapter 2 Operationalisation Transaction Cost Economics theory for gas markets and shale gas). This analysis resulted in the following conclusions.

Flexible and transparent trading

Firstly, due to scattered exploration locations across Europe and stochastic with steep decline production profile in combination with high operational costs, shale gas will require a more flexible (timing of supply and demand) and transparent accessible form of trading and efficient transport/storage, in order for shale gas to compete with conventional gas.

Balancing mechanisms

Secondly, more complexity leads to a larger gap between the commercial network (virtual trading point/hub) and the physical network, that needs to be bridged by balancing mechanisms.

Sufficient transport and storage capacity, TSO investments

Thirdly, the European gas grid is extensive and storage facilities are numerous, so required infrastructure investments are minimal. Clustering of processing facilities minimizes the requirement of pipeline connections. Possible new investments are characterized by high asset specificity and hold up problems and therefore require minimal regulatory uncertainty. These investments will most likely be performed by TSO's as the costs and risks for smaller shale gas companies are too high.

Based on these findings the midstream attributes (asset specificity, uncertainty and frequency) for the trade and transport/storage transactions were defined and are summarized in Table 6. These attributes resulted in the required market governance structure for the Trade transaction and the hierarchy governance structure for the Transport/storage transaction in Table 7.

Transaction Attributes	**Trade and transport/storage Midstream**
Asset specificity	Non–specific (Trade) Idiosyncratic (Transport/storage)
Uncertainty	Low (Trade) High (Transport/storage)
Frequency	Recurrent (Trade) Occasional (Transport/storage)

Table 6 Shale gas midstream transaction attributes

	Trade and transport/storage Midstream
Governance structure	Market (Trade) Hierarchy (Transport/storage)
Involved actors	Producers Shippers and TSO
Covering	Entry/exit point capacity contract (Trade) Reselling capacity contract (Trade) Balancing contract (Trade) Infrastructure investments (Transport/storage)

Table 7 Required shale gas midstream governance structures

The next sub research question analysed the future MECOS GTM and defined its governance structures. Subsequently these were compared with the required governance structures of Table 7, indicating the alignment.

The key characteristics of MECOS GTM were described, according to its three pillars and common foundations. The next step was to identity the MECOS governance structures. This answered the third sub research question:

What are the expected governance structures of the European gas markets under the GTM?

Market and Hybrid governance forms combination

It is interesting to note that MECOS GTM follows from, and builds on current market characteristics. The analysis of GTM governance structures showed that MECOS combines market and hybrid governance forms (see Table 8) to create and connect markets (market form), and realize security of supply and infrastructure investments (hybrid form).

Key characteristics	MECOS
Pillar 1 Enable functioning wholesale markets	Market
Pillar 2 Tightly connect these markets	Market
Pillar 3 Enable secure supply patterns	Hybrid
Common foundations realizing economic pipeline investments	Hybrid

Table 8 Governance structures MECOS

The next step was to compare the MECOS governance structures (Table 8) with the required shale gas midstream governance structures that were identified in chapter 3 (Table 7). This addressed the alignment between chapter 3 shale gas transactions (and resulting required governance structures) with chapter 4 GTM governance structures.

Subsequently, the required midstream shale gas governance structures, were compared with the expected GTM governance structures, which addressed the alignment between chapter 3 shale gas midstream transactions and chapter 4 GTM governance structures (Table 9).

Governance structures	Trade and Transport/storage midstream phase
Required shale gas governance structures	Market (Trade)
	Hierarchy (Transport/storage)
MECOS GTM expected governance structures	Market (Pillar 1) Market (Pillar 2)
	Hybrid (Pillar 3) Hybrid (Common Foundations)

Table 9 Required shale gas and expected GTM governance structures (green=aligned, red=not aligned)

This answered the fourth sub research question, that focused on the limitations and possibilities of future GTM governance structures regarding shale gas transactions:

How do these expected governance structures limit and/or enable European shale gas development?

Midstream trading is enabled, Midstream transport/storage is limited

On one hand, the market approach to midstream shale gas trade enables the required trade flexibility, by following current market characteristics. On the other hand, the hybrid approach however limits the investments in transport/storage infrastructure (which requires a hierarchical form of governance with possibly a larger top down role for TSO's), by relying too much on market forces (non-binding open seasons) within its hybrid approach. This could negatively influence shale gas supporting transport and storage investments.

Feasbility?

What does this mean for the feasibility of European shale gas development? The GTM provides trade flexibility but limits midstream infrastructure investments. Investments by the smaller shale companies themselves, are economically not realistic given the high costs and risks of these infrastructure investments in combination with the high operating costs and stochastic shale gas production profile.

Feasibility depends on the required infrastructure investments

European shale gas development has the potential to be feasible depending on the requirement of infrastructure investments and the way infrastructure investments are organized. When there are minimal infrastructure investments required (drilling sites connected to existing infrastructure), shale gas can be developed and subsequently flexibly traded at European gas markets (hubs). This will be most likely the case as the European gas grid and its storage facilities are extensive.

And on the way infrastructure investments are organized

In contrast however, when there are numerous infrastructure investments required, it is expected that shale gas producers will be hampered in exploitation, as the gas cannot be feasibly transported to or stored for the market. This infeasibility is the consequence of the hybrid GTM infrastructure investment mechanism that results in inefficient expensive long-term contracts.

The next paragraph will reflect on the results and indicate the limitations (discussion points) of the study.

5.2 Reflection and limitations

Research objective

The objective of the research was to gain a better understanding regarding the feasibility of European shale gas development, by looking at the EU future gas market design, under GTM governance structures and their alignment with shale gas transactions. The conceptual framework provided a solid basis for the TCE analysis and clearly structured the study. It helped me to re-scope the research several times, especially in Part II Chapter 3 (European shale gas transaction attributes) that required focus on transaction attributes, allowing for GTM governance structures comparison, as the GTM addresses midstream characteristics. The research outcomes are a confirmation of the expectations, which are now supported by thorough analyses providing a solid base for further European shale gas feasibility research.

Scientific research objective

The scientific objective of the research was testing the use of TCE within the research scope, and the discovery of new insights regarding the alignment of governance structures and transactions in European gas markets dynamics. The research verified that TCE is an effective theory for the static feasibility analysis of European shale gas development, as the analysis methods contributed to the identification of key attributes within the upstream and midstream shale gas value chain and in the GTM. The alignment showed that it is important to focus on comparable aspects within European gas markets dynamics, in which scoping is crucial to overcome alignment analysis issues (such as comparing upstream transaction attributes with midstream GTM governance structures).

Research approach

The research approach was adjusted several times because initially invoked theories (Socio-Technical Systems and Transaction Cost Regulation) were not contributing to the answering of the main question and were therefore left out, which resulted in a stricter approach (including a more direct and scoped introduction) that provided a solid structure for the analyses. As the research scope focused gradually more on the governmental and transaction aspects instead of the social aspects of European shale gas development, the theory of Socio-Technical Systems was not applicable anymore. Transaction Cost Regulation provides a framework to analyse the interaction between governments and investors and places emphasis on understanding the nature of the hazards inherent to these interactions. At first this contributed to the answering of the main question given the focus on governance structures and transactions. However, as the research scope not mainly addresses the hazards and governmental and third party opportunism but aims at understanding the required European shale gas governance structures, Transaction Cost Regulation was left out.
The contribution of the theory of Ménard regarding the interaction between technology and institutions, was limited to the focus on the alignment, and did not emphasize critical transactions. It was possible to answer the main research question without further delineation of critical transactions, in which the theory of Ménard merely functioned as indicator of the interaction between technology and institutions.
The performed desk research that aimed at combining various insights with TCE theory by looking into European (shale) gas market developments and U.S. and U.K. market conditions proved to be difficult at first, but became more effective as more literature was being published. Dividing the analysis in four parts helped to

structure the research problem. The first part of thesis required actively working with theories, identifying their limitations and strengths in respect to the research problem. The following parts were based on the conceptual framework and applied the operationalized theoretical body, which provided a clear basis for analyses.
An important note regarding the research approach is the interaction between theory and practice. The application of Williamson's TCE sometimes proved to be difficult as theoretical concepts such as the length of a contract or the degree of uncertainty, required operationalization to the diverse concepts of European shale gas development. A trade-off between the strictness of the theory and diversity of the practice, contributes to the balance of the research. However, the trade-offs that were made for the operationalization and the alignment of required shale gas and GTM governance structures, strengthed the analyses by focusing on essentials of shale gas feasibility and supported the research outcomes within the research scope.

Discussion points

This research aimed to fill in the alignment efficiency knowledge gap of current available studies, by analyzing specific shale gas transaction attributes (based on U.K. and U.S. market developments) in the European context and future market design under GTM governance structures, resulting in a better understanding of possible alignment regarding European shale gas development feasibility. The study contributed to fill in the alignment efficiency knowledge gap by addressing the feasibility of European shale gas development based on the limiting and enabling alignment factors of future gas market design. The conclusion indicated that the feasibility depends on the required infrastructure investments and the way the infrastructure investments are organized. Within the research scope and according to the research approach the outcome fills in the alignment efficiency knowledge gap. However, taking some distance from the chosen research approach and scope and in the light of more extensive future research, these two preliminary conclusions are discussion points and form a possible limitation to this study.

Required infrastructure investments unclear, Investment mechanism unclear, TCE static analysis

The required infrastructure investments are unclear and location specific. Furthermore, the study is inconclusive about the way the infrastructure investment mechanism should be organized (specification of the open season mechanism). In addition to these two limitations to the results, there is a third limitation to the application of the static TCE theory. The attributes of European shale gas development will change in time, as shale gas development goes through the ramp up phase. The study did not account for those developments and only focused on the feasibility of the static initial phase of European shale gas development. The next paragraph will recommend future research for these three discussion points.

5.3 Recommendations for future research

To generate a more in depth analysis of European shale gas feasibility under future European market design, there is need for a better understanding of the discussion points.

- Required infrastructure investment
  The required infrastructure investments are unclear and location specific. Exploring the potential locations for European shale gas development leads to a better overview of required infrastructure investments. Parameters that need to be researched are for instance the distance from the exploration site to the grid and the proximity of storage facilities. The data gathered from this study contributes to a more robust conclusion on European shale gas feasibility. A comparison with U.K. and U.S. required infrastructure investments could be useful.

- Investment mechanism
  The study is inconclusive about the way the infrastructure investment mechanism should be organized (specification of the open season mechanism). According to the research a more hierarchical approach is required. A deeper analysis of binding open seasons and its NRA country specific criteria (national vs. ACER regulation), and in particular the second open season phase, in which shippers are asked to submit binding bids for infrastructure usage to TSO's, assists in determining the extent of hierarchy (clearer market signals because binding so shippers are committed). A better understanding of the hierarchical organization of the investment mechanism, can facilitate an efficient method to achieve infrastructure investments, contributing to the feasibility analysis. A comparison with the more heterogeneous flexible U.S. method of cost allocation could lead to more insight.

- TCE static analysis
  The attributes of European shale gas development will change in time, as shale gas development goes through the ramp up phase. The study did not account for those developments and only focused on the feasibility of the static initial phase of European shale gas development. A study under different transaction attributes (asset specificity, frequency and uncertainty) allows for further alignment assessment in different shale gas development stages. Combining the results with the outcomes of this study, will provide a more dynamic overview in time of European shale gas feasibility under future gas markets design.

The rise of unconventional gas production, and in particular shale gas, has been the greatest revolution in the U.S. energy landscape since the Second World War. This study indicated that European shale gas development is in potential feasible. However, it will be no revolution, but rather an evolution with the GTM playing an important role in the facilitation of infrastructure and market flexibility.

5.4 Personal reflection

Briefly, I will reflect upon my scientific research from a personal perspective. Choosing shale gas development as my main topic was easy, as I was intrigued by this method of gas exploitation, extending the lifespan of available fossil fuel supplies and revolutionizing the U.S. energy markets. A bigger challenge was specifying the scope given the wide range of possibilities this topic offered. While the research progressed, the main research question and focus of the thesis were adjusted multiple times, which lead to a more specific scope. As most publicly available analyses of shale gas in Europe focus on either macroeconomic and energy market impacts or on the potential cost of developing shale gas in Europe and to date, no studies have focused on the essence of shale gas feasibility regarding future market design, I decided to look into future market shape and circumstances regarding European shale gas development feasibility. It was challenging to stick explicitly to the subject given the numerous available literature about European gas markets and shale gas exploitation. This required a lot of re-reading and re-structuring, in order to understand the theories and apply the ones contributing to my research. By making explicit choices and trade-offs I became better in this process. The most important aspect I have learned is the structuring of complex problems. Going back to the main research question and research problem in troubled times proved to be helpful. Discussing the research with external people also assisted me in streamlining the analysis, especially in the alignment phase of the analysis. This research process was by far the most educational experience with regard to my studies of the past years, and I greatly enjoyed it most of the time.

References

ACER. (2015a). *European Gas Target Model – review and update Annex 6 Tools for gas market integration and connection*.

ACER. (2015b). *EUROPEAN GAS TARGET MODEL REVIEW AND UPDATE*.

Acker, C. (2014). Shale Gas Decline Curves Demystified - Natural Gas Now. Retrieved March 16, 2016, from http://naturalgasnow.org/shale-gas-decline-curves-demystified/#more-4171

Anderson, E. (1985). The salesperson as outside agent or employee: A transaction cost analysis. *Marketing Science*, *4*(3), 234–254. Retrieved from http://bear.warrington.ufl.edu/weitz/mar7786/Articles/anderson.pdf

Ascari, S., Glachant, J., Vazquez, M., & Hallack, M. (2011). A Gas Target Model for the European Union: Contrasting MECOS and EURAM Proposal, (2011).

Baker & McKenzie. (2014). Shale Gas , an International Guide.

BBC. (2015). What is fracking and why is it controversial? Retrieved December 24, 2015, from http://www.bbc.com/news/uk-14432401

Bellelli, J., & Troszczynska - van Genderen, W. (2013). The Shale gas ′ revolution ′ in the United States : Global implications , options for the EU, (April 2013).

Buchan, D. (2013). Can shale gas transform Europe′ s energy landscape?, (July).

CEER. (2011). *Pre-Release Gas Target Model : The MECOS Model*.

CEER. (2012a). Market-Based Investment Procedures for Gas Infrastructure: Issues and Approaches A CEER Public Consultation Paper, (June).

CEER. (2012b). *The MECO-S Model Outline*.

Chyong, C. K., & Reiner, D. M. (2015). Economics and Politics of Shale Gas in Europe. *Economics of Energy and Environmental Policy*, *4*(1), 69–83.

Clemente, J. (2012). Shale Gas in Europe: Challenges and Opportunities.

Colomer, A. A. (2012). *Open season for gas pipeline investment in the EU cross-border: Insights from France-Spain case*.

Continental Economics. (2012). The Economic Impacts of U.S. Shale Gas Production on Ohio Consumers, (January), 1–25. Retrieved from http://energyindepth.org/wp-content/uploads/ohio/2012/02/Economic-Impacts-of-Shale-Gas-Production_Final_23-Jan-2012.pdf

Correljé, A., & Groenewegen, J. (2005). The Gas market , transaction costs and efficient regulation, (2003), 1–16.

Danube Region Strategy Energy. (2014). *Potential for integration of the gas markets in the Danube Region Case study: Austria, Slovakia, Czech Republic and Poland*.

de Jong, S., Auping, W., Govers, J., Peters, M. C. A. M., Widdershoven, C. J. C. G., & Weterings, R. A. P. M. (2014). The Geopolitics of Shale Gas : The Implications of the US' Shale Gas Revolution on Intrastate Stability within Traditional Oil- and Natural Gas-Exporting Countries in the EU Neighborhood. Retrieved from http://www.narcis.nl/publication/RecordID/oai:tudelft.nl:uuid:5bd82932-bbdb-4abc-a90c-d3b4734d7daa

DNV KEMA and COWI. (2013). Study on LT-ST Markets in Gas.

Eijkel, R. Van, & Moraga-Gonzalez, J. (2014). Open Seasons , Investment and Congestion in Energy Markets.

ENTSOG. (2012). Network Code on Capacity Allocation Mechanisms - final Version, *28*(715), 1–30.

ERGEG. (2007). ERGEG Guidelines for Good Practice on Open Season Procedures (GGPOS), (May).

Ernst & Young. (2014). Getting ready for UK shale gas, (April).

Flues, B. F., Löschel, A., Massier, P., & Wölfing, N. (2013). Perspectives on the Future of Unconventional Gas in Europe – Insights from the ZEW Energy Market Barometer, 36–38.

Foss, N. J., & Klein, P. G. (2010). Critiques of transaction cost economics: An overview. *The Elgar Companion to Transaction Cost Economics*, 263–272. Retrieved from http://books.google.bg/books/about/The_Elgar_Companion_to_Transaction_Cost.html?id=6sOi1WDXHGcC

Fracking for Gas. (2016). List Of Businesses involved in UK Fracking. Retrieved March 16, 2016, from http://www.frackingforgas.co.uk/uk-onshore-gas/

GasTerra. (2015a). Annual Report 2014, (2), 81–87. http://doi.org/10.1007/s13398-014-0173-7.2

GasTerra. (2015b). Hub trading. Retrieved November 6, 2015, from http://www.gasterra.nl/en/products-and-services/todays-market/hub-trading

Gasunie. (2012). Connection Code Gas - TSO, (January), 1–19.

Gasunie. (2014). Transmission Code Gas - TSO Part of the Dutch Network Code as referred to in article 12b of the Dutch Gas, (January).

Gasunie. (2016). Tariff information › Gasunie Transport Services. Retrieved March 17, 2016, from https://www.gasunietransportservices.nl/en/shippers/terms-and-conditions/tariff-information

Geńy, F. (Oxford I. for E. S. (2010). *Can Unconventional Gas be a Game Changer in European Gas Markets?*

Glachant, & Ascari, S. (2011). *A Target Model for the European natural gas market - Preliminary Outline*.

Glachant, & Hallack. (2010). The Gas Transportation Network as a "Lego" Game: How to Play with It? Retrieved from http://cadmus.eui.eu//handle/1814/13975

Glachant, Hallack, M., & Vazquez, M. (2013). *Building Competitive Gas Markets in the EU*.

Glachant, J., & Vazquez, M. (2011). A Gas Target Model for the EU: Florence School Proposes MECOS 1.

Haase, N. (2009). *European Gas Market Liberalisation European Gas Market Liberalisation*.

Hallack, M., & Vazquez, M. (2014). Who decides the rules for network use? A "common pool" analysis of gas network regulation. *Journal of Institutional Economics*, *10*(03), 493–512. http://doi.org/10.1017/S1744137414000071

Heather, P. (2012). *Continental European gas hubs: are they fit for purpose? Oxford Institute for Energy Studies. Working paper, n ….* Retrieved from http://www.oxfordenergy.org/wpcms/wp-content/uploads/2012/06/NG-63.pdf

Hodgson, G. M. (2010). Limits of Transaction Cost Analysis, 11.

Hubert, F., & Suleymanova, I. (2008). Strategic Investment in International Gas-Transport Systems: A Dynamic Analysis of the Hold-up Problem. *DIW Berlin*, *846*, 1 – 31.

International Gas Union. (2014). Wholesale Gas Price Survey - 2014 Edition.

Ivanenko, V. (2012). Modularity analysis of the Canadian natural gas sector. *Energy Economics*, *34*(4), 1196–1207. http://doi.org/10.1016/j.eneco.2011.10.020

Johnson, C., & Boersma, T. (2013). Energy (in)security in Poland the case of shale gas. *Energy Policy*, *53*, 389–399. http://doi.org/10.1016/j.enpol.2012.10.068

Joode, J. De, Plomp, A., & Özdemir, Ö. (2012). A model-based analysis of the implications of shale gas developments for the European gas market, 1–7.

Kefferpütz, R. (2010). Shale Fever: Replicating the US gas revolution in the EU?, (210).

Kiewiet, B., Petrov, K., & Vos, M. (2013). Gas Transmission Pricing Models for Entry-Exiy Systems and Implementation Options.

Kowalski, M. (2015). Introduction to Poland ' s upstream oil & gas sector. Retrieved January 24, 2016, from http://infolupki.pgi.gov.pl/en/economy/introduction-polands-upstream-oil-gas-sector

KPMG. (2012). *Central and Eastern European Shale Gas Outlook*.

Kuhn, M., & Umbach, F. (2011). *Strategic perspectives of unconventional gas: A game changer with implications for the EU's energy security* (Vol. 3).

Lee, S., & Liu, C.-Y. (2003). Governance Structures of Alliances: Transaction Costs versus Competence Perspective.

Lowe, P. (European C. (2015). Quarterly Report on European Gas Markets, *8*(3).

MacKay, D., & Stone, T. (2013). Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use, (September).

Mainwaring, J. (2016). Shale Gas UK: A Pivotal Year Ahead Rigzone. Retrieved April 4, 2016, from http://www.rigzone.com/news/oil_gas/a/142402/Shale_Gas_UK_A_Pivotal_Year_Ahead

Maltby, T. (2013). European Union energy policy integration: A case of European Commission policy entrepreneurship and increasing supranationalism. *Energy Policy*, *55*, 435–444. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0301421512010798

Mason, J. E. (Hydrogen R. I. (2011). Well Production Profiles for the Fayetteville Shale Gas Play Revisited. *Oil and Gas Journal*, (516), 1–14. Retrieved from http://solarplan.org/Research/Well Production Profiles for the Fayetteville Shale Gas Play

Revisited_Mason_9 April 2012.pdf

Ménard, C. (2014). Embedding Organizational Arrangements : Towards a General Model ., (April), 1–31.

Miriello, C., & Polo, M. (2015). The development of gas hubs in Europe. *Energy Policy*, *84*, 177–190. http://doi.org/10.1016/j.enpol.2015.05.003

Natural Gas Europe. (2016). Dutch Market is "Changing Radically" - Gasunie. Retrieved March 21, 2016, from http://www.naturalgaseurope.com/dutch-market-is-changing-radically-gasunie-28673

NaturalGas. (2013). Processing Natural Gas.

Neumann, A., Ruester, S., & von Hirschhausen, C. (2015). *Long-Term Contracts in the Natural Gas Industry - Literature Survey and Data on 426 Contracts (1965-2014)*.

Niemiec, J. M., Jessen, A. M., Gooch, M. B., & Zimmer, M. M. (2014). Energy Services & Equipment Sector Report.

Niesten, E. (2009). *Regulation , Governance and Adaptation*.

Peel Gas and Oil Ltd. (2015). Shale Gas - Creating a Supply Hub for the Bowland Shale, (April).

Polish Institute of International Affairs. (2011). *Path to Prosperity or Road to Ruin? Shale Gas Under Political Scrutiny*.

PWC. (2015). Maximizing value of shale joint ventures.

Rious, V. (2007). *Le développement du réseau de transport dans un système électrique libéralisé, un problème de coordination avec la production*.

Ruester, S. (2010). Recent Developments in Transaction Cost Economics, (January).

Ruester, S., & Neumann, A. (2009). Linking alternative theories of the firm – a first empirical application to the liquefied natural gas industry. *Journal of Institutional Economics*, *5*(01), 47. Retrieved from http://www.journals.cambridge.org/abstract_S1744137408001215

Spanjer, A. (2008). Do Article 22 exemptions adequately stimulate investments in European gas markets? *Zeitschrift Für Energiewirtschaft*, *32*(1), 46–51.

Spencer, T., Sartor, O., & Iddri, M. M. (2014). Unconventional wisdom: an economic analysis of US shale gas and implications for the EU, (february).

Taylor, C., Lewis, D., & Byles, D. (2014). Getting shale gas working, 188.

Teasdale, A. (2015). Unlocking the UK shale opportunity - Oil & Gas Financial Journal. Retrieved March 29, 2016, from http://www.ogfj.com/articles/print/volume-12/issue-5/features/unlocking-the-uk-shale-opportunity.html

Tian, L., Wang, Z., Krupnick, A., & Liu, X. (2014). Stimulating Shale Gas Development in China: A Comparison with the US Experience, (July).

U.S. Department of Energy. (2012). How is Shale Gas Produced?, 2010–2012. Retrieved from http://energy.gov/sites/prod/files/2013/04/f0/how_is_shale_gas_produced.pdf

U.S. Energy Information Administration. (2012). Today in Energy: Pad drilling and rig mobility lead to more efficient drilling, (June), 11–12. Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=7910

UtilityWeek. (2015). Ofgem toughens up: the top five biggest energy company fines. Retrieved March 7, 2016, from http://utilityweek.co.uk/news/ofgem-toughens-up-the-top-five-biggest-energy-company-fines/1118582#.Vt1ObMdO8jM

Vazquez, M., Hallack, M., & Glachant, J.-M. (2012a). Building gas markets: US versus EU, market versus market model.

Vazquez, M., Hallack, M., & Glachant, J.-M. (2012b). Designing the European Gas Market: More Liquid & Less Natural? *Economics of Energy & Environmental Policy*, *1*(3), 25–38. http://doi.org/10.5547/2160-5890.1.3.3

Vijver, T. van der. (2008). Exemptions to Third Party Access for New Infrastructures in the European Community Gas Sector - The Exception that Defies the Rule? *European Competition Law Review*, *29*(4), 229.

Wagner Elbing and Company. (2012). *Part I : Design Principles of the CEE Trading Region CEETR – CEE Trading Region*.

Wang, Z., & Krupnick, A. (2015). A retrospective Review of Shale as Development in the United States. Retrieved from http://www.rff.org/RFF/documents/RFF-DP-13-12.pdf

Weijermars, R. (2010). Value chain analysis of the natural gas industry. *Journal of Natural Gas Science and Engineering*, *2*(2-3), 86–104. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S1875510010000284

Weijermars, R., Drijkoningen, G., Heimovaara, T. J., Rudolph, E. S. J., Weltje, G. J., & Wolf, K. H. a. a. (2011). Unconventional gas research initiative for clean energy transition in Europe. *Journal of Natural Gas Science and Engineering*, *3*(2), 402–412. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S1875510011000382

Williamson, O. E. (1985). The Economic Institutions of Capitalism., *12*(2), 1–442. http://doi.org/10.5465/AMR.1987.4308003

Williamson, O. E. (1991). Comparative Economic Organization : The Analysis of Discrete Structural Alternatives Comparative Economic Organization : The Analy- sis of Discrete Structur- al Alternatives, *36*(2), 269–296.

Williamson, O. E. (1996). *The Mechanisms of Governance*. Retrieved from https://books.google.gr/books/about/The_Mechanisms_of_Governance.html?hl=el&id=meERBVysP6YC&pgis=1

Williamson, O. E. (1998). Transaction cost economics: how it works; where it is headed, (1), 23–58.

Zillman, D. N., Roggenkamp, M. M., Barrera-Hernandez, L., & del Guayo, I. (2012). Energy Networks and the Law: Innovative Solutions in Changing Markets. *International Journal of Environmental Studies*, *69*(4), 690–694. http://doi.org/10.1080/00207233.2012.696791