Developing scenarios for the European plastics industry based on the uncertainties of shale gas

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Executive summary

The development of shale gas is considered to be one of the most controversial aspects of the oil and gas sector. The USA has taken a leading role in drilling and processing shale gas. This has resulted in cheaper ethylene as a form of feedstock to produce petrochemicals such as polyethylene. While the USA is preparing for massive ethylene production from shale gas in 2017, Europe has not yet even considered trial drillings for shale gas. The effects of shale gas developments on the European petrochemical industry has raised significant concerns from government and public opinion because of the risks of the non-competitiveness of the European industry. Its future existence or survival could even be threatened.

Currently the industry only tends to consider a limited set of strategies in response to the shale gas phenomenon and therefore an expansion of the decision making space of the actors is required. To achieve this goal, scenarios workshops will be applied in this report. As such this thesis seeks to give an answer to the following research question: To what extent can scenario workshops help actors from the petrochemical value chain to expand the decision-making space in order to deal with socio-technical uncertainties triggered by shale gas developments?

In order to answer the research question, the thesis first presents the theory behind using scenarios types, scenarios workshops, decision making space and learning from scenarios. It distinguishes the different types of scenarios developments.

The next step involves the description of the methodology used in the thesis. Scenario workshops and interviews are described in detail to understand how these methods are applied to the research and emphasize their limitations.

At last, the way the decision making expansion will be assessed is presented. To this end the thesis introduces a method that compares current strategies and new strategies proposed by participants of the scenario workshops.

Furthermore, a method is proposed to assess whether a learning process has taken place during the scenarios workshops. To this end, three indicators of a learning process are presented. The three indicators are the following: change in open attitude towards shale gas phenomenon, change in awareness of the consequences of the shale gas phenomenon, adoption of a critical opinion on the dominant views towards the shale gas phenomenon.
The next part of the report presents the overall European petrochemical industry in particular the plastics industry. In addition to that, shale gas is introduced and described.

Subsequently, it is possible to identify the uncertainties in the petrochemical value chain. First the value chain is presented and divided into blocks which represent the different production steps of petrochemical, in particular polymers. Based on this division, four types of uncertainties (environmental, technological, geopolitical and socio economical) are identified in each block. In addition to that the state of development and the dynamics in development of the technologies involved are described.

The following part involves the introduction of the current dominant existing strategies of the industry on the shale gas phenomena. For every types of uncertainty, the existing strategies are presented. This division is based on the analysis of consultancy reports and interviews conducted with executives in the industry.

Next, three scenarios are chosen based on three types of uncertainties: a war in the Middle East, shale gas boom and a bio plastics revolution. These scenarios constitute the basis of the scenarios workshops. Two workshops were organized with both internal and external participants from the industry in order to analyze how the actors in the industry react on the possible future events. The conclusions drawn are limited to reactions collected from the participants to the workshops.

Finally, based on the existing strategies and the information collected during scenarios workshops it is possible to assess whether and to what extent the decision making space of the participants has been broadened. This will be done by assessing whether new strategies have been proposed by participants during the scenarios workshops.

The analysis reveals that the majority of the strategies proposed by the participants are similar or a variation to the existing strategies. Nevertheless among the proposed strategies, two new strategies have been proposed by the participants. The first technological strategy entails the proposition of transferring technological innovations and trends from the USA to Europe by creating strategic alliances with organizations in the USA to Europe. The second geopolitical strategy would be the minimization of crude oil supply dependency on Saudi Arabia.

Although only two new strategies have been developed, there might still be indicators that suggest a learning process. This was analyzed based on three indicators: change of open attitude towards the shale gas phenomenon, change of awareness towards the shale gas phenomenon and change of critical opinions towards the current existing strategies.
The thesis ends with concluding remarks, limitations and recommendations. The majority of the proposed strategies by the participants in our research were similar or variations of the existing strategies. Only two new strategies were proposed. Some indication of an open attitude, a sense of awareness and of an adoption of critical opinion towards existing strategies was as well detected. But for both it cannot be established whether really new strategies and more open attitude, awareness and critical opinions was detected. On the basis of the research methodology followed in this research, little insights can be given as to whether and to what extent the decision making space of participants has been broadened. Indeed the main limitation entails that no pre and post workshops were conducted to be able to assess the scale of broadening of the decision making space of the participants after the scenario workshops.

**Keywords**

Shale gas - petrochemical industry – polyolefin – uncertainties – scenarios – decision making space - value chain-polymers

**List of abbreviations**

CEFIC: European chemical industry council
EPCA: European petrochemical association
IFRI: Institut francais des relations internationales
PE: Polyethylene
PP: Polypropylene
LNG: Liquefied natural gas
NGL: Natural gas liquids
PE/PP: Polyethylene-Polypropylene
OPEC: Organization of petroleum exporting countries
LYB: LyondellBasell
1 Introduction

1.1 Topic introduction

Four years ago if anyone in the petrochemical industry had said that North America would be the second lowest-cost producer of the largest chemical building block known as ethylene in the world and that companies would invest billions of dollars in new crackers, they would have been either fired or called crazy. But that is exactly what has happened with the key driver being shale gas, enabled by new technologies such as Horizontal Drilling and Fracturing. This technological development for recovering unconventional hydrocarbons in the United States, particularly shale gas, has attracted the attention of the petrochemical industry. As shale gas - often referred to as unconventional gas explorations - expands internationally, the dynamics of the European petrochemical industry in particular the global olefins and polyolefins sectors will change dramatically. Gas is not only used as fuel generating feedstock but also as a very important raw material in the production of petrochemicals [1]. As a result, this so-called “American Revolution of shale gas” has major implications not just in the energy sector but also in the petrochemical industrial sector [1].

The petrochemical industry has until now been dependent on naphtha produced from crude oil. Naphtha constituted the main feedstock of European crackers that generates olefins. These compounds are then converted into polyolefins. These involve a wide range of polymers. These products constitute a fundamental basis for the production of extensive amounts of final products extending from supermarket bags to agricultural pipes [2]. One of these products is Polyethylene (PE) or Polypropylene (PP), these are the most produced plastic raw material in the world [2], their attractive chemical properties such as its robustness and resistance to aggressive substances makes them irreplaceable for many applications.

The worldwide polyolefins market is becoming increasingly global and intensive competition has dominated the market as a result of the massive introduction of cheap shale gas from the United States. In a context of a European plastics industry that is slow growing because of weak economic growth and market maturity [3], the sector faces great challenges including the introduction of cheap ethane feedstock derived from shale gas. Taking into account that the prices of ethane, the gas extracted from shale gas, has been divided by three between 2008 and 2012 [14] and with a context of aging European petrochemical production facilities, the European petrochemical industry is facing a challenging period in
terms choosing adequate feedstocks for the production of its petrochemicals. We can notice (as will be further elaborated in chapter 6) that actors are influenced by existing strategies and opinions. In fact, these actors consider shale gas development either as a threat to growth in the sector or are not concerned at all with the phenomenon. The petrochemical industry seems to have not explored any possible outcome or scenario that would involve a radical or unprecedented change caused by shale gas. With that, these ways of thinking may not be able to react on radical changes. In fact radical changes involve events that are not common to the industry and these are often excluded from the limited set of strategies currently developed by the industry (see chapter 5). Examples of radical changes would be a war or other events that could trigger out of the box reactions.

There thus seems a need for expanding the decision space of the actors in the European petrochemical industry. This thesis will explore how this is possible for one specific company, Vinmar. This research will apply scenario workshops in order to investigate whether such workshops are instrumental in expanding the decision making space of the workshop’s participants. To this end, three scenarios are developed to help actors understand the multiplicity of possible futures and to confront them with uncertainties. By confronting the main actors involved in the European petrochemical sector with three scenarios that describe possible futures that cover every part of the value chain insight is created in how the plastics industry could pre-empt on the uncertainties.

The master thesis research was conducted in close collaboration with a company named Vinmar. Vinmar is a petrochemical distribution and trading company that distributes more than three million metric tons of petrochemicals around the world. Their customers are companies that process and convert petrochemical into consumers or industrial products. The position of Vinmar in the polyolefins value chain is at the end of the chain. In fact, their activities involve the distribution of polymers to plastics that produce the final products. Vinmar International is seeking to have more insight in the impact of shale gas developments on the European polyolefin’s sector. Therefore, Vinmar made available the participants of the workshop.
1.2 Structure

The master thesis is structured as following: Chapter 1 outlines the scope of research, the problem statement and the research questions. Chapter 2 presents the underlying theory of the thesis. Chapter 3 presents the methodology followed in the master thesis. Then chapter 4 presents the European petrochemical industry in particular the plastics industry. Chapter 5 contains a description of the petrochemical value chain. This value chain will help identifying the uncertainties the European petrochemical industry will have to deal with as a result of the shale gas developments.

Chapter 6 focuses on the current existing strategies of actors in the industry on the shale gas topic. It contains the presentation and analysis is the existing strategies on the impact of shale gas on the European petrochemical industry.

Next, chapter 7 presents the scenarios used in the two workshops to confront the actors in the industry. Scenarios workshops are organized in order to guide actors to better cope with these identified uncertainties. These scenarios have as objective to confront the participants and let them reflect upon the uncertainties. To put this into practice, workshops with actors will be held to present and confront the actors with these scenarios.

Chapter 8 presents the analysis of the scenarios workshops. Their reactions and opinions will be analyzed before and after the workshops in order to understand if the workshops have helped them to think of better strategies.

Finally, chapter 9 will draw conclusions focusing on evaluating whether the scenarios workshops succeeded in broadening the decision making space of the workshop participants. Finally limitations will be discussed and recommendations will be given for improving the ways the scenario workshop was used, and new paths for future research will be proposed.
The following flowchart exhibits the overall research structure of the master thesis:

**Value chain**
- The petrochemical value chain

**Uncertainties**
- Uncertainties identification

**Analysis of current situation**
- Dominant views
- Current situation and strategies

**Scenarios workshops**
- Confront actors with scenarios based on identified uncertainties

**Workshops analysis**
- Did the workshops help to broaden the decision making space of participants?

*Figure 1: Research structure*
1.3 Problem statement and scope of research

There is no doubt that the shale gas revolution has revived the North American petrochemical industry. Thus the European petrochemical industry will be affected by these developments. Actors in the petrochemical industry are not prepared for the consequences the shale gas developments could have. They are too often busy with their daily operations and short term vision on shale gas. Actors lack insights on what are the risks and opportunities of shale gas in a wider context. Therefore we need to expand the decision-making space of actors in the petrochemical industry. By making actors think “beyond their frames of reference and to scrutinize underlying assumptions, or at least become aware of them” [31] the thesis aims at challenging the minds of actors in the industry.

The petrochemical industry is a major contributor to economic growth in Europe [3]. Nevertheless the industry is confronted with several challenging uncertainties. To begin with, the increasing price of raw materials; second less competitive energy prices; and finally increasingly expensive labor costs. Facing these uncertainties, Europe is closely following the developments of shale gas in the USA. Petrochemical companies are interested in the development and technology dynamics of shale gas [4]. In fact, the gaseous ethane which is extracted from shale gas is a direct feedstock of crackers that produce olefins such as ethylene and propylene. These chemical compounds are then used as feedstock to generate polymers such as polyethylene, polypropylene and other polymers. These are the so-called plastics raw materials or resins. Consultancy and public organizations reports [5, 1] have been published that seek to describe the impact of low costs feedstock based on shale gas on the European petrochemical industry. Knowing that the American petrochemical companies have gained a significant competitive advantage in comparison to the European industry as a result of the shale gas revolution, petrochemical companies in Europe and consultants expect shale gas to be a game changer to industry in particular in the polyolefin’s sector.

The European polyolefin’s industry has been confronted with a declining European demand for polymers as a result of a global economic recession triggered by the financial crisis. As such, they follow all the developments of the new petrochemical feedstock and position themselves in order to deal with new upcoming situations. Understanding the shale gas developments from the USA is an important step towards adapting to these developments. If Europe is to reshape its industry the major uncertainties should be investigated.
The scope of research is limited to understanding and explaining the uncertainties triggered by shale gas for the European plastics sector. Four types of uncertainties will be investigated: environmental, geopolitical, technological and socio-economic. Moreover, the wide range of actors’ existing strategies will be examined. The following figure exhibits the scope of research. The latter is composed by one central unit of analysis: the European petrochemical industry and in particular the European plastics industry. Affecting this industry are four types of uncertainties (technological, socioeconomic, environmental and geopolitical) that are part of the scope of research.

Figure 2: Scope of research of the master thesis (The arrow indicates the European polyolefins industry as part of the European petrochemical industry).
1.4 Aim of research and research questions

The research aim of the thesis is to provide insights on how the European petrochemical industry can react to the shale gas phenomenon. The main objectives of this thesis are:

- To identify the current dominant strategies and decision-making space of the actors in the petrochemical value chain;
- To identify the uncertainties caused by shale gas developments in the petrochemical value chain;
- To develop scenarios on basis of these uncertainties;
- To reflect and to evaluate if scenarios approach was successful in expanding the decision-making space of participants.

The main research question of this thesis is:

To what extent can scenario workshops help actors from the petrochemical value chain to expand the decision making space in order to deal with socio-technical uncertainties triggered by shale gas developments?

In order to answer this central research question, three sub research questions are formulated. Together these three research questions cover each step of the research approach.

1) What are the current dominant strategies of the actors in the industry with respect to the impact of shale gas on the European petrochemical industry?

2) How can uncertainties be derived from the petrochemical value chain system and give insight into the possible effects of shale gas on the European petrochemical industry?

3) What scenarios can be developed based on the main uncertainties that the European petrochemical industry is facing concerning the shale gas phenomenon?
The managerial relevance of the master thesis lies in the extent to which scenarios workshops can help to expand the decision making space of actors within the industry. This is needed in order to prepare actors on radical changes in the petrochemical industry as a result of shale gas developments. The academic relevance lies in the contribution of the understanding of how scenarios workshops can be applied to a practical case in order to identify the socio-technical uncertainties triggered by shale gas developments.
2 Theory

The following chapter presents the main theoretical concepts that are used in this master thesis: “decision making space”, “scenarios types”, “scenarios workshops”, “uncertainties” and “learning from scenarios”.

2.1 Defining decision making space

This thesis seeks to explore how scenarios workshops can contribute to extending the decision making space of scenarios workshops participants. The first concept that is to be clarified is decision making space in the context of shale gas developments and its impact on the petrochemical value chain. In this research, decision-making space is defined as the ability of participants to have knowledge of the possible strategies to address the potential consequences of shale gas developments on the petrochemical industry.

2.2 Scenarios types

Scenarios techniques entered the global world when business organizations based their strategy building on oil shocks and economic crisis scenarios [8]. The variety of future study approaches contributed to the production of global scenarios. Scenarios are defined as “plausible and internally consistent descriptions of possible future states of a system” [27]. Scenarios do not have the pretention to predict or forecast the future but they aim to explore possible future paths. An important field of application of scenarios is strategic planning. In fact, long term visions are important for organizations investing in the future and are keen on exploring possible outcomes in the future. Van der Heyden 1996 states the following: “scenarios are the art of strategic conversation” [32 page 1]. According to scenario literature [7] the future can be divided in three categories: probable future, possible future and preferable future. Three main scenarios can be associated with future thinking: a predictive scenario, an exploratory scenario and a normative scenario [9]. The predictive scenario include forecasts and “what if” scenarios [9]. The exploratory scenario is characterized by the identification of key uncertainties. Finally, normative scenarios studies include transforming and preserving scenarios [9]. The following figure presents the main types of scenarios:
• **Strategic scenarios**

These scenarios are used by modelers. Their objective is to identify inconsistencies in the different approaches used to describe a system.

• **Exploratory scenarios**

Exploratory scenarios are described in literature as “Exploratory scenarios describe events and trends as they could evolve based on alternative assumptions on how these events and trends may influence the future, i.e. “What can happen?” The exploratory scenario type provides a plurality of plausible alternative futures, in which active strategies to adapt (or not) have been pursued” [9 p725].

• **Anticipatory scenarios**

These scenarios make use in the opposite way (from the future to the past) to look into future events. Meaning that these scenarios are developed backwards in time to try to unveil the future.

In this research, the exploratory scenario method will be applied. The reason why exploratory scenarios were chosen for this research is because they invite the participants to react on radical changes. In fact this kind of scenario is effective in making participants react to radical changes because the scenarios formulated explore reactions of real life participants to unexpected events such as a war in the Middle East or a bio-plastics boom. In both predictive and normative scenarios such unexpected events
are not taken into account. Moreover, exploratory scenarios can contribute more out of box information and more alternative outcomes than normative scenarios. The approach starts with the present as starting point and moves forward to the future by asking ‘what if’ questions about implications of possible events outside familiar trends. The following section presents the theory of scenario workshops.

### 2.3 Scenario workshops

In addition to the various types of scenarios presented above, scenarios workshops are described in existing in literature as the way to discover future events [27]. They have as main objective to trigger actors within the industry to think of the future by taking into consideration more than their own interests. Moreover, by interacting with different actors, actors are forced to take into account the strategies and opinions of others. Scenarios workshops are used in this master thesis to investigate how the petrochemical industry deals with the uncertainties triggered by shale gas. In order to understand the uncertainties triggered by shale gas and the development of new strategies. The scenarios workshop method opens the door to protected environments where radical changes are often not taken into accounts in decision making. The reason why this method is used is because it evaluates the extent to which actors can expand their decision making space by being confronted with scenarios that are not part of the existing strategies. In case of the shale gas developments, it is essential for actors to look further than dominant opinions already presented by various reports.

In addition to scenario theory, scenarios workshops are used in research to create scenarios and trigger reactions from participants. The process of creating the scenarios: interviewing actors implies triggering the subjects to reflect on issues [27, 7]. It will already stimulate actors to think through lenses that they normally do not use. The use of scenarios workshops can be considered as a highly appropriate method for involving actors in developing future visions on the impact of shale gas on the European plastics industry [26, 7].
2.4 Why and how using a scenario approach?

The objective of the master thesis, as stated above, is to broaden the decision making space of actors in the petrochemical industry in the light of shale gas developments. This is necessary because the petrochemical sector copes with many uncertainties that are triggered by shale gas developments and actors within the industry need to be prepared for radical changes. In order to achieve this objective this research uses a scenario approach and more specifically scenario workshops. The following part of the thesis justifies and explains why the use of scenario workshops is considered to be an appropriate method to broaden the decision making space of the actors concerned.

2.4.1 Why using the scenario approach in this research?

In light of existing literature [34, 35, 36], the following part of the thesis argues why for the purpose of this study the scenarios approach is the right approach to expand the decision making space of actors.

In the first place, the scenario approach allows broadening the decision making space of actors. Schoemaker [36] makes a clear link between decision making and the scenarios approach. He states that: “By identifying basic trends and uncertainties, a manager can construct a series of scenarios that will help to compensate for the usual errors in decision making” [36 page 25]. Similarly, Burt and Chermack [34 page 288] make a clear link between scenario planning and decision making: “the strengths of scenario planning to support executive decision making “This suggests that the scenario approach could be considered a tool to stimulate thinking and the debate regarding the implications of the shale gas phenomenon on the daily practices in the industry.

Secondly, the scenario approach is expected to be an appropriate method in clearing out defensive routines and to stimulating learning. Burt and Chermack [34] define scenarios planning as: “Scenario planning is usually situated in the domain of strategic and business planning, yet it is increasingly considered a major organizational intervention approach to overcome organizational defensive routines and bring about learning and change in organizations” [34 pp 285].

Thirdly, the scenario approach has the ability to ‘challenge the minds’ of those working in the petrochemical industry. This means that scenarios help actors to think differently and challenge them to critically reflect on their current strategies towards shale gas developments. Burt and Van der Heijden [35]
apply scenario development to small and medium sized enterprises (SMEs) in Scotland. The purpose of the scenario development was to evaluate the added value of the approach in terms of strategic management and learning process. The article concludes that the scenarios approach can be a “mind challenger” and influence decision making in an organization or public debate. In this research, I seek to find out whether the scenario approach could influence the thought and minds of the actors. In fact, the current attitude of actors in the shale gas debate is sought to be influenced by raising awareness on the consequences the shale gas development might have for the petrochemical industry.

To conclude, scenario approach can be considered the appropriate approach to influence decision making space of actors involved in the petrochemical industry by challenging the actors to go beyond the existing strategies towards shale gas and perhaps even to find a new strategies for dealing with shale gas developments.

### 2.4.2 How to use scenario approach in order to expand the decision-making space of actors?

Having addressed the question why the scenario approach was chosen to expand the decision making space of actors in the petrochemical industry, the next question is how to expose actors in the petrochemical industry to the scenarios on the consequences of the shale gas phenomenon.

The method that will be used is the organization of scenario workshops, whereby participants from both inside and outside the petrochemical industry are confronted with three scenarios related to the development of shale gas.

First, these scenarios workshops constitute mind challenging situations which are likely to promote out of the box thinking and to stimulate the actors to come up with alternative ways to respond to the shale gas development. As [30 page 1-2] states scenarios workshops “raise awareness among policy-makers, politicians and the general public about alternative perspectives on future needs and the implications hereof for present-day actions”[30 page 1-2].

In this respect, the room for interactions, discussions and sharing of knowledge between participants is considered an important feature of scenario workshops. By providing a new thinking environment, actors within the petrochemical industry are stimulated to rethink and reflect on their current strategies. Furthermore, during the workshop actors are invited and encouraged to come up with actions needed from inside or outside the industry regarding their strategies on the shale gas debate [30].
2.5 Uncertainties

Uncertainties have been defined and discussed in scenarios literature. In fact, the scenarios approach is often described as a solution to uncertainties [34]. Scenarios that are considered as images of the future could explain or give answers or solutions to uncertainties [34]. The latter is a key aspect in my research as we are studying the uncertainties in the petrochemical value chain based on the scenario approach. Bood and Postma [35] present an overview of the role of scenarios approaches, in particular how such approaches can deal with bottlenecks in public debates. They state that “the use of multiple scenario analysis has been increasingly propagated as an approach to deal effectively with the many long-run uncertainties that surround business organizations” [35 page 1013].

In this thesis, uncertainties in the petrochemical value chain are identified in order to be able to construct several key scenarios that will form the basis of the reflection and debate on the phenomena. As Shoemaker [36 page 26] states: “By identifying basic trends and uncertainties, a manager can construct a series of scenarios that will help to compensate for the usual errors in decision making “[36 page 26].

2.6 Learning from scenarios workshops

As scenarios and uncertainty theory has been explained, the next part of the thesis describes the concept of leaning from scenarios workshops. One of the main reason to choose scenario approach in this research is because it can be a mind challenger as presented in paragraph 2.4.1. But the question arises how to define “learning form scenario workshops”? 

The Danish participatory model [37] presents the concept as:” In scenario workshops, a group of citizens interacts with other actors to exchange knowledge and experience, develop common visions and produce a plan of action” [37 page 331]. The article defines scenarios workshops as a “framework for dialogue among policy-makers, experts and ordinary citizens” [37 page 331].

The use of scenarios is thus expected to trigger a learning process among the participants. In this research, this scenario based learning process can be defined as “the process of acquiring knowledge through the interaction with participants in scenario workshops” can contribute to a better understanding on how to deal the uncertainties triggered by shale gas [27].

As the learning process has been defined the two main learning objectives that are at the heart of the scenarios workshops methodology are presented:
1. Identification of the uncertainties triggered by shale gas on the European plastics industry

2. The existence of other strategies besides the existing current strategies

The first learning objective entails the identification of the uncertainties triggered by shale gas on the petrochemical value chain. These uncertainties will be the basis of the scenarios workshops that are at the heart of the second learning objective. In fact, through scenarios workshops, the thesis seeks aims at finding if there are new strategies besides the exiting current strategies.

The next part of the thesis presents the methodology used to identify the uncertainties in the petrochemical value chain and develops scenarios that will be put into practice during workshops.
3 Methodology

As the previous section presented the theoretical framework of the research, the following section presents the methodology used in the thesis seeks to find out how the actors in the petrochemical industry could deal with the uncertainties triggered by shale gas. The methods described are the scenarios approach, the workshops method, interviews and the tracing method for the decision-making expansion.

3.1 Uncertainties identification and developing scenarios

The framework used in this thesis to identify the uncertainties triggered by shale gas developments is the scenarios workshop. The master thesis applies uncertainty identification and scenarios workshops methodology on the impact of shale gas developments on the European petrochemical industry. Through the exploratory scenarios, participants of the workshops will be stimulated to think about and react on the uncertainties. Uncertainties will be identified by the studying and describing of the petrochemical value chain. First, an overall flowchart of the petrochemical value chain is presented. Second, a division in blocks is applied on the value chain to give a clear overview and understanding on how the uncertainties are identified in the chain. Moreover the complexity of the chain is simplified with this approach. The scenarios methodology used in the thesis is based on [24]. It has five key steps that are applied to our research. The steps are the following:

- **Identification of actors**
  Who are the main actors affected or involved in the effects of shale gas on the European petrochemical industry? This will investigated through studying the petrochemical value chain.

- **Identify the issues**
  What are the main shale gas impacts and how will this affect the industry? This will be investigated through studying the petrochemical value chain.

- **Identification of drivers of change**
What will shape the reactions of the industry as a result of the shale gas phenomenon? This will investigated through the analysis of existing strategies found in literature and interviews.

- **Formulation of scenarios**

What particular scenarios can be selected to confront actors with the shale gas phenomenon? This will done by identifying and studying the uncertainties that will be formulated basis of on the value chain and formulating scenarios on the basis of this.

- **Development of scenario narratives**

The developments of possible narratives will be conducted through workshops during which actors are confronted with the scenarios.

The value chain description is key in the identification of uncertainties. Through the identification of actors, issues and drivers of change, the major uncertainties caused by the shale gas developments are identified. The method consists of subdividing the value chain in blocks and describing for each block the socio technical uncertainties. Scenarios workshops are used to trigger reactions from participants on how the European petrochemical industry will react on the shale gas effects. Based on these definitions workshops participants will give their own perceptions.

### 3.2 Workshops : Role play

The workshops are organized to make the participants aware of the uncertainties of shale gas and to investigate whether the workshop helps the participants to enlarge their decision making space. The sessions are held through a role play. In order to understand the reactions of different participants within the petrochemical industry role plays have as objective to trigger reactions and to make observations as to whether the participants broaden their decision-making scope. In fact, the scenarios formulated based on the petrochemical value chain system include events that are not common in the industry and represent new perspectives for the participants. These scenarios are presented in chapter 7. By organizing a role play, every participant will represent one actor and seek to defend its interests. By doing so, debates are expected to arise and scenarios are discussed. This approach needs a strict organization and structure. One internal workshop was organized at a petrochemical distribution company where all participants were employees of the company. Because of confidentially matters only employees could participate. The second workshop included students from the TPM (Technology, Policy and management) faculty.
Moreover, gathering feedback from the participants will be the basis for reflecting and evaluating if the scenarios approach was successful to expand the decision-making space of the participants.

### 3.3 Interviews

The interviews that have been conducted are exploratory interviews. Their aim is to gather information on how different actors in the petrochemical industry stand regarding the shale gas phenomenon. Four interviews were conducted to distinguish the dominant strategies and opinions on the shale gas developments for the European petrochemical industry. Four executives of two petrochemical companies named LyondellBasell (LYB) and INEOS were interviewed. The main topic of the interviews was: How do petrochemical companies prepare or deal with the effects of shale gas developments? The interviews structure and questions are presented in appendix 2 and the interviews results are presented in section 5.1 of the thesis. Three executives of LYB were interviewed. LYB is the one of the world major petrochemical companies. The company supplies thousands of customers with petrochemical products. The key aspect of these interviews was to understand how the shale gas phenomenon will impact the production facilities of LYB. Moreover the interests of the interview laid in the geostrategic importance of shale gas in Europe. Another interview was held with a representative of INEOS. The petrochemical supplier is a pioneer regarding shale gas in Europe. In fact, the company is the first to integrate LNG terminals in the supply chain and import shale gas directly from the USA into Europe. INEOS has taken one of the leading roles in Europe to take advantage of shale gas [15].

The next section presents the method used to trace the possible expansion of decision making space of the participants of the scenarios workshops.
3.4 Tracing the expansion of decision making space

As mentioned in the theoretical part of the thesis, the objective of the master thesis is to broaden the decision making space of actors in the petrochemical industry in the light of the shale gas developments on the basis of the scenarios workshops. The following flowchart presents the process that will be followed to assess whether the decision making space of participants has been broadened.

In order to be able to assess whether the decision making space has been broadened, the analysis seeks to find out if new strategies have been proposed by the participants of the workshops in comparison to the current and existing strategies presented in part 4.6 (figure 19). To this end, first the strategies proposed during the workshop will be identified. Secondly, these strategies will then be compared to the existing strategies presented in figure 19. It will be analyzed whether the strategies are ‘new’ strategies, or whether the strategies are similar to or variations of the existing strategies. Eventually, it is possible to conclude whether new strategies have emerged and to what extent the decision making space has been broadened.

Furthermore, it will be analyzed whether a learning process of the participants has taken place. Indeed, as explained in paragraph 2.4 the exposure of the participants to the scenarios could trigger a learning process among the participants. In paragraph 2.6, scenario based learning has been defined as “the process of acquiring knowledge through the interaction with participants in scenario workshops”.

Figure 4: Decision-making space broadening research framework

ZERO POINT: Current strategies Part 4.6 (figure 19)

Workshops: NEW strategies

Decision making space of participants broadened

Workshops: NO new strategies

Decision making space of participants not broadened
explained before, the presence of a learning process might lead to an extension of the decision making space in the future.

The question is how to identify whether a learning process has taken place. The following indicators that are based on literature that considers that scenarios can be “mind challenging”, raise awareness and trigger critical opinions could be of help in order to see whether a learning process has taken place. The indicators are the following:

- Change in open attitude towards the shale gas phenomenon
- Change in awareness of the consequences of the shale gas phenomenon
- Adoption of a critical opinion on the current strategies towards the shale gas phenomenon

This first open attitude indicator assesses whether the participants have come to better understand and to familiarize themselves with the shale gas phenomenon due to the exposure to the scenarios workshops. Secondly, the awareness indicator assesses whether participants become more aware of the consequences of the shale gas phenomena. Thirdly, the adoption of a critical opinion can be defined as the ability of the participants to take a more critical stance towards the current dominant views vis-à-vis the petrochemical development.

Before analyzing if and to what extent the decision making space of participants has been broadened due to the scenario workshops, the next chapters first provide insights in how the shale gas phenomenon has come about and presents the effects of shale gas on the petrochemical industry.
4 The European petrochemical industry

The following chapter presents the European petrochemical industry in particular the plastics industry. Its main production process and basic applications are described. In addition to that, shale gas is defined as its role within the European petrochemical landscape is presented.

4.1 Defining the European petrochemical industry

The European petrochemical sector accounts for more than 1 % of the total EU gross domestic product [2]. Petrochemical products constitute the building blocks of the chemical industry that affect a wide range of petrochemicals users. Moreover, the petrochemical products represent 25 % of the European chemical markets [6]. Petrochemicals can be produced either from crude oil using both a refinery and a naphtha cracker or natural gas liquids (NGL). This latter involves a NGL separator and an ethane cracker. The following figure presents the overall production process of petrochemicals based on either gas or crude oil.

We distinguish the plastics industry which is a part of the european petrochemical industry. It involves the production of polymers based the last chemical building blocks of the overall production process exhibited in figure 5. The next subchapter presents one of Europe’s most important industry.
4.2 Defining the European plastics industry

In Europe the plastics industry employs 134,000 people and assembles more than 1.2 million plastics converters [6]. Its economic contribution amounts to 26.3 billion euros every year [6]. This industry includes almost 150,000 people in Europe working for various organizations or firms involved in polyolefin industry [6]. These numbers emphasize the importance of the plastics industry for the overall European economy. The following figure of Plastics Europe exhibits the key figures to remember.

![Figure 6: Key figures to remember on the European plastics industry [15]](image)

The European plastics sector is one of the most important petrochemical activities on the European continent. With a yearly European demand of 46.3 million metric tons of material as exhibited in figure 6, the polymers are present in the most important applications of consumers. The most important applications as presented in figure 7 are: packaging, building & construction and various consumers’ goods. Packaging accounts for almost 40% of polymers demand. The building construction application is the second with a demand of more than 20%. The plastics application touch our everyday life in all aspects.
For every application in the plastics industry, different plastics families are used. The main polymers families are: PE, PP, PET, PS and PVC. These are called plastics resins. These raw materials are transformed into plastics products. Figure 8 presents the main final products produced by plastics converters. The two sectors where the demand of polymers is the highest are film industry that mainly uses PE and the injection industry that mainly uses PP. The figure below sums up the important polymers applications in Europe.

*Figure 7: Polyolefins demand in Europe per application [15]*
In order to process the plastics resin into final products, converters use different processes. The following table presents the main plastics processing methods and the polymers used respectively.

<table>
<thead>
<tr>
<th>Process</th>
<th>Final products</th>
<th>Polymers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection</td>
<td>Flowerpots</td>
<td>PP</td>
</tr>
<tr>
<td>Extrusion</td>
<td>Plastic bags</td>
<td>PE</td>
</tr>
<tr>
<td>Compounding</td>
<td>Color compounds</td>
<td>PP, PE</td>
</tr>
<tr>
<td>Thermoforming</td>
<td>Plastics buckets</td>
<td>PP</td>
</tr>
<tr>
<td>Roto-molding</td>
<td>Garbage containers</td>
<td>PE</td>
</tr>
</tbody>
</table>

Table 1: Plastics production processes and the respective final products and polymers

The next part of the chapter presents the basic information regarding shale gas.
4.3 What is shale gas?

In order to understand and analyze the impact of shale gas on the petrochemical value chain, shale gas is defined in the following chapter. Shale gas can be defined as: “Shale deposits are rock formations thousands of feet below the surface that trap natural gas. Shale rock has small pores like a sponge or sheets that trap natural gas flow unless they are artificially fractured to create channels so the gas can flow out” [22]. The composition of shale gas is presented in the figure below.

The composition of shale gas is presented in the figure below.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Share, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>74.22</td>
</tr>
<tr>
<td>Ethane*</td>
<td>15.62</td>
</tr>
<tr>
<td>Propane*</td>
<td>5.46</td>
</tr>
<tr>
<td>Butane*</td>
<td>1.40</td>
</tr>
<tr>
<td>Pentanes*</td>
<td>1.00</td>
</tr>
<tr>
<td>Hexanes*</td>
<td>1.00</td>
</tr>
<tr>
<td>inerts/other</td>
<td>1.30</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

* heavies

The two main gases present in shale gas are methane and ethane. Ethane gas is used as a feedstock for the crackers to generate olefins such as ethylene and propylene. The latter are the main building blocks for polyolefin. The gas widely used in the polyolefin value chain is ethane. In fact as ethylene production accounts for the major part of olefins production, ethane gas is the predominant gas extracted from shale gas resources.

4.3.1 Shale gas revolution in the USA

While gas production in the United States was on the downside between 1990 and 2006, it has returned to growth and significantly increased between 2007 and 2012 as exhibited in figure 10. This rapid growth was the effect of the production of shale gas, which now provides 34% of gas production in the United States [1]. The production of shale gas has reached 230 billion cubic meters (Gm$^3$) in 2012. It has more than quintupled since 2007 [1]. As exhibited in the figure below, the volume of shale gas in the overall gas exploration in the USA has significantly increase between 2004 and 2012. In fact it went from around 500 Gm$^3$ to almost 700 Gm$^3$. 

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In addition to figure 10, appendix 3 presents the shale gas resources per country. We can notice that the USA has the second largest reserve of shale gas after China. Moreover, appendix 5 presents all the projects on shale gas in the USA that are planned for starting production in 2017 - 2020. We can observe that most important petrochemical companies will take part of this new investment in shale gas based assets in the USA. In response to the shale gas revolution illustrated above, the European petrochemical industry has been in stagnation [4]. In fact, increasing energy prices have put pressure on the competitive advantage of European petrochemical companies. Therefore, the sector started focusing more and more on niche products such as innovative plastics for example bio-plastics [1]. In order to cope with international competition, the European petrochemical industry will have to restructure itself by adapting its production process to alternative feedstock such as shale gas [1]. Thus, the European petrochemical industry is faced with one of its greatest challenges in decennia. With the rise of shale gas based production plants, the flexibility to use a wide range of alternative feedstocks is becoming very central. Moreover the prices of oil and gas shown in figure 11 which are the two main feedstocks for the production of petrochemicals have experienced a huge price gap beginning 2009. This can be explained by the exploitation of shale in the USA. The following figure outlines the prices fluctuations of oil and gas in the USA in the time range from 2000 to 2013.

**Figure 10: Gas supply in the USA 1990-2035 [14]**
Figure 1 illustrates the fact that the production of petrochemicals will more and more shift to gas feedstock as gas prices makes it economically much more profitable. The uncertainties regarding the alternative feedstock that could be used in the European petrochemical industry is raising many concerns. With this extensive gas supply generated by shale gas resource in the USA, Europe has kept its position unchanged regarding shale gas exploration. Nevertheless, the continent possesses shale gas resources that are becoming a source of debate in the many European countries. The next part of the thesis presents shale gas and its particularities as a feedstock.

4.3.2 Shale gas in Europe

The exploration and drilling of shale gas in Europe has raised significant concerns through governments and public opinion. Nevertheless, several oil companies have initiated explorations and trial drillings in many countries in Europe. The map of figure 12 exhibits the locations where explorations of shale gas have been initiated. The two countries that draw the attention are the United Kingdom and Poland. In fact these two countries have taken a leading role in shale gas exploration. The oil/gas companies that are active in these regions face less regulations and obstacles from governmental institution to initiate their activities.
Figure 12: Shale gas exploration in Europe [16]

The following part of the thesis exhibits the impact of shale gas on the European petrochemical industry through identifying the uncertainties triggered by the phenomenon.
5  Shale gas and the petrochemical industry

The next step of this thesis is to identify the uncertainties triggered as a result of the shale gas developments in Europe. To achieve that goal, a petrochemical value chain system will be developed based on the polyolefin value chain. The main contribution of the petrochemical value chain approach is the following; first the approach is not reductionist, meaning it takes into account all complex factors involved. In fact complexity is explicitly considered as a relevant feature of the process; this features suits the description of the petrochemical value chain that is characterized by its complexity. Moreover the value chain will be used as the basis of a scenario tool. In fact by understanding the petrochemical value chain, the major’s uncertainties will be distinguished. These uncertainties will the basis of the scenarios narratives that will be confronted to participants during two workshops.

The following chapter defines the polyolefin value chain, it will figure as the basis for the uncertainties identification. Moreover, the uncertainties of each block of the value chain are identified and described.

5.1  Defining the petrochemical value chain

The value chain sets out with two types of raw materials: either shale gas or crude oil. The first stage involves either a separation plant that makes it possible to extract valuable gases such as ethane propane, butane or pentane to be fed into the ethane cracker. The other alternative is to first refine the crude oil to generate naphtha. The latter is then fed into a naphtha cracker. The cracking process generates olefins. These chemical compounds are then fed into polymerization plants that produce polyolefin’s. The final stage consists of transforming the polymers by plastics converters into daily used or industrial plastics final products. The following figure exhibits the overall petrochemical value chain.
Based on figure 13, the value chain of the polyolefin’s industry can be presented in a more simplistic flowchart of the polyolefin value chain:

Figure 14: Value chain of the Polyolefin

Next to the petrochemical routes for the production of polyolefin, an additional bio based production route exists and is attracting more and more attention. This route involves biomass as raw material. Further the biomass is processed through a catalytic dehydration. This generates bio-ethylene, an olefin which is identical to petrochemical ethylene. The olefins can then be further processed into polyethylene. The latter is at the basis of bio-plastics [23].

The next part of the thesis explains the relation between shale gas and the petrochemical industry followed by the description of the petrochemical value chain.

The petrochemical industry is an industry that is based on either a crude oil based production or a gas based production. Figure 15 presents two routes: the oil based route or the gas based route. One
important aspect of distinguishing the routes are the ratio of petrochemical produced from different feedstocks. On one hand, based on an ethane cracker, almost 80% of the production is ethylene. On the other hand, based on a naphtha cracker, almost 35% of the production is ethylene. Moreover, the propylene ratio is very low for an ethane based cracker. In contrast, in the presence of a naphtha based cracker, almost 20% of the production will be propylene. The latter will could be considered as a main advantage for choosing naphtha as the main cracker feedstock.

Figure 15: Petrochemicals generated by two types of routes (Oil and gas based) [4]

In order to investigate and analyze the impact of shale gas developments, the overall petrochemical value chain was selected as main unit of analysis. Based on the petrochemical value chain, the uncertainties defined in the scope of research will be identified.

The thesis presents in figure 16 the polyolefin value chain. This value chain approach system subdivides the large scale system in subsystems defined as blocks. This is done to simplify and understand the complexity of the polyolefin value chain and to give boundaries to the system. Moreover, based on the division of the petrochemical value chain in specific blocks, uncertainties triggered by shale gas developments can be identified. This approach should provide the relevant information for the identification of technology development in the petrochemical value chain as a result of the uncertainties
triggered by shale gas developments. The following figure presents the boundaries and blocks of the value chain:

![Figure 16: Boundaries and blocks of the petrochemical value chain](image)

The value chain involves the following stages:

| Block 1 | • Refining  
|         | • Gas separation |
| Block 2 | • Cracking process |
| Block 3 | • Polyolefin productions |
| Block 4 | • Plastics manufacturing |
| Block 5 | • Plastics consumption |
**Block 1**: The red area presented in figure 16 represents block 1 of the value chain. It involves two chemical processes: Refining and gas separation.

**Block 2**: The blue area figure 16 represents block 2 of the value chain. It involves the cracking process. The cracking process is explained in detailed in appendix 4.

**Block 3**: The brown area in figure 16 represents block 3 of the value chain. It involves polyolefin productions.

**Block 4**: The purple area in figure 16 represents block 4 of the value chain. It involves plastics manufacturing.

**Block 5**: The black area in figure 16 represents the plastics consumers.

In order to understand the blocks of the value chain, the state of development of the Technology, the dynamics in development of this technology and the different actors involved in the technology are presented in the following part of the thesis.

### 5.2 State of development and the dynamics in development of this technology

The state of development of the technology involved in each block will be described and it’s dynamic regarding it technological pathway will be discussed.

#### 5.2.1 Block 1

The first step in the polyolefin value chain involves two main chemical processes. One route that transforms shale gas into a mixture of various gases involves gas separation units. The current technologies used are either adsorption, distillation that separate various hydrocarbons (ethane, propane, butane, and pentane) from the shale gas. The alternative to gas separation is membrane separations that use a different separation method involving natural organisms as membranes. The main criteria used to select the appropriate process units are: energy efficiency and yield of gases. The second route that transforms crude oil into naphtha makes use of a refinery. The latter is the industrial plant where crude oil is processed and refined into naphtha. The industrial refining plant involves different chemical process. The important propelling forces behind choosing between the crude based naphtha and shale gas based ethane are raw material prices and geographical proximity of resources.
Technological progress is very present in the refining process. It involves the stimulation of waste management and the reduction of carbon dioxide emission and the improvement of energy efficiency. Technological progress in gas separation plants aims at reducing wastes and improving operations conditions. One important aspect of gas separation plants is safety. As flammable gases are generated, safety regulations are improved continuously and their implementations are closely monitored.

5.2.2 Block 2

The second step in the polyolefin value chain involves a cracking process. This is a very energy consuming chemical process involving either a steam cracker or other types of cracker. Either ethane or naphtha molecules are cracked into olefins such as ethylene and propylene. The selection of a particular feedstock has an effect on the type of cracker. Therefore a technical alternative was introduced: the flexible cracker that can both process ethane and naphtha. The propelling forces behind choosing a type of cracker are the cracker geographical location and the selection of its output products.

Most European crackers are considered as aging facilities. In fact, their average age is 30 years old. This implies that significant investment is needed to readjust and modernize the cracker. As result of the shale gas development, petrochemical companies choose to adapt their naphtha base cracker to a flexible cracker. This gives the company the choice to either select naphtha or ethane according to raw material prices and output products (polyolefin) demand.

5.2.3 Block 3

The third block involves the polymerization process. A petrochemical plant transforms olefins (ethylene and propylene) into polyolefin (polyethylene and polypropylene). Coordination polymerization is the common process for this chemical reaction. The process involves a catalyst that can be either metals chlorides or metal oxides. This catalyst reduces the activation energy of the polymerization reaction and therefore polymer chains are generated. These chains are polyethylene or polypropylene molecules.

The dynamic of development in the polymerization process is characterized by the ability of these plants to produce the highest possible number of different grades of polyolefin. This is conducted because each plastics application requires a specific type of polymer grade. This means that polymerization plants concentrate their production process on more specific grades for specific applications. Niche markets such as luxury packaging or the medical and pharmaceutical industry are growing in Europe. These markets
need specific grades that are not commonly produced. Therefore polymers suppliers tend to adapt their output products range to the highest demand market where profitability is high.

5.2.4 Block 4

Block 4 in the value chain involves polymers converter and transformers. Common processes that generate plastics material are extrusion, thermoforming or compounding. Moreover, plastics converters select machines that are more and more energy efficient and are able to process the material in a more and more cost efficient way. Block 4 represents the main stage of interest. In fact Vinmar as a polyolefins distribution company is part of this block. Therefore, the focus will lie on the uncertainties triggered by shale gas on this part of the value chain.

Polymers converters are facing a challenging choice in their polyolefin selection. In fact, besides prime material which is produced by major petrochemical suppliers, the converters can also choose from recycled material or the so “off grade”. The last two represent a new dynamic in the polymers converters sector. This is the result of high prices of prime material and the competitiveness of off grade and recycled material.

5.2.5 Block 5

The last step in the value chain is the plastics consumption by end users. These include packaging consumers for example. The consumption of plastics can be translated in the added value of plastics products such as irrigation pipes that is a major tool in the agriculture sector or packaging that has a added value in the conservation of food products.

5.2.6 Stakeholder’s analysis

The following part of the thesis entails a stakeholder’s analysis. In fact, many different actors are involved petrochemical value chain affected by shale gas developments. Having to cope with numerous uncertainties, these actors will place themselves in the public debate. The following figure presents the main actors:
Following, the main actors in the petrochemical value chain are defined and examples are given:

**Petrochemical suppliers:** These include petrochemical production companies that own petrochemical assets. These assets can be crackers, refineries, gas separation installations of polymerization plants. All these assets are part of the overall petrochemical value chain. LyondellBasell is an example of a petrochemical company.

**Refineries:** refineries are the industrial plants that process the crude oil or natural gas into chemical compounds that are further processed. An example is Shell. Refineries are at the heart of the technological debate of shale gas as the refining sites in Europe are not familiar with shale gas based production.

**Gas separation plants:** gas separation plants are industrial sites that separate gases. This is done to select the appropriate gas for the production of petrochemicals. An example is an NGL separator.

**End users:** end users are the consumers of plastics products. They make use of the advantages of packaging or irrigation plastics pipes. This group incorporates all plastics consumers. End users closely follow the shale gas debate and are concerned about the possible invasion of the American petrochemicals in Europe.

**Petrochemical public organizations:** These include CEFIC, IFRI, and Plastics Europe. These non-profit organizations bring petrochemical companies together through seminars, trainings and exhibitions. Their goal is to create synergy within the industry and stimulate knowledge and network sharing.

**Plastics converters and processors:** These companies represent the last stage of the polyolefin value chain. In fact, these firms purchase the polymers from petrochemical suppliers and distributors to manufacture
final plastics products. These actors are worried about their position in the shale gas debate as they could face prices increase of the raw material. Through organizations and they seek to protect their interests in the industry and wish to be involved in discussion concerning the strategy of the European polyolefin industry.

**Governmental organizations:** this group entails organizations that are not in the value chain but play an important role in the strategies chosen to deal with the uncertainties triggered by shale gas. These organizations are the policy makers that have an impact on the overall strategies of the actors in the value chain. Through programs and governmental financial support, these organizations influence the choices of the actors in the value chain.

### 5.3 Uncertainties identification

As explained in the methodology part of the thesis, uncertainties are identified through the studying of the petrochemical value chain. First, an overall flowchart of the petrochemical value chain is presented. Second, a division in blocks is applied on the value chain to give a clear overview and understanding on how the uncertainties are identified in the chain.

Based on the description of the petrochemical value chain system the following section identifies four types of uncertainties defined in the scope of research in each block of the value chain.

#### 5.3.1 Uncertainties in block 1

In block 1 of the petrochemical value chain, several uncertainties arise due to the shale gas developments. To begin with, one **socio economic uncertainty** is the import of shale gas from the USA. This is the result of the more competitive American petrochemical industry in terms of feedstock’s prices. The European industry might then choose to import the feedstocks from the USA to reduce their production costs. Regarding the **geopolitical uncertainties**, political tensions triggered by geographical interests could affect the shale gas exploration. Moreover, the crude oil price is sensitive to political decisions made by governments and the OPEC organization. Shale gas developments could sharpen these economic uncertainties by influencing the crude oil price set by OPEC.

Regarding the **technological uncertainties**, the shale gas based route is more attractive than the crude oil based route as the natural gas prices are significant lower than the crude oil price. This will have
an effect on separation gas plants that will have to adapt to higher capacity to be able to offer enough olefins for the European polymers demand.

### 5.3.2 Uncertainties in block 2

In block 2, a similar phenomenon might occur. In fact, European petrochemical companies could choose to import ethane feedstock for the European crackers from the USA. This will induce technological uncertainties, such as the rise of flexible cracker and ethane feedstock storage tanks developments. The high financial investments that are needed to convert naphtha and ethane cracker into flexible crackers is a clear uncertainty. In addition to that, a third uncertainty is: the stimulation or not of costal cracker and close inland crackers assets. As coastal cracker can benefit from shale gas imports through their strategic geographical location whereas inland crackers are not attractive for shale gas transport and logistics. Moreover, a trend towards vertical integration is an uncertainty. In fact, petrochemical suppliers could choose to integrate crackers plants with polymerization process facilities in one industrial site. This will be done to reduce costs of transports of feedstocks and secure their products inputs. In addition to that, a geopolitical uncertainty is the delocalization of the European cracker to the USA. This could be the result of a sector that seeks to take advantage of the shale gas phenomenon at its source.

As presented above in the uncertainties identification part of the thesis, the cracker is a main area of focus regarding the uncertainties triggered the shale gas phenomenon. Typical feedstocks used by European crackers are: Naphtha, Ethane, propane and butane. One of the most important uncertainties in the polyolefin value chain is the European cracker. Will it be a cracker running on naphtha or ethane extracted from shale gas? In fact the type of feedstock used has a direct effect on the margin of operational cracker. Figure 18 presents the cracker margins based on the selected feedstocks. It can be noticed that the use of ethane creates the so called “Ethane advantage” as its price is lower than naphtha.
5.3.3 Uncertainties in block 3

In block 3, polymerization industrial sites will cope with the uncertainty of product demand from the plastics industry. In fact, the development of niche markets will represent an increasing part of the overall polymers demand. Polymerization plants in Europe are to face product special grade demand. Regarding the technological uncertainties, investment might have to be done to adapt to a more sophisticated and demanding special grades production. The choice of an ethane, naphtha or flexible cracker is crucial as the output products ratio will be very different. This can imply a shortage of certain products such as propylene that have a low output ratios in the case of an ethane cracker [4]. This uncertainty could stimulate petrochemical firms to invest in “on purpose” polymerization plant that process one particular olefins to compensate the shortage created by shale gas developments.

5.3.4 Uncertainties in block 4

In block 4, an important socioeconomic uncertainty is the import of polymers from the USA. This will put the European polymers converters at disadvantage. Moreover a second uncertainty that is present as a
result of the shale gas advantage of the American petrochemical industry is the closure of plastics converter and so the loss of wealth and increase in European unemployment rate. This could mean a decrease or stagnation in economic growth.

5.3.5 Uncertainties in block 5

In block 5, the sustainable and environmental friendly production of bio plastics is a major topic for plastics consumers. In fact, consumers pay more and more attention to biomass that can be used as a natural resources to generate bio-ethylene. The latter is then converted into polyethylene. A major uncertainty in this process is the availability of biomass and its normal use for food or other food related application. Therefore, the use of biomass for the production of polymers could have an impact of food availability and prices.

To sum up, the description and analysis of the value chain has brought to attention the major uncertainties triggered by shale gas on the petrochemical value chain. The technological uncertainties are dominated by the cracker. In fact the question is raised if Europe will see its flexible cracker amount increase. The cracker that can produce ethylene and propylene based on gas or crude oil is at the heart of the shale gas phenomenon. The geopolitical uncertainties are dominated by the impact of increasing prices that could give the USA a geostrategic significance in the European petrochemical landscape. Finally the environmental uncertainties are dominated by the risks of shale gas exploration that has not yet been accepted by European government. Will the European policy maker have to adapt their oil gas exploration process to the shale gas developments? We can conclude that the geopolitical uncertainties are the most represented in the petrochemical value chain. In fact every actors in the value chain will be confronted with the economic effects of higher polymer prices and an increasing political influence of the American petrochemical industry. The geopolitical advantage of the American industry with their shale gas based production of petrochemicals could significantly impact the European actors. In appendix 1 a table is presented with a different type of categorization of the uncertainties. In fact, medium, low and high impact uncertainties are distinguished to emphasize the degree of which the uncertainty has an impact.

The next chapter of the thesis presents the current existing strategies on the impact of shale gas on the European petrochemical industry. These current strategies are presented and described based on consultancy reports, interviews and published reports.
6 Current existing strategies on shale gas and its impact on the European petrochemical sector

The following part of the report exhibits a review on reports and press releases published that focus on shale gas and its impact on the European chemical and petrochemical sectors. As the research topic is still discussed in current news, not many scientific papers have yet been published. Nevertheless, consultancy and news reports are available. In order to address the reaction of the European petrochemical industry on the shale gas phenomenon, it is important to understand the current existing strategies that have been presented in recent literature and press release. The following part of the report presents the main reports that have been published to this date. These reports have been collected through Google search and are based on the advice of the account managers of Vinmar, the executive of LYB and my own perception. These reports have been chosen because they reflect the most updated vision of the industry on the shale gas phenomenon. Moreover, different institutes have conducted the research which guarantees a certain objectivity of the analysis.

6.1 Interviews results

The following section presents a summary of the interviews conducted with four executives of two petrochemical companies named LyondellBasell and INEOS. These interviews reflect existing strategies and opinions on the shale gas phenomena in Europe.

Paul Turner is the Vice president of Polyolefin Europe. He is responsible for the Sales of Polyolefin in Europe through direct and indirect channels. He points out the following: matching supply and demand from all the assets of LYB and the plastics converters is a big challenge. His opinion on shale gas is clear; LYB is and remains a supporter of shale gas developments. LYB USA has already begun investing in new assets that will produce polymers based on shale gas feedstocks. In Europe, Paul Tuner expresses its concern on how European institutions will create a new framework that will help companies to invest and take advantage on the shale gas effects. No clear actions or strategy have been laid out yet by the European commission to absorb the shale gas effects.
Dick Stolwijk is the manager of Planning & Strategy for LYB. He is responsible for monitoring the production planning of the assets to meet the requirements of the sales targets. Dick Stolwijk focused his answers on the impact of shale gas on the production capacities and output. In fact if a new feedstock would be introduced in the assets of LYB in Europe, the crackers would need to be adapted and so the production schemes and flowchart. As a manager, he would have the responsibility to create a new framework that can absorb the production effects of new feedstocks.

Dominico Gigliobianco is the marketing manager of PE in Europe. He is responsible for the sales of PE. His opinions on shale gas are straightforward: he is supporter of shale gas but in a controlled manner. As a matter of fact, LYB should only consider taking advantage on its own production facilities in the USA. This would imply LYB importing its own polymers (PE) from the USA to avoid high feedstock costs in Europe.

The INEOS representative whose name cannot be disclosed represents a petrochemical company that is a pioneer in the European shale gas developments. In fact, INEOS decided to build infrastructure to import shale gas from the USA and has made significant investment in securing shale gas supply form the USA. The representative of INEOS was interviewed during a Vinmar academy. His speech was a very Pro-shale gas. No companies can miss out on the shale gas opportunity was his opinion. INEOS has invested and will keep investing in new LNG terminals to clear out the handicap of inland cracker and stimulate flexible crackers which can run on ethane extracted from shale gas.

From the interview results presented above we can see that no clear action has yet been taken in Europe to react to the shale gas effects and to prevent any market instability. In particular in the polymer sector, current actions are not enough to create awareness or simply to inform the actors on the future landscape of the European plastics industry. A lack of knowledge sharing has been noticed. The only interview that has underlined the clear action taken is the INEOS representative that points out the development of LNG terminals and flexible/coastal crackers to facilitate the import of shale gas feedstocks.
6.2 Consultancy reports

A report published by consultancy firm Deloitte entitled: “The shale gas revolution and its impact on the chemical industry in the Netherlands” represents the Dutch VNCI vision 2030-2050 focusing on the long term prospect of the chemical sector in the Netherlands [4]. This report presents courses of actions as a result of the USA shale gas phenomenon. The report envisions the future of the Dutch chemical industry for 2030-2050. Both organizations VNCI and Deloitte have assessed the potential impact of the shale gas revolution on the Dutch chemical industry. Moreover, the report presents the course of actions that could be undertaken by the Dutch government to take advantage of the emergence of US shale gas [4]. The report concludes that the emergence of US shale gas which has inducted very attractive gas prices will impact the ethylene production. The latter will have an effect on the Dutch chemical industry employment and hundreds of thousand jobs will be at risk [4]. This will induce an impact on the whole Dutch economy as a whole.

The report presents two major mitigating factors to prevent the above mentioned effects; a combination of higher global demand and a restrained capacity expansion in China and Middle East. The second factor would be a drop in European naphtha to US ethane prices. The latter will mitigate a part of the European disadvantage in the production of petrochemicals. Finally the report provides remarks that the Dutch chemical sector should set strategic objectives in order to prepare itself and act in this new shale gas context. In addition to that, the authors recommend a policy development that includes tax deductions and subsidies for European petrochemical suppliers to make their transition to shale gas developments possible.

6.3 Public organization reports

In the European petrochemical sector in particular in the polyolefin industry the following major organizations play an important and active role:

- EPCA (European petrochemical association)
- CEFIC (European chemical industry council)
- IFRI (Institut français des relations internationales)
- PE (Plastics Europe)
• Price/information reporting agencies (Platts, ICIS)

The organizations presented above have published reports regarding the impact of shale gas on the European industry. To begin with, the CEFIC (European chemical industry council) position paper entitled: “The implications of the shale gas revolution for the European chemical industry” [1] published in March 2013 presents several key messages and recommendations. These include a warning that if Europe delays its strategies regarding shale gas developments, the continent will increase dependence on imports and a reduction in investments in European petrochemical assets which will lead to reduction in employment and less overall economic growth [1]. Therefore, CEFIC recommends starting the exploration and the production of shale gas resources. Moreover, it recommends to intensify the flow of LNG and NGL’s into Europe. These can be alternative feedstock for the European petrochemical production facilities.

The IFRI (Institut Francais des relations internationals) report entitled “The impact of the development of shale gas in the united states on Europe’s petrochemical industries” published in November 2013. The report first presents the competitive advantage of the USA petrochemical industry due to the shale gas phenomenon. This effect makes itself felt downstream in the sector [1]. The warning for a “made in America” petrochemical invasion that is expected in 2016-2017 is emphasized in the report. Moreover, the worldwide petrochemical competition will see its dynamics change as Europe petrochemical will not benefit from low costs raw material: shale gas. This implies according to the IFRI that Europe’s petrochemical sector faces restructuring and rationalization of its production assets [1]. Moreover, the report recommends diversification and redirection to high demand products such as innovative products and bio plastics. The latter is part of the transition to a sustainable bio based economy envisioned by many actors and European governments.

Moreover, as the topic of research attracted significant political attention in Europe, media releases have been published. Various websites and newspaper have published these articles. Europe plastics have published the article entitled: “Ratcliffe: Europe must go for shale gas” [3]. The central question in the press releases is: Can shale gas save the European petrochemical industry? The question is raised on how Europe can take advantage of the shale gas phenomenon. Some argue that if Europe does not decide to explore its own sources it will have to cope with a declining petrochemical industry that might vanish. These opinions reflect on the sense of urgency the media want to emphasize.

The following part of the chapter presents the currents strategies of the European petrochemical industry and distinguish the four types of strategies.
6.4 Current strategies

In order to understand the current strategies of the European petrochemical industry, companies and organization have undertaken particular actions. Figure 19 presents the existing strategies that have been proposed in consultancy reports to ensure a sustainable European petrochemical industry that can remain competitive in a context of the shale gas phenomenon rising from the USA [4, 5, 6 and 17].

<table>
<thead>
<tr>
<th>Socio economic strategies</th>
<th>Technological strategies</th>
<th>Geopolitical strategies</th>
<th>Environmental strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs reductions closure of sites integration of refining and cracking diversification of raw material</td>
<td>Integrating through to the end client and the development of chemical users</td>
<td>Investment in growth region</td>
<td>Innovations and sustainable development</td>
</tr>
<tr>
<td>Reinforce structural barriers to imports (duties and tariffs rates put in place in order to protect European market)</td>
<td>Develop chemical clusters, synergies</td>
<td>Improve the image of the European petrochemical industry (communicate its contributions, quality of life, provider of solutions)</td>
<td>Providing solution to their customers for sustainable solutions that respect the environment</td>
</tr>
<tr>
<td></td>
<td>Repositioning in innovative and differentiated niche products with value added</td>
<td>Seek greater support from European policy makers (European commission and national policy makers)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Green plastics resins or elastomers</td>
<td>Develop more coastal crackers for ethane imports</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stimulate integrated petrochemical manufacturing clusters (ex: Antwerp, Rotterdam…): there is a value to be gained from integration</td>
<td>Risk of underinvestment and cluster disintegration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase consumption of advantaged feedstock’s (liquefied petroleum gas, ethane from shale gas)</td>
<td>Trans European olefins network pipeline that could consolidate the European monomers availability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>On purpose propylene plants using propane dehydrogenation</td>
<td>Consolidation phase to be continued already undergoing since 20 years</td>
<td></td>
</tr>
</tbody>
</table>

Figure 19: Four types of European strategies proposed in order to cope with shale gas developments [6]

These strategies can be divided into four categories. First, the socio economic categories which imply the undertaken costs reduction in the industry. This can illustrated by the closures of numerous petrochemical sites in Europe [4] or the reinforcements of trade’s barriers. These include the import duties
put in place for import from the USA. Secondly, the technological strategies that include the integration of petrochemical processes and the development of niche products with high added value. Thirdly, several geopolitical actions have been proposed including the improvement of the image of the industry and the investment in several pan European petrochemical projects. Finally, several environmental propositions have been made such as the stimulation of biopolymers in order to contribute to sustainable development in the overall industry.

The following table presents for every uncertainty why the existing strategies are insufficient to deal with every specific uncertainties.

<table>
<thead>
<tr>
<th>Socio-economic uncertainties</th>
<th>Technological uncertainties</th>
<th>Geopolitical uncertainties</th>
<th>Environmental uncertainties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategies such as cost reductions do not take into account a possible economic crisis or a war that could endorse a new economic context.</td>
<td>Strategies such as the integration of petrochemical complexes or the developments of green plastics are insufficient to deal with a possible huge drop in oil prices where these projects are not viable any more.</td>
<td>Strategies to seek greater support from European institutions will not be sufficient to deal with the geopolitical uncertainties where decision are made on an international level. European institution are too often too divided in their strategies to deal with the geopolitical uncertainties as national interest prevail above European interest.</td>
<td>Strategies to seek for environmental friendly solutions can endanger the position of oil/gas firms that will protect their interests.</td>
</tr>
</tbody>
</table>

Table 2: Why existing strategies are insufficient to deal with the four uncertainties

Based on the interview results presented in part 6.1 and table 2 we can conclude that the existing strategies contain risks and shortcomings. One example of a risk is the oil price volatility or the international sensitive context in which petrochemical companies have to operate in. This risk is not taken
into consideration when applying the current strategies. Based on the uncertainties stated above we can observe that no radical changes or unexpected events are taken into account in the analysis. In any case the decision making space of actors needs to be expanded through scenarios workshops.

The following chapter presents the scenarios that be used in the scenarios workshops.
7 The scenarios

The following chapter formulates three exploratory scenarios that form the basis of the workshops. In fact facing the above developed uncertainties, the European petrochemical industry might have to prepare itself for different scenarios that could unfold as a result of the shale gas phenomenon initiated in the USA. We have chosen three extreme situations in which the industry might be confronted with if shale gas developments run out of control. For every uncertainty, one specific scenario is chosen. We can notice that no scenario is presented based on technological uncertainties. In fact we decided to focus on external events, whereas technology is something that can be controlled to some extent by the plastics industry itself. The decision to adapt the processing technology such as crackers to shale gas is under control of the petrochemical companies themselves. The first scenario chosen which is based on geopolitical uncertainty was selected because it is the most extreme event that could destabilize the industry as a whole. Saudi Arabia is the most sensitive geopolitical area in the Middle East and represents a turning point if its internal geopolitical situation would change as a result of a war. Based on the socio economic uncertainties, a boom in shale gas is chosen as a second scenario. It represents an out of control event that involves a boom in shale gas developments. The third scenario is based on the environmental uncertainties. The bio plastics boom has attracted a significant attention from European policy maker to achieve the zero carbon objectives. The following table sums up the three scenarios corresponding to each uncertainty:

<table>
<thead>
<tr>
<th>Geopolitical uncertainties</th>
<th>Socio economic uncertainties</th>
<th>Environmental uncertainties</th>
</tr>
</thead>
<tbody>
<tr>
<td>War in the Middle East (Saudi Arabia)</td>
<td>Boom of shale gas from USA</td>
<td>Shale gas boom to Bio-plastics boom</td>
</tr>
</tbody>
</table>

*Table 3: Three scenarios selected based on three types of uncertainties.*
7.1 Scenario 1: War in Middle East spreading to Saudi Arabia

The first scenario involves a war in the Middle East spreading to Saudi Arabia which is the biggest oil producing country in the world. This can have significant consequences on the petrochemical industry. This first scenario could be considered as a major event that could influence the strategic position of shale gas in the European petrochemical industry. A war in the Middle East has been chosen because it illustrates a radical geopolitical change in the industry. No companies or organizations seem to be prepared for such events to occur.

7.2 Scenario 2: Boom of shale gas from USA

The second scenario is characterized by an extreme boom of shale gas in the USA. As a result shale gas would be the only petrochemical feedstock available for supplying production sites. Its boom is translated into a massive import of shale gas into Europe from the USA the latter could trigger a complete shift from oil based production to shale gas production of petrochemicals. This scenario could have unforeseen technological consequences to all actors in the value chain.

7.3 Scenario 3: From shale gas boom to Bio plastics boom

The third scenario is characterized by a bio plastics boom. Bio plastics are considered a possible substitution to conventional plastics. These products could play a key role as a result of shale gas developments. Existing strategies often neglect the position of bio plastics and give them minor importance their positive environmental aspect is one of their main advantage to the industry and public.

7.4 Workshops

Based on the analysis of consultancy reports and press releases and the interviews conducted with actors in the European petrochemical industry we concluded that actors tend to react to the shale gas phenomenon on the basis of two dominant ways of thinking (Chapter 6). In addition to that, the current
strategies of the actors in the European petrochemical industry are characterized by a lack of awareness of, and insight into radical changes. In fact companies and organizations have announced their strategies on current shale gas effects but it seems that the industry is not prepared for unexpected changes that could occur as an effect of these developments. The interviews presented in Appendix 2 reveal that the actors are not well prepared for radical changes as a result of shale gas effects. The workshops confronted the actors with radical changes, as exemplified by the above explained scenarios, to see whether this would enlarge their decision space.

The workshop had different rounds that included different uncertainties categories. These rounds were based on the three scenarios presented above in which the actors react on these unexpected radical changes. Finally, actors reflected on the way they experienced the workshop.

The participants of the two workshops are the employees of Vinmar and TBM students. Each participant was assigned to play the role of a particular stakeholder. The actors represented in the workshops are the following:

- LyondellBasell: a petrochemical producer
- Hyplast: a plastics converter
- Plastics Europe: a European plastics organization representing European converters
- Total SA: an Oil and gas refining company

Regarding anonymity, every participant agreed his or her only fist name could be used in the workshops outcomes. No last names can be used that could reveal a full identity of the participant.

7.5 Workshop 1: From inside the industry

The main aim of the first workshop was to trigger reactions from participants from inside the industry and confront them with radical changes in the industry as a result of shale gas. By confronting the participants with several scenarios that describe possible futures that cover every part of the value chain insight is created the plastics industry could pre-empt on the uncertainties in the value chain. The latter could result in expanding the scope of possible alternatives that are taken into consideration in its strategic decision making.

In appendix 7, the workshop structure is presented. Along this presentation, the role play is explained. In fact every employee of Vinmar represents one actor in the petrochemical value chain. These
specific roles have been chosen to represent the entire value chain and get insight in how employees within Vinmar react on the scenarios. As the workshop was interactive, the most predominant ideas and propositions were selected as reaction to the three scenarios. The following part of the chapter presents the reactions of the actors that participated in the workshop to the scenarios in addition to the description in appendix 7.

**Scenario 1:**

Scenario 1 entails a war in Saudi Arabia, one of the world’s largest oil producing countries. The first reaction of LYB played by participant Adis was that it will have to expand its supplier portfolio because its crude oil input will be affected by the war. Further, the firm is worried about its production in Europe. They might not be able to offer the same products to their customers. It might have to put a hold on specific products produced with feedstock’s coming from Saudi Arabia. Plastics Europe played by participant Edoardo S stated that they will have to ease the tension of European converters that might be worried about an increase in price and an uncertain availability of products. Moreover, Plastics Europe will start lobbying to accelerate shale gas projects to be less dependent on oil from SA. Total SA played by participant Edoardo Z stated that it is necessary to expand its cooperation with integrated petrochemicals companies to secure their feedstocks. Total SA will start to explore new alternatives sources for the production of olefins. Hyplast is worried about its supply of raw material produced in Saudi Arabia as it will not accept a stop or lack of supply even if this war in SA occurs.

**Scenario 2:**

Scenario 2 entails a Boom of shale gas from USA. LYB played by Adis will not remain blind to the shale gas phenomenon and will invest in the shale gas project to secure its distribution volume. PE played by Edoardo S will seek to create an alliance with organization in the USA in order to find ways to create awareness on how shale gas will impact the industry. Hyplast played by participant Olivier states that it will prepare a plan to assure supply from the USA if shale gas will result in lower polymers prices.

**Scenario 3:**

Scenario 3 involves a shale gas boom to a Bio plastics boom. LYB played by Adis states that it will explore the bio plastics market. This would involve convincing customers to test Bio plastics instead of polymers. Moreover, he wants to create awareness to converters by explaining the advantages of bioplastics. PE played by Edoardo S insists to incorporate shale gas in its annual plan to be able to convince the converter
of its advantages. Hyplast played by participant Olivier is worried about the difference in processing of the bio plastics raw material and its increasing price compared to plastics.

7.6 Workshop 2: From outside the industry

The main purpose of the second workshop is to trigger reactions from participants from outside the industry. For this so called “external WS”, the actors were from outside the industry. By confronting these external actors with several scenarios that describe possible futures of that cover every part of the value chain insight is created the plastics industry could pre-empt on the uncertainties in the value chain. The latter could result in expanding the scope of possible alternatives that are taken into consideration in strategic decision making. As all participants are external actors in this industry, the workshop focuses on primary reactions involving less technological uncertainties on the topic but more social and geopolitical uncertainties.

In appendix 7, the structure of workshop 2 is presented. The second workshop included students who were not experts in the field. Thus the reactions should be placed in a broader context and not be linked to their positions within Vinmar. The participants received instructions and literature before the workshop.

Scenario 1:

The scenario 1 is represented by a war in Saudi Arabia, one of the world’s largest oil producing country. The first reaction of Lyondellbasell played by George, was to minimize the dependence on Saudi Arabia. In fact he considers shale gas as an alternative to mitigate the risks of their current operation in Saudi Arabia. Moreover this event will force LYB to invest in unconventional resources, restructure current investments planning. For Plastics Europe played by Rania/Stefania, this event will stimulate the developments of a common European framework to enhance sustainability. Moreover the necessity will rise to create strategic alliances with companies in the USA. Regarding Total SA who was played by participant Dimitra, the priority lies in the search for resources that are economically viable. If the war in SA was to start, oil price could increase so the company will for new investments in other parts of the world. The position of Hyplast played by participant Fiorella toward this scenarios is the following; they are very worried about the consequences on their raw material supply. Moreover the prices will increase as a result of the increasing oil price.
**Scenario 2:**

The scenario 2 is represented by Boom of shale gas from USA. Lyondellbasell played by participant George sates that the trends and technological innovations can be transmitted from the USA to Europe. The company will prepare itself to operate shale gas based facilities in both continent. Finally, LYB is seeking to take advantage of shale gas before competitors do. Plastics Europe played by participant Rania/Stefania proposed to create strategic alliances with USA to be a part of the shale gas boom. Moreover, plastics Europe will take up the role of convincing other actors of the advantage of shale gas. Regarding Total played by participant Dimitra, the company will explore more shale gas. It states that Europe should not rely on importing shale gas but develop its production on the continent. Finally, it states that the EU should support shale gas exploration. The last actor, Hyplast played by Fiorella is very worried about the consequences on its raw material supply and the prices of European material compared to the material from the USA.

**Scenario 3:**

The scenario 3 can be described as: “From shale gas boom to Bio plastics boom”. Lyondellbasell played by George states that the bio-economy is not developed enough to have a significant impact. Moreover, the petrochemical companies are waiting if companies are willing to invest in bio-based products. The bioplastics path still involves many uncertainties. Plastics Europe played by Rania/Stefania reacts by stating it will contribute to a strategic European plan to stimulate bio plastics. It considers the transition from shale gas to bio-plastics a positive development. Total played by Dimitra states that it is not an ideal scenario. But if it were to become a reality, the firm would start to invest in the production of niche products and highly innovative products. Finally, Hyplast played by Fiorella would be worried about the costs it would endure bio-plastics becomes predominant. Moreover, the firm has no guaranty its customer are willing to commute to bio-plastics.
8 Analysis of workshops

The following chapter analyses whether the scenarios workshops have been able to broaden the decision making space of the participants of the workshops. It starts with the overall analysis of the identification of the strategies based on the methodology presented in part 3.4. The second part deals with the possible learning process triggered by the indicators explained in part 3.4. Finally the differences between the two workshops are presented.

8.1 Overall analysis

Based on existing reports and interviews presented in chapter 6, a series of current strategies have been distinguished in figure 19 to deal with the uncertainties triggered by the shale gas developments. These strategies presented below are divided in four categories: socio economic, technological, geopolitical and environmental strategies.

![Figure 19: Four types of European strategies proposed in order to cope with shale gas developments [6]](image_url)
As explained in part 3.4 this thesis seeks to find out if new strategies have emerged during the scenarios workshops. Indeed, decision-making space can be considered as broadened if the participants develop new strategies regarding the impact of shale gas developments on the European petrochemical industry. The following part of the thesis presents the strategies proposed by the participants during the workshops and compares these to the existing strategies presented in figure 19. The strategies of the participants are regrouped in the three categories that cover the three types of uncertainties (socio economic, technological, geopolitical and environmental).

8.1.1 Socio economic strategies proposed by participants

Based on the information collected from the reactions of the participants presented in paragraph 7.5 and 7.6 and appendix 6, the following table presents the socio economic strategies proposed by the participants during the two workshops.

<table>
<thead>
<tr>
<th>Workshop 1</th>
<th>Workshop 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Expand suppliers portfolio Sc 1</td>
<td>• Restructure current petrochemical investments Sc 2</td>
</tr>
<tr>
<td>• Ease the tension and worries of converters: debates sessions Sc1</td>
<td>• Stabilize prices and supply to plastics converters: Increase local production Sc 2</td>
</tr>
<tr>
<td>• Secure the raw material supply of converters Sc1</td>
<td></td>
</tr>
<tr>
<td>• Do not delocalize companies from Europe Sc2</td>
<td></td>
</tr>
<tr>
<td>• Try to mitigate the risks of shale gas Sc2</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: Socio economic strategies proposed by the participants*

Regarding the socio economic strategies in workshop 1, participant Adis confronted to Scenario 1 proposed to expand the portfolio of suppliers. This was followed by another participant Edoardo S that suggested to ease the tension and worries caused by shale gas. This could be done by organizing debates sessions and/or by securing raw material supply of converters. Another strategy suggested by participant Edoardo Z is to not delocalize companies from Europe as result of shale gas developments but try to mitigate the risks.

In workshop 2, two strategies were proposed by participants: first participant George proposed to restructure the current investment of petrochemical assets according to the shale gas developments. The
second proposition came from Fiorella who proposed to stabilize prices and supply of raw material to converters by increasing local production.

The question arises: are the strategies proposed new strategies or the same or even variation of the current strategies? This is discuss in the paragraph below.

It can noticed that several variation of current strategies presented in figure 19 have been proposed. First, the restructuring of petrochemical assets could be compared to the introduction of coastal crackers or a trans-European olefins network. Secondly, the easing of the tension and worries of converters by securing the raw material supply and avoiding the delocalization of companies in Europe can be compared to the existing strategy formulated as improving the image of the European petrochemical industry. Finally, the strategy of prices stabilization and increase of local production can be compared to the reinforcement of structural barriers to protect the European petrochemical industry. To sum up, no new socio economic strategies have been detected during the workshops.
8.1.2 Technological strategies proposed by participants

Based on the information collected from the reactions of the participants presented in paragraph 7.5 and 7.6 and appendix 6, the following table presents the technological strategies proposed by the participants during the two workshops.

<table>
<thead>
<tr>
<th>Workshop 1</th>
<th>Workshop 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Expand cooperation with integrated petrochemical assets Sc 1</td>
<td>• Transfer technological innovation/trend from USA to Europe Sc 2</td>
</tr>
<tr>
<td>• Explore new alternatives sources for olefins productions Sc 3</td>
<td>• Take the first mover advantage and invest in new production assets Sc 2</td>
</tr>
<tr>
<td>• Explore the technological implication of bio plastics production Sc 3</td>
<td>• Explore more shale gas opportunities</td>
</tr>
<tr>
<td>• Construct ethylene/ethane tanks for USA imports Sc 2</td>
<td>• Invest in R&amp;D for specialty polymers Sc 3</td>
</tr>
<tr>
<td>• Expand from commodities production to niche products production Sc 2</td>
<td></td>
</tr>
<tr>
<td>• Adapt the production scale of current assets and increase their scale Sc 2</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Technological strategies proposed by the participants

Regarding the technological strategies in workshop 1, participant Patrick confronted to scenario 1 proposed to expand the cooperation with integrated petrochemical assets to be fully independent on crude oil or olefins resources. Moreover, the same participant proposed to explore new alternatives sources for olefins production. This adds up to the strategy of constructing ethylene and ethane tanks in Europe to be able to stock imports from the USA another strategy and to expand the production scale of European assets and focus on niche products where the global competition is limited.

In workshop 2, the first strategy proposed by one participant George confronted to scenario 1 is to transfer technological innovations and trend from the USA to Europe. Moreover, it was suggested by participant Stefania to take to first mover advantage of shale gas developments by adapting to production assets in Europe. Another strategies is described as: investing in R&D department to develop more specialty polymers.
It can be noticed that here again several variations of current strategies have been proposed. The expansion of the cooperation of integrated petrochemical assets including the construction ethylene or ethane tanks and adapting the production scale by expanding the production from commodities to niche products are variation of the exiting strategy of restructuring the petrochemical assets and repositioning the production to more innovative products. Furthermore the exploration of the technological implications of bio plastics and new alternatives for olefins production can be described as similar to the existing strategy of providing sustainable solution that respect the environment.

However, one new strategy was detected: the transfer of technological innovations and trends from USA to Europe. This strategy is not mentioned in figure 19 and therefore can described as a new insight developed by the participants.

### 8.1.3 Geopolitical strategies proposed by participants

Based on the information collected from the reactions of the participants presented in paragraph 7.5 and 7.6 and appendix 6, the following table presents the geopolitical strategies proposed by the participants during the two workshops.

<table>
<thead>
<tr>
<th>Workshop 1</th>
<th>Workshop 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lobby for more shale gas opportunities within Europe Sc 2</td>
<td>• Minimize crude oil supply dependency on Saudi Arabia Sc 1</td>
</tr>
<tr>
<td>• Create strategic alliances with organization in the USA Sc2</td>
<td>• Create shale gas departments at European ministries levels Sc 2</td>
</tr>
</tbody>
</table>

*Table 6: Geopolitical strategies proposed by the participants*

Regarding the geopolitical strategies in workshop 1, participant Olivier suggest to lobby for more shale gas opportunities in Europe. Moreover Edoardo Z suggested to create strategic alliances with organization in the USA to take advantage of their knowledge and influence.

In workshop 2, participant George confronted to scenario 1 proposed to minimize the supply dependency on oil producing country: Saudi Arabia. Moreover, participants Stefania and Rania propose to create shale gas departments at European ministries levels to implement concrete political measures to protect the European petrochemical industry.
It can be noticed that several strategies that are variation of existing ones. Lobbying for more shale gas opportunities or asking for more governmental support van be compared to the request of more support of European policy makers as presented in figure 19.

Two new strategies have been proposed. The first one is the creation of strategic alliances with organizations in the USA to better understand the sale gas developments. The second new strategy would be to reduce supply dependency from Saudi Arabia, one of the world largest oil producing country.

8.1.4 Environmental strategies proposed by participants

Based on the information collected from the reactions of the participants presented in paragraph 7.5 and 7.6 and appendix 6, the following table presents the environmental strategies proposed by the participants during the two workshops.

<table>
<thead>
<tr>
<th>Workshop 1</th>
<th>Workshop 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Accelerate the testing phase of bio plastics for plastics converters Sc 3</td>
<td>• Stimulate a common European regulation framework regarding bio plastics Sc 1</td>
</tr>
<tr>
<td>• Create awareness among converters on advantages of bio plastics Sc 3</td>
<td>• Enhance sustainability measure for petrochemical companies Sc 2</td>
</tr>
<tr>
<td></td>
<td>• Develop thee bio economy to reach more bio plastics end users Sc 2</td>
</tr>
</tbody>
</table>

*Table 7: Environmental strategies proposed by the participants*

Regarding the environmental strategies in workshop 1, participant Olivier proposed to accelerate the testing phase of bio plastics to be sure these new products can be used at an industrial scale. Moreover, he suggests to create awareness among plastics converters regarding the advantages of processing bio plastics.

In workshop 2, the participants Stefani and Rania proposed to develop a common European regulation framework regarding the use of Bio plastics by end users. The next measure proposed by Fiorella would be to enhance sustainability measure in the petrochemical industry. The last strategy proposed by Dimitra entails the continuation of developing the bio economy to be able to reach more and more bio plastics end users.
It can be noticed that all the strategies proposed by participants are variations of the existing strategies. The creation of awareness among converters of the advantages of bio plastics and endorse the development of the bio economy by stimulating sustainability measures can be compared to the existing strategies formulated as providing innovation and sustainable solution to the customers and improving the image of the European petrochemical industry. The stimulation of a common European regulatory framework can be compared to the support seeking of European policy makers.

8.1.5 Conclusion: New strategies?

Based on the above analysis of the workshops it can be concluded that the majority of the strategies proposed by the participants are similar or variation of the existing strategies. Yet, among the strategies that emerged during the scenarios workshops, two new strategies were identified. The first new strategy entails the transfer of technological innovations and trends by creating strategic alliances between organizations in the USA and Europe. This strategy can be related the technological type of uncertainty. The second new strategy entails the minimization of the crude oil supply dependency on Saudi Arabia. This strategy can be related the geopolitical type of uncertainty. It can be noticed that no new strategies have been proposed related to the socio economic and environmental uncertainties.

The following table summarizes the two new strategies:

<table>
<thead>
<tr>
<th>New strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Proposition of the transfer of technological innovations and trends by creating strategic alliances between organizations in the USA and Europe</td>
</tr>
<tr>
<td>• Minimization of crude oil supply dependency on Saudi Arabia.</td>
</tr>
</tbody>
</table>

Table 8: New strategies proposed by participants of the scenarios workshops

The question now arises: does the emergence of the two new strategies indicate that decision making space of the participants has been broadened?

Based on the framework presented in 3.4 it can concluded that the decision making space has been broadened if we compare the new strategies proposed by the participants to the existing strategies of figure 19. The decision making space has been broadened only to a limited extent as only two new strategies were proposed that each relate to one type of uncertainties. For the other two types of uncertainties, no new strategies have emerged.
However, it must be remarked that it cannot be ascertained that the two ‘new’ strategies were proposed as a result of the exposure to the scenarios introduced during the workshops. Indeed, it cannot be ruled out that these strategies were already part the participants initial strategies before the workshops. This points a weakness on the research method that will be elaborated in chapter 9.

8.2 Indicators of a learning process

Above it is concluded that two new strategies were mentioned during the scenarios workshops. The next section explores whether in addition to these strategies indicators can be found that due to the exposure of the participants to the scenarios reflect a learning process among the participants. When a learning process takes place this might lead to more new strategies in the future and thus an extension of the decision making space. The question is how to identify whether a learning process has taken place. As explained in part 3.4, this will be done by analyzing of the indicators which are the following:

- Change in open attitude towards the shale gas phenomenon
- Change in awareness towards the shale gas phenomenon
- Change in critical opinion towards current strategies

The following section explores whether these indicators have become visible during the scenarios workshops.

8.2.1 Change in open attitude.

The first indicator is the change in ‘open attitude’ towards the shale gas phenomenon. This indicator assesses whether the participants have come to better understand and to familiarize themselves with the shale gas phenomenon due to the exposure to the scenarios workshops.

Based on the feedback of the participants presented in appendix 7, a more open attitude for the shale gas phenomenon has been detected from one participant. Participant George reacts on scenario 2: “In order to understand the sense of urgency of the shale gas developments, I was able to gain more knowledge and insights on the phenomenon through the workshops”.

Other participants emphasised the importance of understanding the shale gas development in general. For instance, participant Patrick mentioned during the workshop: “It is a chance of Europe to wake
up”. And, participant Edoardo Z and Fiorella S remarked: “We need to understand shale gas to be able to react on its effect on the European petrochemical industry“.

These remarks show that the participants consider it is important to understand and take an open attitude towards the shale gas development. However, these remarks do not show whether the participants through the workshops gained a better understanding of the shale gas phenomenon.

To conclude, only the remark of participant George indicates that he himself has gained a better understanding of the shale gas development and that he thus has taken a more open attitude. The other quotes only illustrate that the participants consider important a good understanding of the shale gas development, but do not show as to whether the participants themselves have taken a more open attitude towards the shale gas development then before the workshop.

8.2.2 Change in awareness

The second indicator is the change of ‘awareness’. This indicator assesses whether participants become more aware of the consequences of the shale gas phenomena.

The discussion of the workshops in paragraph 7.5 and 7.6 shows that the participants are aware of the consequences of the shale gas development that are triggered by the three scenarios that were proposed. For instance, as for scenario 1, participant Edoardo Z said “it was very useful to be confronted to scenarios that were not included in any long term strategy of the company”. Participant Stefania remarks: “the shale gas boom will stimulate the development of a common European framework to enhance sustainability”. For scenario 2, insights in the consequences of the shale gas development are, for instance reflected in the quote of participant Rania that said: “my strategic positioning was broadened as I acknowledge the necessity to cooperate with other parties such as the USA to deal with the uncertainties triggered by shale gas” . Moreover participant Dimitra remarks: “Europe should not be dependent on the American shale gas”.

Similarly, the participants showed awareness of the consequences of scenario 3. For instance Edoardo Z pointed out the importance of American petrochemical companies and participant Olivier mentioned the importance of the securing a possible supply of shale gas from the USA.

What can be concluded on the basis of these quotes? In the case of all three scenarios the participants mention possible consequences related to the shale gas development. But, it remains
uncertain as to whether these quotes indicate that the participants have more awareness as to the consequences of the shale gas development than before the workshop. Perhaps, participants were already aware of the potential consequences of the shale gas development to the same extent as during and after the workshop. Thus, based on the scenarios outcomes presented in 7.5 and 7.6 it can be concluded that the participants are aware of the consequences of shale gas developments, but that it is difficult to say whether the participants have become more aware of the potential consequences of the shale gas developments due to the workshops.

8.2.3 Change in critical opinion

The third indicator is the adoption of a more ‘critical opinion’. This indicator assesses the ability of the participants to take a more critical stance towards the current dominant views vis-à-vis the petrochemical development.

Several quotes of participants suggest that they adopt a more critical attitude towards the current strategies. The first remark is made by participant Adis F remarked the following: “current practices of the European petrochemical industry are undermining the importance of the Asian petrochemical industry that could be of crucial value to Europe.” This reaction illustrates the critical behavior and reflective approach towards current practices that focus on existing strategies and opens alternative views on new paths such as the Asian petrochemical industry.

The second remark that indicates the appearance of a critical opinion is made by Plastics Europe and Total SA played by Edoardo S. and Edoardo Z. Both participants reacted by considering “current costs reductions of the European petrochemical industry is the wrong answer for regaining competiveness “.

Thirdly, participant Patrick describes the existing strategies of the industry by criticizing the petrochemical companies’ long term strategy. He states the following: “the shale gas dilemma is often not a part of any long term plan of companies”.

To conclude, these participants’s quotes illustrate a more critical opinion towards the existing strategies. Nevertheless, it remains uncertain as to whether these quotes indicate that the participants have adopted a more critical opinion on the shale gas development than before the workshop.
8.3 Workshop 1 versus Workshop 2

Table 9 presents the differences in feedback from internal and external participants of the workshops. This allows to see whether there are difference between the reactions of the participants in workshop 1 and workshop 2.

<table>
<thead>
<tr>
<th>Internal WS 1 participants</th>
<th>External WS 2 participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Worried about the scenarios outcomes and statements</td>
<td>• Gain knowledge on the shale gas phenomenon</td>
</tr>
<tr>
<td>• Make the participants think of out of the box strategies.</td>
<td>• Well prepared WS that facilitated the discussions</td>
</tr>
<tr>
<td>• Help to explain to others actors the impact of shale gas</td>
<td></td>
</tr>
</tbody>
</table>

*Table 9: Feedback of internal and external workshops participants*

From the table we can see differences between the two workshops. External participants were focused on gaining knowledge and information on the shale gas phenomenon. In contrast, internal participants tried to think of strategies such as creating their own opinion on how the industry should react.

This difference may be explained by the different backgrounds of the participants in the two workshops. The interest in gaining knowledge of external participants may be explained by the ‘non-expert’ background of these participants. On the other hand, the more strategic approach of internal participants may be explained in light of the fact that these participants work in the petrochemical industry and thus may be considered experts on the topic. They are not focused in the first place on gaining more knowledge on the shale gas phenomenon, but rather on the consequences for their daily practices. For instance, they are concerned about the volatility of prices of polymers and their profits.
9 Conclusions and recommendations

The final part of the thesis presents the concluding remarks and recommendations based on the research conducted. The paragraph seeks to conclude if the scenarios approach was successful in broadening the decision-making space of the participants of the workshops.

9.1 Answering the research questions

The shale gas phenomenon has attracted a lot of attention yet its consequences have thus far largely remained uncertain. The decision-making space of actors in the petrochemical industry is currently limited to the existing strategies that do not suffice to address the potential consequences of the shale gas developments. Therefore, the fundamental research question raised in this research is: **To what extent can scenario workshops help actors from the petrochemical value chain to expand the decision-making space in order to deal with socio-technical uncertainties triggered by shale gas developments?**

The research approach used is based on a four-step process. First, the current existing strategies are presented related to four types of uncertainties (socioeconomically, technologically, geopolitically, and environmentally). The information was collected from press releases, literature, and interviews. Secondly, the petrochemical value chain is presented and the major uncertainties triggered by shale gas are identified. The same four types of uncertainties are distinguished: socioeconomically, technologically, geopolitically, and environmentally. Based on the three types of uncertainties, three scenarios are developed and scenario workshops are organized to see how participants react on the radical changes involved in the scenarios. Finally, the research reflects whether and to what extent, can scenarios workshops contributed to expanding the decision making space of participants. This is done evaluating as to whether new strategies have emerged during the scenarios workshop and whether a learning process has taken place.

The following questions presented in chapter 1 that follow from the above outlined research approach are answered as follows:
1. What are the current strategies to deal with the shale gas phenomenon?

Figure 19 in part 4.6 presents the existing current strategies proposed by various consultancy reports, public reports and executives in the petrochemical industry. These strategies have been related to four types of uncertainties triggered by shale gas developments.

2. How can uncertainties be derived from the petrochemical value chain system and give insight into the effects of the shale gas phenomenon?

Four types of uncertainties are derived (technological, socio-economic, geopolitical and environmental uncertainties) from the value chain by dividing the chain into blocks. For every block four types of uncertainties are analyzed. Moreover a stakeholder analysis is performed.

3. How do the scenario workshops affect the decision-making space of the participants of those workshops?

From the analysis of the workshops it can be concluded that the majority of the strategies proposed by the participants are similar to or variations of the existing strategies.

Nevertheless, two new strategies were proposed: the proposition of the transfer of technological innovations and trends by creating strategic alliances between organizations in the USA and Europe and the minimization of crude oil supply dependency on Saudi Arabia. These two strategies relate to two types of uncertainties; technological and geopolitical. For the other two types of uncertainties, no new strategies have emerged. These two strategies are new in relation to the current strategies mentioned in literature. It is difficult to say whether the decision making space of the actors was expanded because we don’t know whether participants had the same current strategies prior to the scenarios workshops to the current strategies in literature.

Similar, as regards to the learning process it is difficult to draw conclusions based on the scenarios workshops that were held. Although indications of open attitude, awareness and critical opinions have been identified, it remains uncertain whether the participants show a more open attitude, more awareness and a more critical opinion than before the scenarios workshops.
4. Final research question

To what extent can scenario workshops help actors from the petrochemical value chain to expand the decision-making space in order to deal with socio-technical uncertainties triggered by shale gas developments?

Two new strategies have emerged from the participants during the scenario workshops, that were not present in the current strategies employed in the petrochemical industry. However, on it cannot be ruled out whether the participants of the workshops were already aware of these strategies before the workshops.

Furthermore, some indications of an open attitude towards the shale gas developments, awareness of the consequences of the shale gas developments and a critical opinion on the existing strategies were identified. However, it has not been possible to detect whether there was a change in open attitude, a change in awareness and a change in the critical opinion compared to the situation before the workshop. This means that on the basis of the results of the workshops it appeared difficult to establish whether a learning process is triggered by the workshop.

On the basis of the research methodology followed in this research, little insights can be given as to whether and to what extent the decision making space of participants has been broadened. This leads to the reflections on and limitations of this research.

9.2 Reflections and limitations

The following section reflects on the research that has been conducted and in particular seeks to identify its limitations. First, this paragraph reflects on the description of the petrochemical value chain and the identified uncertainties. Secondly, this paragraph reflects on the methodology used in the research.

The contribution of this thesis in particular lies in the contribution that is made to providing insights in the potential impact of shale gas development on the petrochemical industry. In this respect, the identification of uncertainties on the basis of a description of the petrochemical value chain has appeared a useful way in order to identify the possible consequences of the shale gas development. Especially, the description of the petrochemical value from the refining of crude oil all the way to plastics processing allows to identify a wide range of uncertainties. During this first phase of the research process no obstacles were encountered.
The scenario workshop was chosen as a methodology to explore whether the decision making space of the participants can be broadened. During this phase of the research process limitations and difficulties were encountered.

First, the research did not include an overview of the strategies proposed by the participants before they participated to the scenarios workshops. This research, in contrast, used as initial measurement the strategies mentioned in existing literature on the impact of shale gas on the petrochemical industry and during interviews. Subsequently, these strategies were compared to the strategies mentioned by participants during the scenario workshop. However, no information was collected on the strategies proposed by the participants before the workshop. This made it difficult to assess whether the strategies mentioned during the scenario workshop really were ‘new’ strategies proposed by the participants, or whether these strategies were already in their minds before the workshop. Thus, the missing of a ‘pre workshop measurement’ is a first weakness of the research methodology used in this research.

Secondly, a second weakness encountered in this research is that it has appeared difficult to identify whether as a result of the scenarios presented during the workshop a learning process has taken place among the participants. This research sought to identify whether a learning process was triggered by the exposure of the participants to the scenarios related to the shale gas development and to this end, the results of the workshops were assessed in light of three indicators (change of open attitude, change of awareness and the adoption of a critical opinion towards current strategies). Here again, however, no initial measurement has been conducted. Did the participants already have an open attitude towards shale gas before the workshops? Where the participants already aware of the consequences of the shale gas development? And did the participants already have a critical opinion towards the existing strategies? The second weakness thus also relates to the absence of a pre workshop measurement, this time as related to the attitude, awareness of attitudes towards the shale gas development and the critical opinion of actors towards the existing strategies.

The third weakness encountered in this research is that it has appeared difficult to describe the extent to which the decision making space of the participants has been broadened. Indeed no measurement scale has been developed to be able to assess the scale of broadening of the decision making space of the participants after the scenario workshops. The absence of a measurement scale can be seen as a research shortcoming.
Finally, a fourth limitation of this research is that due to the qualitative approach chosen, a limited set of respondents was reached. The conclusions drawn are based on the outcomes of the interviews and workshops that involved a limited set of participants from both the academic and businesses environment. Therefore we cannot generalize the conclusions for all the actors involved in the industry.

To sum up, the practical relevance of the thesis lies in the better understanding of the shale gas developments through the description of the uncertainties in the petrochemical value chain. However, the scientific relevance remains limited because of the difficulties encountered using the scenarios workshops methodology.

### 9.3 Recommendations for future research

In view of the limitations identified related to the methodology of scenarios workshops, future research could be conducted in order to further optimize the methodology of scenario workshops, so that it is possible to assess whether scenario workshops can contribute to extending the decision making space of participants.

In the first place, future research can be conducted as develop a method that measures the status quo of the decision making space of actors before the workshops. The research related to this pre workshop measurement could cover two elements. In the first place, the research could focus on the identification of the current strategies to address the consequences of shale gas of the participants before the workshops are held. Perhaps, a pre session could be held where the participants are invited to list the strategies they would use to address the shale gas development. These strategies could then be compared to the strategies that are mentioned by the participants during and after the workshop.

Secondly, the future research could explore how to identify whether a learning process has taken place as a consequence of the use of scenario workshops. Also in this respect, research could be conducted on the development of a measurement tool to measure whether more open attitude, more awareness and more critical opinions were noticed through the scenarios workshops. This could help to draw measurable conclusions on the exact extend to what the participants showed more open attitude, awareness and critical opinions related to the existing strategies.

Thirdly, it would be recommended to research the relationship between learning through scenarios workshops and the broadening of the decision making space. Does a learning process lead to an expansion
of decision making space? In this respect, it could be recommended to organize a series of workshops in order to be able to assess whether a learning process takes place over time. What is more, the learning process might be facilitated by the organization of a mixed workshop where outsiders from the industry as well as actors from inside the industry are present. This mixed workshop setting would allow to confront the reactions from outsiders with the opinions of the insiders of the industry, which might encourage an interaction and exchange of knowledge and insights between both groups.

9.4 Implications for management of technology

As concluded above the thesis explored the effects of new technologies related to shale gas developments such as flexible/coastal crackers or the developments of integrated petrochemical assets on the European petrochemical industry. This can give insights to professionals in the management of technology field on when and how to use these new technologies in the context of the shale gas developments. Moreover, taking into consideration theses technological changes, professionals within the industry could use the information of the thesis to understand and reflect upon their decisions made within technology organizations on how to incorporate shale gas developments in the long term strategy of companies.

If view of the current strategies presented in the report and the new strategies recommended by the participants, it can be recommended that the European plastics industry should focus its policies on regaining the trust and the confidence of the actors in the industry. A managerial recommendation could be to set up a committee that would guide and help all actors in the value chain to adapt to the shale gas developments. This committee could be composed of independent members that do not have any link with any political lobby or organization. The latter should guarantee the impartiality of the committee. In addition to that, a recommendation for Vinmar would be to set up a pilot group of employees that inform and monitor the shale gas development and inform their colleagues.

In an economic context where the price of crude Brent has dropped to 40 USD the last months, shale gas developments remain more and more uncertain. A sensitive question arises: are all the new shale gas projects in particular in the USA still profitable and can this new feedstock still compete with crude oil?

As the price of oil is becoming more and more attractive, the shale gas interest might not be such a game changer after all. The geopolitical context that is reflected in the decision of OPEC to keep oil prices
low and Saudi Arabia decision not to reduce its crude oil production will put shale gas in a second priority position. Only the future will tell us how our developed scenarios might unfold.
10 References


[27] “Scenarios for actors learning about and participation in sustainable urban development”. Udo Pesch and Karel Mulder
## 11 Appendixes

### 11.1 Appendix 1: Uncertainties Categorization

<table>
<thead>
<tr>
<th>High uncertainties</th>
<th>Medium uncertainties</th>
<th>Less uncertainties</th>
</tr>
</thead>
</table>
| **Shale gas import in EU (not processed gas) from USA**                              | A more likely outcome is that ethane and naphtha will co-exist and feedstock choice will be a function of individual producer strategies and market fundamentals.  
  Naphtha is already widely used and will not likely be displaced as a feedstock  
  However cracking lighter feeds has a negative impact on yields of heavier products. The benefits to ethylene and derivatives do not out weight the costs to Butadiene, propylene, and aromatics. | Ratios small volume (compare to total volume)  
  Coastal crackers (geography)  
  Balance in terms cracker capacity (balance products A)  
  Product range  
  Companies active in EU and USA (adjust activities)  
  Great investment (NPV negative)  
  Price of shale gas increase (long term impact)  
  Greater worldwide exploration/exploitation of shale gas (not unique advantage of US)ex: China (very large reserves)  
  Tsunami of products from Middle East  
  Cheap feedstocks (learn from the past)  
  No new assets build in EU (EU is not attractive investment climate)  
  Specialty products (specialty or bioplastics) grades in health care and automobile industry) (look for alternatives).  
  Each company has its own strategy  
  Naphtha remain main feedstock (polymer price based on Naphtha)  
  Sustainability issues/Environmental footprint of greenhouse gases and waste of plastics (CO₂ emissions...) |
| **Ethane imports in EU from USA**                                                    |                                                                                       |                                                                                     |
| **Ethylene feedstock’s imports in EU from USA**                                     |                                                                                       |                                                                                     |
| **Final products (polymers PE, PP) imports in EU from USA**                         |                                                                                       |                                                                                     |
| **Vertical integration (Integrate cracker and PE/PP Plant) see figure**              |                                                                                       |                                                                                     |
| **Ethane storage tanks**                                                             |                                                                                       |                                                                                     |
| **Ethylene terminals**                                                              |                                                                                       |                                                                                     |
| **Investment uncertainties (closure Naphtha crackers EU) Use examples**              |                                                                                       |                                                                                     |
| **Local levels decision makers**                                                    |                                                                                       |                                                                                     |
| **Technological adjustments on crackers**                                           |                                                                                       |                                                                                     |
| **Flexible crackers**                                                               |                                                                                       |                                                                                     |
| **Shortage of products (ex: polypropylene)**                                        |                                                                                       |                                                                                     |
| **Domino effect (closures crackers)**                                               |                                                                                       |                                                                                     |
| **Delocalization Industry to USA/ME**                                               |                                                                                       |                                                                                     |
| **Impact on manufacturing industry (down value chain)**                             |                                                                                       |                                                                                     |
| **Loss of wealth and increase in European unemployment rate** meanign no economic growth |                                                                                       |                                                                                     |
| **Shale gas exploration in EU (Poland, France)**                                    |                                                                                       |                                                                                     |
11.2 Appendix 2: Interviews

Attendees:

Name of Interviewee:

Constantijn Engels (Master student Management of Technology TU Delft & Intern at Vinmar BV)
Fernando Navarro (Regional Manager Vinmar BV)

Agenda Interview:

- Short Introduction of attendees
- General questions about the Impact of shale gas on the European petrochemical industry
- Lyondellbasell and Shale gas
- Time for discussion

The first part of the interview will contain general questions about the shale gas phenomenon in the petrochemical industry. The second part of the interview will be about Lyondellbasell and your experiences as a Strategy director within the company. The last part will include a general discussion about the topic. I would like to emphasize that this is an explorative interview meaning that its purpose is to obtain information that will help me to write the scenarios. I will come back with more specific question later on in my thesis if you agree of course.

The production of shale gas has reached 230 billion cubic meters (Gm$^3$) in 2012. It has more than quintupled since 2007. No petrochemical and chemical suppliers can remain blind to this phenomenon. The American petrochemical industry is preparing itself for a massive production of petrochemicals based on shale gas in 2016-2017. Moreover, Lyondellbasell is strongly present in the US and Europe meaning that it will have to operate in two different environments.

There is no doubt that Europe feels the implications of greater exploitation of shale gas even if the continent does not exploit its reserves. The impact of shale gas goes beyond American borders:

Which major implications will the shale gas developments in the USA have on the European chemical industry?
How could you describe the short and long term position of Lyondellbasell’s regarding the shale gas developments? Will the shale gas developments put the company at an advantage or disadvantage? What are the strategies to follow to create a competitive advantage regarding these developments?

I have thought of three major scenarios regarding the introduction of shale gas in the petrochemical/chemical industry: (explain scenarios)

1) Which scenarios do you see as plausible and realistic and why? Could you add another possible scenario that you would consider as probable?

2) Which geopolitical or political implications will the shale gas developments have on the European chemical industry? (Russian gas uncertainties)?

3) Which policy implications might be involved regarding effort to mitigate the risks of shale gas developments?

4) What would be a possible outcome of investment uncertainties as a result of shale gas developments for the European petrochemical/chemical industry?

5) The petrochemical industry is confronted with aging facilities. How will this affect the transition to shale gas based production of petrochemicals?

Are there major technological adjustments that have to be made to adapt crackers from Naphtha to ethane feedstocks? The “what if” reasoning is used to tell stories that could unfold as a result of a USA shale gas phenomenon.

- What if, Europe does not take a defensive stand point towards the development and seeks to find ways to innovate its polyolefin’s industry as a result of the USA shale gas developments? (Ideas: develop niche markets, specialty plastics)
- What if, Europe seeks to compensate its disadvantages due to shale gas phenomenon by adapting its energy policy making the energy prices more competitive for the petrochemical industry?
- What if, the geopolitical effects of shale gas turn the European petrochemical industry into an import market where no local industry could survive?
- What if, the shale gas explorations in the USA turns out to be a complete failure due to water contamination on large scale and earthquakes, how will the European petrochemical industry position them?
• What if, the European crackers close or adapt them themselves to shale gas developments?
• What if, there is massive explosion at a LNG terminal or ethane tanks used for shale gas imports?
• What if, the price of ethane extracted from shale gas reached the price of Naphtha, giving away the price competiveness of ethane away for crackers?
• What if, the value chain of polyolefin’s is not affected entirely making the shale gas effect not so significant anymore?
• What if, assets keep closing in Europe and the continent does not have a polyolefins industry?

<table>
<thead>
<tr>
<th>Person</th>
<th>Functions/Role</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Turner</td>
<td>Vice president Polyolefins Europe</td>
<td>Lyondellbasell</td>
</tr>
<tr>
<td>Dick Stolwijk</td>
<td>Manager Planning &amp; Strategy</td>
<td>Lyondellbasell</td>
</tr>
<tr>
<td>Domenico Gigliobianco</td>
<td>Marketing Manager Polyethylene Europe</td>
<td>Lyondellbasell</td>
</tr>
<tr>
<td>Guillermo Ruiz</td>
<td>Managing director</td>
<td>Vinmar</td>
</tr>
<tr>
<td>Fernando Navarro</td>
<td>Regional manager</td>
<td>Vinmar</td>
</tr>
<tr>
<td>INEOS representative</td>
<td>Marketing manager Europe</td>
<td>INEOS</td>
</tr>
<tr>
<td>Ricardo Chihuan</td>
<td>Account manager</td>
<td>Vinmar</td>
</tr>
<tr>
<td>Vinmar Academy</td>
<td>Many speakers</td>
<td>INEOS/Vinmar/LDB</td>
</tr>
<tr>
<td>Willem Auping</td>
<td>Phd /Researcher</td>
<td>HSSC</td>
</tr>
</tbody>
</table>
11.3 Appendix 3: Shale gas resources

![Graph showing technically recoverable resources of shale gas by country]

Source: EIA/ARI, World Shale Gas Resources 2011

11.4 Appendix 4: Cracking process

**Cracking**
The feedstock is converted to ethene / ethylene

![Diagram of the cracking process]

- Hydrogene
- Fuel gas
- Ethylene
- Propylene
- MTBE
- Raf II
- SCN
- Fuel oil
- CBFS
- H2O
- Steam
### 11.5 Appendix 5: New shale gas projects

<table>
<thead>
<tr>
<th>Companies</th>
<th>Announcement</th>
<th>Ethylene committed</th>
<th>Ethylene planned</th>
<th>Propylene</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aither Chem/RMB</td>
<td>Appalachia novel catalytic cracker ($750MM)</td>
<td>-</td>
<td>1,000</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Bayer</td>
<td>Promoting investing at its site</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Braskem-IDESA</td>
<td>New cracker/PE in Mexico</td>
<td>1,000</td>
<td>-</td>
<td>-</td>
<td>2015</td>
</tr>
<tr>
<td>Chevron Phillips</td>
<td>Announced new cracker (Gulf Coast)</td>
<td>1,500</td>
<td>-</td>
<td>-</td>
<td>2017</td>
</tr>
<tr>
<td>Cunningham Energy</td>
<td>Announced new cracker (WV)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Dow</td>
<td>Restart Hahnville, LA cracker</td>
<td>350</td>
<td>-</td>
<td>-</td>
<td>2012</td>
</tr>
<tr>
<td>Dow</td>
<td>Increase flexibility at existing crackers</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2013</td>
</tr>
<tr>
<td>Dow</td>
<td>New cracker, TX</td>
<td>1,900</td>
<td>-</td>
<td>-</td>
<td>2013</td>
</tr>
<tr>
<td>Dow</td>
<td>PDH, TX (PO &amp; merchant)</td>
<td>-</td>
<td>-</td>
<td>750</td>
<td>2015</td>
</tr>
<tr>
<td>Eastman</td>
<td>Restart 4th idled cracker/metathesis</td>
<td>200</td>
<td>-</td>
<td>200</td>
<td>2013</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Incremental expansions</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Formosa Plastics</td>
<td>Expansion; Pt. Comfort, TX</td>
<td>800</td>
<td>-</td>
<td>600</td>
<td>2017</td>
</tr>
<tr>
<td>Indorama</td>
<td>Studying new cracker (Gulf Coast), JV</td>
<td>-</td>
<td>1,500</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Ineos</td>
<td>EO/EG: 500 KTA; Debottleneck, TX (KBR)</td>
<td>210</td>
<td>-</td>
<td>-</td>
<td>2013</td>
</tr>
<tr>
<td>LyondellBasell</td>
<td>Debottlenecks</td>
<td>600</td>
<td>-</td>
<td>-</td>
<td>2013</td>
</tr>
<tr>
<td>LyondellBasell</td>
<td>Studying new JV cracker and PDH</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2015+</td>
</tr>
<tr>
<td>NOVA</td>
<td>Cracker/PE in Canada</td>
<td>1,000</td>
<td>-</td>
<td>-</td>
<td>2014-17</td>
</tr>
<tr>
<td>Oxychem</td>
<td>Ingleside, TX (EDC)</td>
<td>500</td>
<td>-</td>
<td>-</td>
<td>2016</td>
</tr>
<tr>
<td>Shell</td>
<td>Studying new cracker, PA (JV?)</td>
<td>-</td>
<td>1,600</td>
<td>-</td>
<td>2017-19</td>
</tr>
<tr>
<td>Sasol</td>
<td>Studying new cracker, Gulf coast (2013)</td>
<td>-</td>
<td>1,400</td>
<td>-</td>
<td>2016-18</td>
</tr>
<tr>
<td>Westlake</td>
<td>Debottleneck, planning additional</td>
<td>110</td>
<td>-</td>
<td>-</td>
<td>2012-13</td>
</tr>
<tr>
<td>Westlake</td>
<td>Cracker Conversion at Calvert City</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Williams</td>
<td>Geismar, LA Debottleneck (CB&amp;I)</td>
<td>275</td>
<td>-</td>
<td>-</td>
<td>2013</td>
</tr>
<tr>
<td>Confidential*</td>
<td>Various</td>
<td>-</td>
<td>2,600</td>
<td>1,600</td>
<td>2017-8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>8,445</td>
<td>4,500</td>
<td>3,150</td>
<td></td>
</tr>
</tbody>
</table>

*There may be others not known to PCI
11.6 Appendix 6: Workshops

Internal Workshop 25/6/2015: Role Play

Attendees: Adis Sophie - Constantijn Engels-Olivier - Patrick Edoardo Salassa, Edoardo, Fernando Navarro

Chairman: Constantijn Engels

Topic: Scenarios development of the impact of shale gas on the European plastics industry.

The workshop will have different rounds that will include different uncertainties categories. These rounds will be based on three scenarios, in which the actors have to make a strategy about how the petrochemical industry should react to the challenges that are presented in that challenge. Subsequently, the different strategies will be discussed by contrasting them with three propositions about an overarching strategy for the European petrochemical industry with regards to plastics production. Finally, actors will reflect on the way they experienced the workshop.

Roles attributed:

- Adis represents a petrochemical supplier (Lyondellbasell).
- Olivier represents an important European plastics converter (HYPLAST)
- Patrick represents a European petrochemical association (EPCA)
- Edoardo Salassa represents an lobby organization (Plastics Europe)
- Edoardo Zerbinati represents Oil/gas refinery (TOTAL)
Procedure of Workshop:
The workshop will follow the following flowchart:

Part 1:
- The chairman explains the topic of the thesis and his important findings **10 mins**
- Each representative presents itself (activities in Europe, stand point of competiveness and overall European market position) **10 mins**
- The chairman explains the procedures and the focus of the workshop **10 mins**

Part 2:
Step 1: Scenarios presentation **10 mins**

**Scenario 1 War in Middle East spreading to Saudi Arabia (biggest oil producing country)**
Round 1: Technological uncertainties
Round 2: Socio-economic uncertainties
Round 3: Political uncertainties
Round 4: Environmental uncertainties

**Scenario 2 Boom of shale gas from USA taking**
Round 1: Technological uncertainties
Round 2: Socio-economic uncertainties
Round 3: Political uncertainties
Round 4: Environmental uncertainties

**Scenario 3 From shale gas boom to Bioplastics boom**
Round 1: Technological uncertainties
Round 2: Socio-economic uncertainties
Round 3: Political uncertainties
Round 4: Environmental uncertainties

Step 2: How do the different actors react on scenarios? (Feedback) **20 mins**
Step 3: Propositions presented **5 mins**
Step 4: General debate on propositions **30 mins**
Step 3: Discussion on the workshop itself. What have people learned? **10 mins**

Outcome of workshop:

Adis who represented LYB in the workshop gave her first remarks on the technological uncertainties triggered by shale gas. The development of ethane and ethylene storage tanks will be a reality. Moreover a vertical integration and flexible crackers will be noticed for petrochemical companies. Adis as an account manager for France within Vinmar is concerned with the prices of the polymers. Her customers could complain on the volatility of price as a result of shale gas developments. She extended her thoughts on the advantages of a cheaper feedstock’s but she expressed her opinion to use shale gas based feedstock’s for only niche products with economic added value so not for commodities.

Olivier who represented Hyplast, a plastics converter was very concerned for the delocalization of companies to the USA where feedstocks are cheaper. Moreover, Hyplast was not confident in the quality assurance of products produced based on shale gas and their reliability for the machines. Olivier as an account manager for UK/Benelux is concerned about the tax barriers and international regulation that might be implemented as a result of shale gas. It could have a significant impact on the polymers trade between Europe and the USA.

Patrick who represented the EPCA, a worldwide petrochemical association was pointing out the geopolitical interest that will arise as a result of shale gas. Such as a domino effect on other countries or continents to take advantage of the shale gas phenomenon. Moreover a loss a wealth or an increase of unemployment might be noticed if Europe does not take action in adapting its petrochemical industry. Patrick as an account manager for Italy is very happy with the shale gas developments. He states that it is a unique chance for Europe to wake up and adapt its production and long term strategy. In Italy, the
customer are complaining on the lack of competiveness of the European petrochemical industry. The shale gas effects could help Europe to regain competiveness and profitability and so market share is Ital

Edoardo S who represented plastics Europe is steering the conversation to the environmental footprint of shale gas. In fact the production and extraction of shale gas is controversial as hydraulic cracking can cause water contamination. In this perspective PE states that these environmental risks taken in the USA should be of concern in Europe. Edoardo S as an account manager for Italy states that specialties products based on shale gas feedstock’s are the way forward for Europe at least in the Italian market. In addition to that bioplastics should be seen as a possible alternative to conventional polymers as European regulations

Edoardo Z who represented TOTAL SA is steering the conversation to the economic advantages shale gas has to offer for the European industry. In fact, as an oil/gas company TOTAL sees in shale gas an alternative feedstocks that can reboost the industry. By providing new investments and economic growth to Europe. In addition to that it will have an impact on the entire value chain of plastics as all actors will have to adapt their strategy to the effects of shale gas. As an account manager of Italy, Edoardo Z has the same opinions than Patrick.
External Workshop 10/7/2015: Role Play

Attendees: Rania, Fiorella, Gorge, Stefania, Dimitra, Udo, Vassilis, Constantijn

Chairman: Constantijn Engels

Topic: Scenarios development of the impact of shale gas on the European plastics industry.

The workshop will have different rounds that will include different uncertainties categories. These rounds will be based on three scenarios, in which the actors have to make a strategy about how the petrochemical industry should react to the challenges that are presented in that challenge. Subsequently, the different strategies will be discussed by contrasting them with three propositions about an overarching strategy for the European petrochemical industry with regards to plastics production. Finally, external actors will reflect on the way they experienced the workshop.

A comparison will be made of the results during external WS to the results during the internal WS conducted at Vinmar. This will give a clear overview on opinions differ from an outside to an inside point of view.

Roles attributed:

- Gorge represents a petrochemical supplier (Lyondellbasell).
- Fiorella represents an important European plastics converter (HYPLAST)
- Stefania/Rania represents an lobby organization (Plastics Europe)
- Dimitra represents Oil/gas refinery (TOTAL)
- Constantijn : Chairman

Procedure of Workshop:

The workshop will follow the following flowchart:
Part 1:

- The chairman explains the topic of the thesis and his important findings **10 mins**
- Each representative presents itself (activities in Europe, stand point of competiveness and overall European market position) **10 mins**
- The chairman explains the procedures and the focus of the workshop **10 mins**

Part 2:

Step 1: Scenarios presentation **10 mins**

**Scenario 1** War in Middle East spreading to Saudi Arabia (biggest oil producing country)

Round 1: Technological uncertainties
Round 2: Socio-economic uncertainties
Round 3: Political uncertainties
Round 4: Environmental uncertainties

**Scenario 2** Boom of shale gas from USA taking

Round 1: Technological uncertainties
Round 2: Socio-economic uncertainties
Round 3: Political uncertainties
Round 4: Environmental uncertainties

**Scenario 3** From shale gas boom to Bioplastics boom

Round 1: Technological uncertainties
Round 2: Socio-economic uncertainties
Round 3: Political uncertainties
Round 4: Environmental uncertainties
**Step 2**: How do the different actors react on scenarios? (Feedback) **20 mins**

**Step 3**: Propositions presented **5 mins**

**Step 4**: General debate on propositions **30 mins**

**Step 3**: Discussion on the workshop itself. What have people learned? **10 mins**

**Outcome of workshop**

**George** who is the participant who played the role of LYB focused his argumentation on mitigating the risks of shale gas while taking advantage of the developments. He mentioned the strategic planning should a priority for companies to adapt according to a new feedstock. George as a TBM student showed interest and a sense of urgency on this topic. A sense of awareness for Europe to take action was noticed.

**Fiorella** who is the participant who played Hyplast, a plastics converter was very worried regarding the shale gas developments. As a TBM student, she expressed her doubts and questions marks on how Europe can take advantage of this new feedstock without actually exploiting its own resources. Moreover, she could not understand the added value for plastics converter as the raw material quality could not be guaranteed with the new feedstock. Fiorella was asking many questions to Oil/gas representative to understand the practical impact of shale gas developments.

**Stefania/Rania** who are the participants who played Plastics Europe, European Lobby organization for the plastics industry focused their speech on creating a strategic alliance with organizations in the USA to understand and be able to adapt to the shale gas developments.

**Dimitra** who is the participant who played TOTAL SA focused her speech on the necessity to create a European shale gas department within European ministries. Her idea to make shale gas the feedstock of the future was surprising as, TOTAL is a French company which has no attention to explore shale gas resources. Moreover Dimitra is very worried on the security of supply of shale gas. The guarantee to provide the feedstock is limited and uncertain. In case of an accident in the USA, Europe might lose its supply which could have serious consequences on the European economy.
11.7 Appendix 6: Feedback of participants

In addition to the two workshops, the feedback of the participants was collected. The participants were asked to give feedback on their experience. The following table sums up the reactions of all participants after the workshops. Please notice that the reactions are attributed to different participants. As the feedback was similar from different participants it was decided to sum up all the feedbacks in one table.

<table>
<thead>
<tr>
<th>Participant WS 1</th>
<th>Participant WS 1</th>
<th>Participant WS 2</th>
<th>Participant WS 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The WS gave an overall strategic positioning on extreme scenarios that are probable to occur.</td>
<td>• Understood how sensitive the issue was</td>
<td>• Broaden its view of the reaction of plastics converters</td>
<td>• Gain knowledge on the shale gas phenomenon</td>
</tr>
<tr>
<td>• Confronted with uncertainties that were not a part of any long term plan of the company</td>
<td>• Understood the importance to anticipate the effects of shale gas</td>
<td>• Acknowledge the important to create an alliance with the USA</td>
<td>• Is prepared to see prices increase on European raw materials</td>
</tr>
<tr>
<td></td>
<td>• It wants to minimize the geopolitical uncertainties identified</td>
<td></td>
<td>• Understood how important American petrochemical companies will be in the future</td>
</tr>
</tbody>
</table>