Analysis of the Carbon Bubble Risk of Oil & Gas Companies in the Dutch Pension Market

Assessing the carbon bubble risk in Dutch pension portfolios via interviews with actors in the Dutch pension market & scenarios for O&G companies

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Master Thesis

System Engineering Policy Analysis & Management

May, 2017

TU Delft Delft University of Technology

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Analysis of the Carbon Bubble Risk of Oil & Gas Companies in the Dutch Pension Market

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **System Engineering Policy Analysis & Management**

Faculty of Technology, Policy and Management

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To be defended in public on: May 22th, 2017

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Acknowledgements

This thesis is the result of eight months of research, for the master System Engineering, Policy Analysis & Management at the faculty of Technology Policy & Management of the Delft University of Technology.

I would like to thank my supervisors from the TU Delft, Zenlin Roosenboom-Kwee, Linda Kamp and Kornelis Blok for their time and useful feedback during the process of writing this thesis. Their comments contributed in bringing this research to a higher level.

Also, I would like to thank Andrea Kralikova, Joost Brinkman and Rutger Hagendoorn from Accenture, who gave me the opportunity to write this thesis at Accenture, provided feedback and linked me to valuable connections within their network. Conducting the research in this professional environment contributed to my learning experience.

Third, I would like to thank all respondents of the interviews and all people involved in this thesis in the last eight months for their views, contributions and discussions on this subject.

Table of Contents

Acknowledgements 4
List of figures 9
List of tables 10
List of Acronyms 11
Executive summary 13
PART I *Thesis Definition* 16
1. Introduction 17
1.1 Problem exploration 17
1.2 Knowledge gap & Problem statement 18
1.3 Research Question 20
1.4 Research objective & deliverable 21
1.5 Theory & scientific relevance 21
1.6 Societal relevance 22
1.7 Outline 22
PART II *Conceptualization* 24
2. Methodology 25
2.1 Research design 25
2.1.1 Sub-question 1 25
2.1.2 Sub-question 2 26
2.1.3 Sub-question 3 26
2.1.4 Sub-question 4 26
2.2 Research methods 27
2.2.1 Literature Research 27
2.2.2 Desk research 27
2.2.3 Scenario Analysis 29
2.2.4 Interviews 31
2.2.5 Case studies 35
3. Literature Review 36
3.1 Climate risk: The carbon bubble 36
3.2 External risks which can cause stranded assets 37
3.3 The Dutch pension market 41
3.4 Strategic Asset Allocation 44
3.5 Asset Liability Management 45
3.6 The O&G sector 46
3.6.1 Types of ownership 46

3.6.2 The Oil & Gas value chain 46
3.6.3 Scale advantages & disadvantages 47
3.6.4 Oil demand per sector 47
3.6.5 Peak oil demand instead of peak oil supply 48
3.6.6 Reserve valuation 49
3.7 O&G company valuation model 51
3.8 Company Risks in O&G sector 52
3.9 Key findings of the literature review 54
PART III *Results* 55
4. Factors of O&G company valuation for investors 56
4.1 Investment strategy of Dutch pension providers 56
4.2 Indicators & methods O&G valuation from interviews 57
4.3 Analysis of indicators of the model from the literature 59
4.4 View of the respondents on the model 62
4.5 Reflection on the interviews 62
4.6 Key findings 63
5. Influence of COP21 on valuation of O&G companies 64
5.1 COP21 implications 64
5.2 New Directive: IORP II 65
5.2.1 Status quo Dutch pension providers on IORP II 66
5.3 The 1.5 & 2 ˚C target 68
5.4 Reflection on the interviews 69
5.5 Key Findings 69
6. Effects of O&G devaluation in pension market due to carbon bubble burst 70
6.1 Factors leading to a carbon bubble burst 70
6.2 Earlier studies on the value at risk of O&G companies due to climate change 71
6.2.1 Carbon Trust - Climate change – a business revolution? (2008) 71
6.2.2 HSBC - Oil & carbon revisited -Value at risk from 'unburnable' reserves (2013) 72
6.2.3 Comparing earlier studies 72
6.3 Defining the scenarios 73
6.3.1 Important factors per scenario 73
6.3.2 The Carbon Budget 74
6.3.3 Sample of O&G companies 75
6.3.4 Ranking the O&G companies 75
6.4 Scenario: Business as Usual 76
6.4.1 Ability to meet growing fossil fuel demand 76

6.5 Scenario: Carbon Bubble Burst 79
6.5.1 Unburnable Carbon 79
6.5.2 Carbon bubble Burst | Adaptability O&G companies 88
6. 6 Effect carbon bubble burst for Dutch pension market 92
6.6 Response to carbon bubble burst of Dutch pension market 93
6.7 Reflection on the interviews 94
6.8 Key Findings 94
7. Risk valuation of a Carbon bubble of O&G companies in the portfolios 95
7.1 Data, indicators & methods for valuing the carbon bubble risk 95
7.1.1 Data 95
7.1.2 Indicators 96
7.1.3 Methods for risk valuation 98
7.2 Risk valuation of carbon bubble burst 100
7.2.1 ''Energy transition will happen gradual instead of abruptly'' 100
7.2.2 ''Deflation is more probable than a bubble burst'' 101
7.2.3 ''Rise in energy demand is dominant'' 101
7.2.4 ''Transition to lower carbon economy is no a threat to share price of O&G companies'' 102
7.2.5 ''O&G investment benefits: return, diversification & inflation hedging'' 102
7.2.6 Reflection on the arguments 105
7.3 Two Specific cases 107
7.3.1 Case: Arctic oil projects 107
7.3.2 Case: Funding dividend through debt 108
7.3.3 Reflection on the cases 109
7.4 Is the carbon bubble risk priced in the market? 110
7.4.1 Efficient Market Hypothesis 110
7.4.2 View of the European Systemic Risk Board 111
7.5 How to deflate the potential carbon bubble in the pension market 112
7.6 Key Findings 114
PART IV *Evaluation* 115
8. Conclusion 116
8.1 Main findings 116
8.2 Implications & Recommendations 117
9. Discussion 120
9.1 Quality of the research 120
9.2 Limitations & future research 121
9.3 Reflection 122

References 123
Appendix I Interview questions 133
Appendix II Codes of interviews 135
Appendix III Types of climate risks and related financial impacts 136
Appendix IV French Energy Transition Law – Article 173 138
Appendix V: Main world energy drivers in 2050 140
Appendix VI: Overview of international cooperation on climate change 141
Appendix VII Importance of risk factors for O&G companies 142
Metrics Risk factors O&G companies 143
Appendix VIII Specifications MSCI Index Ex Fossil Fuels 144
Appendix IX Carbon Budget elucidation 145
Appendix X Calculations on Stranded assets of O&G companies in < 2 ˚C 147

List of figures

Figure 1: Overview of actors in the system investigated in this research 19
Figure 2: Schematic overview of research design 25
Figure 3: Overview of risk factors for stranded assets for O&G companies 40
Figure 4:Overview of actors related to the pension market and the financial authorities 41
Figure 5: Calculated Average allocation per asset class of five largest Dutch pension funds in 2015. 43
Figure 6: The relation between risk attitude, risk profile and efficiency 45
Figure 7:Value Chain of O&G industry. 46
Figure 8:Breakdown per fuel type of total 1370 MToe demand in 2014. 47
Figure 9: Oil and gas consumption per sector in percentage in 2014. 48
Figure 10: Predicted world oil demand and oil price per scenario. 49
Figure 11: Visual presentation of the Petroleum Resources Management System (PRMS) 50
Figure 12: Factors which can lead to a carbon bubble burst 70
Figure 13: Calculated value creation and transition value-at-risk for different sectors. 71
Figure 14: Overview of the two scenarios and the key factors determining the impact 73
Figure 15: Indicators used in the Business as Usual scenario 76
Figure 16:Indicators used for amount of burnable carbon O&G companies 79
Figure 17: Industry production cost curve. 80
Figure 18:Emissions embedded in hydrocarbon reserve portfolios. 82
Figure 19: O&G companies' hydrocarbon production per region. 84
Figure 20:Overview regulatory frameworks of Global GHG emissions. 85
Figure 21: Indicators used for adaptability of O&G companies 88
Figure 22: Cumulative index performance of gross returns in USD 103
Figure 23: Sub-industry weights of MSCI World Energy index. 103
Figure 24: Historical Index performance US$ of MSCI ACWI Index & MSCI ACWI Ex fossil fuels 105
Figure 25: Production costs rise due to shifts towards more production of unconventional fields... 107
Figure 26: Impasse between pension funds and pension providers 112
Figure 27: Factors shaping world energy. 5. 140
Figure 28:Global warming versus the cumulative CO2 emissions in the atmosphere. 145

List of tables

Table 1: Overview of the roles and relations of the actors in the system investigated 19
Table 2: Research sub-questions 20
Table 3: Overview of the reports per subject resulted from the desk research 27
Table 4:Overview of scenarios, key factors, and indicators used with source. 30
Table 5: Preliminary interviews with other relevant organizations 31
Table 6: Respondents interviewed, pension providers & fund 32
Table 7: Overview titles and functions of respondents 33
Table 8: Criteria for financial crisis sensitivity of asset classes. 37
Table 9: Role of related actors in the Dutch pension market 42
Table 10: peak oil demand predictions per scenario 49
Table 11: Overview Risk factors for O&G companies in literature 53
Table 12: Frequency of indicators for O&G valuation during interviews 57
Table 13: Carbon budget after 2016 per temperature threshold for 66% probability 74
Table 14: overview MCap of 11 large O&G companies. 75
Table 15: Development status & Reserve production ratio. 77
Table 16:Ranking of companies in Business as Usual scenario. 78
Table 17: Overview financial data O&G companies.. 81
Table 18: CO_2 content of fossil fuels. 81
Table 19: Approximation of stranded reserves per company within 1.5 ˚C target 83
Table 20: Emission reduction targets from (I)NDCs per country/region and associated risk levels.. 85
Table 21: Risk level per O&G company regarding reserves in environmental regulatory regions 86
Table 22:O&G companies most at risk regarding unburnable carbon 87
Table 23: Overview alternative energy assets & investment of O&G companies. 88
Table 24: Values and ranks of Proven reserves Debt/Equity and CF/CAPEX 90
Table 25: Average rank of adaptability indicators 91
Table 26: O&G Companies most at risk in carbon bubble burst scenario marked red. 91
Table 28:Overview examples ESG factors 96
Table 29: Overview of indicators mentioned for risk analysis of O&G companies 96
Table 30: MSCI indicators for risk mitigation O&G companies. 97
Table 31: Coding Scheme of the interviews with the Dutch pension market 135
Table 32: Overview of different types of climate risks & financial impacts FSB 136
Table 33: Overview of average risk factors scores for O&G companies internal 142
Table 34: Overview internal risk factors and metrics for O&G industry. 143
Table 35: Specifications of Key metrics of low carbon Indices from MSCI 144
Table 36: Cumulative CO2 emission consistent with limiting warming 145
Table 37: Carbon budget after 2016 and importance of factors 146
Table 38 Overview fossil fuel type proven reserves of O&G companies 147
Table 39: Effects of reserve limitation on MCap of the 11 O&G companies 148
Table 40: Years of production left of Proven reserves of 11 O&G companies. 149

List of Acronyms

ACWI	*All Countries World Index*
AFM	*Authority of Financial Markets in the Netherlands*
ALM	*Asset Liability Management*
BOE	*Barrel of Oil Equivalent*
CAGR	*Compound Annual Growth Rate*
CAFE	*Corporate Average Fuel Economy*
CAPEX	*Capital Expenditures*
CCS	*Carbon Capture & Storage*
CDP	*Carbon Disclosure Project*
COP21	*Conference Of Parties, 21st edition*
CO_2	*Carbon Dioxide*
CSR	*Corporate Social Responsibility*
DNB	*De Nederlandse Bank (Dutch Central Bank)*
DCF	*Discounted Cash Flow*
EFAMA	*European Fund and Asset Management Association*
EMH	*Efficient Market Hypothesis*
E&P	*Exploration & Production*
EROI	*Energy Return on Investment*
ESG	*Environmental Social Governance*
ESMA	*European Securities and Market Authority*
ESRB	*European Systemic Risk Board*
F&D costs	*Finding & Development costs*
FSB	*Financial Stability Board*
GAAP	*General Accepted Accounting Principles*
GHG	*GreenHouse Gas*
GSE	*Government Sponsored Enterprises*
Gt	*Giga Tonnes*
IEA	*International Energy Agency*
IFRS	*International Financial Reporting Standards*
IOC	*International Oil Company*
IORP II	*Institutions for Occupational Retirement Provision, Second European Directive*

IPCC	*Intergovernmental Panel on Climate Change*
KPI	*Key Performance Indicator*
MCap	*Market Capitalization*
MSCI index	*Morgan Stanley Capital International Index*
Mtoe	*Million tonnes of oil equivalent*
NDC	*National Determined Contributions*
NOC	*National Oil Company*
O&G	*Oil & Gas*
O&M	*Operation & Maintenance Costs*
OPEC	*Organization of Petroleum Exporting Countries*
PPM	*Parts Per Million*
PRMS	*Petroleum Research Management System*
PV10	*Present Value at 10% discount rate*
RPC	*Representative Concentration Pathways*
ROACE	*Return On Average Capital Employed*
ROI	*Return On Investment*
RRR	*Reserve Replacement Ratio*
SAA	*Strategic Asset Allocation*
SEC	*Securities and Exchange Commission*
SPE	*Society of Petroleum Engineers*
TPES	*Total Primary Energy Supply*
UNFCC	*United Nations Framework Convention on Climate Change*
VAR	*Value At Risk*
WTI	*West Texas Intermediate*

Executive summary

One of the important tasks for financial markets is to accurately price risks, to make well informed investment decisions. To allocate the capital as efficiently as possible at given risks, transparency and perfect information are desired. Imperfect information in financial markets makes the financial system less stable to external shocks and lowers its ability to recover from those potential shocks. The Dutch central bank and the Bank of England, have already emphasized that climate risks can pose a serious threat to the financial markets, through physical risks (impact of extreme weather events) and non-physical risks (regulatory risk, technological risk, market risk or reputational risk).

Since the Paris agreement in 2015 and its ratification in 2016, the direction of future policy is set to keep global warming within 2 ˚C increase compared to pre-industrial levels, aiming for below 1.5 ˚C. Together with the developments in alternative energy sources and energy efficiencies, this amplifies the need for carbon-intensive companies to adapt their business models to mitigate these risks, which previously seemed to be a long-term concern.

Suddenly, unanticipated devaluation of assets as a consequence of an abrupt energy transition, will not only affect companies in the fossil fuel intensive industries, but also the associated financial markets. The risk that carbon-intensive companies will lose value due to these stranded assets, is called the carbon bubble. In the Dutch financial sector, the exposure to a potential burst of such a carbon bubble, is the highest for the Dutch pension market. The pension participants have no free choice of pension fund and are left to the fiduciary duty of these institutions to hedge optimally for the risks. The pension fund is the administrator of the pension money of its participants. For the allocation of this capital at an optimal return against a given risk, the fund outsources this money to the pension provider. The pension provider manages the allocation of this capital, within the mandate provided by the pension fund. Climate risks could be underexposed, regarding the focus on backward looking data plus the absence or decreased reliability of GHG data used in the risk assessments of the pension providers. Since Oil & Gas companies are still dominantly present in the portfolios of the Dutch pension market and account for 50% of global CO_2 emissions, the aim of the research was to analyze:

''How should the Dutch pension market value the carbon bubble risk of O&G companies in their portfolio?''

Seventeen interviews were conducted with a pension fund, pension providers, and actors related to the pension market, comprising of 990 out of the 1300 billion euros in assets under management of the Dutch pension market. The average exposure to O&G companies in the pension portfolios is 7.45%. This implies substantial reductions to the pension payments to be made if the carbon bubble bursts, especially since this would have an effect in other sectors like utilities, transportation and heavy industries. A scenario analysis using data of 11 O&G multinationals with a combined Market Capitalization of 25% of all companies in the fossil industry, showed Occidental Statoil and Eni are most at risk in a *Business as Usual* scenario. ConocoPhillips, Exxon Mobil and Chevron are most at risk in a *Carbon Bubble Burst* scenario, assuming an abrupt energy transition.

Currently, no O&G companies are excluded based on environmental risks among the interviewed pension providers. The main method for valuation of companies is Discounted Cash Flow (DCF). The exact elements included in the DCF models of O&G companies are classified, but proven reserves, profitability indicators, cost indicators and oil price play an important role.

COP21 did not change the way pension providers value O&G companies yet, but it gave investors more leverage to ask for transparency and progress regarding the participation of O&G companies in the energy transition. Adaptation of the IORP II Directive by the European Parliament in November 2016 requires European pension funds to equally assess risks of the Environmental, Social & Governance factors along with the operational, liquidity or asset risks. Besides little awareness among the respondents, not all pension providers are on track with their risk management or support this new regulation which comes into force January 17, 2019. Strategic Asset Allocation tools like Asset Liability Management studies are scarcely applied to assess climate/carbon risks on portfolio level, mainly since the associated costs of these studies seem to outweigh the expected benefits.

Pension providers currently acknowledge the potential impact of a carbon bubble burst, but do not consider it probable. Mainly due to an expected dominant demand for fossil fuel energy which will only decrease gradually. A crucial aspect of the carbon bubble theory is whether the carbon risk is currently priced into the financial markets. The Dutch pension market is highly divided on this. Being on the safe side requires decarbonization of the pension portfolios. This is currently impeded by an impasse between the pension fund and the pension provider:

The fund has the normative mandate to instruct the pension provider to decarbonize, but lacks the knowledge and expertise on risk management, vis-à-vis the pension provider, which has the knowledge and expertise, but lacks the normative mandate to divest carbon-intensive assets.

The conclusion is, that the Dutch pension market can and should do more to value climate risks like a carbon bubble. As long as the established risk methodologies of the pension providers underexpose these climate risks, little actions are undertaken by these providers to decarbonize the pension portfolios. To alleviate the lack of data subject to potential mispricing of climate risks and the impasse between the pension fund and provider, several recommendations are proposed:

Public Policy

I. A Dutch Energy Transition Law should be implemented by the Ministry of Finance, which requires investors to disclose their impact on the environment and requires equal attention to ESG risks compared to other risks. This will increase the data availability on climate risks.
II. The European Commission should propose a *Shadow Carbon Price* Directive, which requires carbon-intensive sectors to account for a shadow price on carbon. This info will also be available for investors to reduce the risk on asymmetric information and stranded assets.
III. A legally binding form of the long-term goal to reach a carbon-neutral economy should be designed by the Ministry of Finance. The current Energy Agreement (Energieakkoord), does not provide sufficient detail or certainty for investors. More specific transition pathways, on national and sector level, towards a lower-carbon economy along a more detailed timeline are required.

Dutch Pension market

IV. Pension funds and their boards should inform themselves about the risks associated with carbon and engage with their pension provider on what methodologies can be developed.
V. Pension providers should start with testing of new methodologies to assess climate risks and present alternative investment views to the funds.

VI. Both pension funds and pension providers should not wait until data & methodology on climate and carbon risks are fully developed, but start using them since the risks can materialize in portfolios before that time.

Financial Authorities

VII. The Ministry of Finance, AFM & DNB should set up working groups to create support within the Dutch financial system on the important aspects and regulatory details of this Dutch Energy Transition Law.

VIII. DNB should prepare internal policy to develop new channels and methods to control the compliance of the new Dutch Energy Transition Law, since this data will be not standardized yet.

IX. DNB should monitor if pension funds and providers are on track regarding the adaptation of IORP II, and facilitate information sharing sessions with the pension funds and providers. Potential bottlenecks can be deducted from the transcribed interviews of this thesis.

X. AFM should develop internal policy which focusses on the impasse between Dutch pension funds and pension providers. Point IV, V, and VI to alleviate this impasse should be addressed in surveys and interviews with the boards of Dutch pension funds and providers. The AFM can use these assessments to intervene where needed. The ostrich policy of the boards of the pension funds and providers regarding climate risks can in this way be transformed to a more progressive attitude towards assessing these risks.

The results of this research can be used by other institutional investors to obtain insight into carbon bubble risk valuation. Furthermore, it provides transparency for the Dutch citizens with a pension plan in how their pension providers value these risks. The scientific relevance of this thesis is the verification of the usage of ALM and SAA methods at O&G sector level on carbon bubble risk with practitioners in the Dutch pension market. Future research can be devoted towards the potential indirect impact of a carbon bubble burst on other sectors in the pension portfolios, or optimal strategies for pension providers to deflate a potential carbon bubble without facing the risk of missing additional returns.

PART I

Thesis Definition

1. Introduction

Climate risk is defined as a systemic risk, since it could generate severe instability to our economic system (Guyatt et al., 2011; Schoenmaker; 2015; ESRB, 2016). Anthropogenic carbon dioxide emissions are one of the main contributors to climate change and carbon risk is to an increasing extent incorporated in the risk management of companies (Busch et al., 2006; Bokenkamp et al., 2005). An example of a specific carbon risk, is the burst of a carbon bubble. The carbon bubble refers to the overvaluation of fossil fuel reserves and related assets, taking into account the world complies with Paris' (COP21) goal to limit climate change. Avoiding irrepressible consequences of climate change implies we must control the global temperature rise well below 2 ˚C compared to the pre-industrial levels and aiming below 1.5 ˚C. If we meet this target, there is a limit on future carbon dioxide emissions and on the volume of fossil fuels which can be burned. The emissions associated with the combustion of the current global reserves of coal, oil and gas are multiple times larger than this amount, even if emissions are restored via carbon capture and storage (IPCC, 2014; Heede, 2014; Helm, 2015; McGlade et al., 2015; Weyzig et al., 2014).

Limiting the carbon bubble implies a large share of the fossil fuel reserves can become stranded assets: they cannot be exploited aiming to avoid detrimental climate change. Investments in energy are part of the portfolio of many institutional investors. The burst of this bubble could create a carbon shock with heavy implications for our financial system (Caldecott et al., 2015; Halle et al., 2014; Lucas, 2015; FSB, 2016; DNB, 2016).

The academic interest in the carbon bubble took off in recent years, and lately on the role the financial sector can play to deflate this bubble (Weyzig et al., 2014; Dietz et al. 2016; Ritchie et al., 2015). The institutional investors comprise the investments funds, insurance companies, pension funds and banks. Among the Dutch institutional investors, pensions funds are exposed the most to the risk of such a carbon bubble burst, since these parties have sizeable investments in fossil fuel operating companies and hence more exposed to these risks than banks and insurance companies (DNB, 2016a).

Nevertheless, the long-term focus on return on their investments, gives pension funds the ideal profile to invest in renewable energy projects, which also yield profits in the longer term. The pension funds do have investments in the energy sector. However, the investments of pension funds in such green assets remain low (Della Croce et al., 2011; Sievänen, 2013). So far, the investments in the fossil fuel industry are still valuable for these pension funds. However, adequate risk management of these pension funds and the pension providers managing their money is required, taking into account the risks of stranded assets of these oil & gas multinationals (Harding et al., 2012).

1.1 Problem exploration

Weyzig et al. (2014), analyzed that the 23 largest EU pension funds are exposed to 260-330 billion euros if fossil fuel companies become stranded, which represents 5 % of their total assets. This is more than the fossil fuel exposure of the European banks (1.4%) and insurance companies (4%). Research of The Dutch Central Bank (DNB, 2016a) indicated that 5.5% of the Dutch pension capital, equal to 37.8 billion euros, is exposed to fossil fuel producers. Although these numbers are not extreme, doing nothing can increase this risk and increase the impact of such a carbon bubble burst. Furthermore, the total impact of such a shock will have consequences in many industries, like land-transportation, aviation, shipping, manufacturing industries, real estate and more. For this reason, especially the larger Dutch pension funds are more exposed to this risk of a carbon bubble than smaller institutional investors. Due to their larger volume and international diversified portfolio, they are more exposed to such climate related risks (DNB, 2016a). Besides the research of the DNB, little research is done in the Netherlands focusing on the carbon bubble risk of pension funds and providers (DNB, 2016b; Weyzig et al, 2014; ESRB, 2016).

The Dutch Central Bank (2016b) recently published a report on sustainable investments, where it stated pension funds and providers are engaging more in sustainable investments and will continue to do so in the future. 219 Dutch pension funds were investigated. Follow-up actions included more transparency and more collaboration within this sector regarding these renewable investments. Research of the VBDO, the Dutch organization for sustainable investment, confirms that Dutch pension funds can work better together to map the risks of carbon in their portfolio under current conditions. Moreover, more transparency is needed (Verstappen et al., 2015).

According to the DNB (2016b), exclusion of specific types of assets is mentioned as one of the key instruments to achieve a more sustainable portfolio. About 90% of the Dutch pension funds currently have these exclusion criteria, but these criteria often not include oil & gas multinationals yet. In addition, these funds seem to acknowledge the reputational risk of investments which are perceived as non-sustainable. If the ESG performances are below average, these reputational risks can develop into direct financial risks of the non-sustainable O&G companies in their portfolio and indirect financial risks due to companies in their portfolio which do business with these companies (DNB, 2016b).

1.2 Knowledge gap & Problem statement

Although the financial sector is becoming more aware of the risks associated with climate change, the uncertainty related to climate change makes it difficult for investors to hedge for this risk and make strategic decisions (Lempert et al., 2006). Academic research focused on how much Strategic Asset Allocation can attribute to the portfolio returns of institutional investors (Brinson et al., 1986; Grinblatt et al., 1989; Brinson et al., 1991; Ibbotson et al. 2000). These studies did not include the climate risks involved. Other research was done on how pension funds can be stimulated to finance more green growth initiatives (Della Croce et al., 2011). The risks of stranded assets for multinationals operating in the fossil fuel industry were also investigated lately (Van der Ploeg, 2016). Helm (2015), addressed the complexity of governmental policy in fostering a renewable energy transition and the end of the fossil fuel era. None of these studies, however, elaborated on the carbon bubble risks of O&G companies for the financial sector specifically. Busch et al. (2006) identified that the financial institutions started around 2006 to recognize the climate change aspects into their valuations. Although the climate risk valuations are developed since then, it remains an inferior aspect within the risk management. The role of financial sector and climate risk was also discussed by various authors (Bokenkamp, 2005; Weyzig et al., 2014; Ritchie et al., 2015; Dietz et al. 2016). However, none of these studies focused explicitly on Dutch pension funds and providers. Recently, the main risks for pension fund ABP in the Netherlands were identified by Kleynen (2015). Due to changing environment, they have to, to a greater extent, deal with individualization as a result of less solidarity and more stable contributions, ageing of the pensioners' population and more need for transparency in their investment practices. Climate risk is not explicitly mentioned in this research. The existing literature does not include the carbon bubble risk of O&G companies for the Dutch pension market in the same study, hence further research is needed to investigate how these risks are valued.

Little is known on how Dutch pension funds and providers specifically value the risk of oil and gas companies in their portfolio. This knowledge gap can lead to an underpricing of these risks, which can lead to losses of these pension funds and providers (Schoenmaker et al., 2015; Guyatt et al., 2011; DNB, 2016b). Since the pension money of the Dutch citizens is at stake, more knowledge and transparency on how the Dutch pension funds and providers value the risk of these O&G companies in their portfolio is crucial to secure the future payments of the Dutch pensions.

Elaborating on the report of DNB(2016a), this research will focus more on the carbon bubble risk of the O&G companies. Coal companies are excluded, since these companies have a different production process, subject to different risks compared to the O&G multinationals. Furthermore, the investments of pension funds and providers in coal companies are decreasing, so assessing the risks of O&G

companies will be more relevant for the future. Although coal is the most polluting fossil fuel, the emissions of the products of the O&G industry account for half of the global CO_2 emissions in scope 1, 2 and 3[1](IEA, 2015). After Weyzig et al. (2014) analyzed the carbon bubble risk for institutional investors on European level, this research focuses only on the Dutch pension market. Dutch Banks are less vulnerable for this carbon bubble risk, since their exposure is mostly loans with a maximum of five years and at most less than one year. Insurance companies are least exposed (DNB, 2016a). Besides analysis of annual reports to assess the Dutch pension funds and providers as in the research of DNB, this thesis will conduct more in-depth interviews with the pension providers. The accessibility of gathering Dutch data, taking into account the time constraints of this research, is another reason to focus this research on the pension funds and providers within the Netherlands. This research will not primarily focus on the role of institutional investors in financing clean energy, since investigating the risk valuation of the O&G industry in the Dutch pension market is the core goal. A visual representation of the actors in this system is given in figure 1, followed by a description of their roles and relations in table 1.

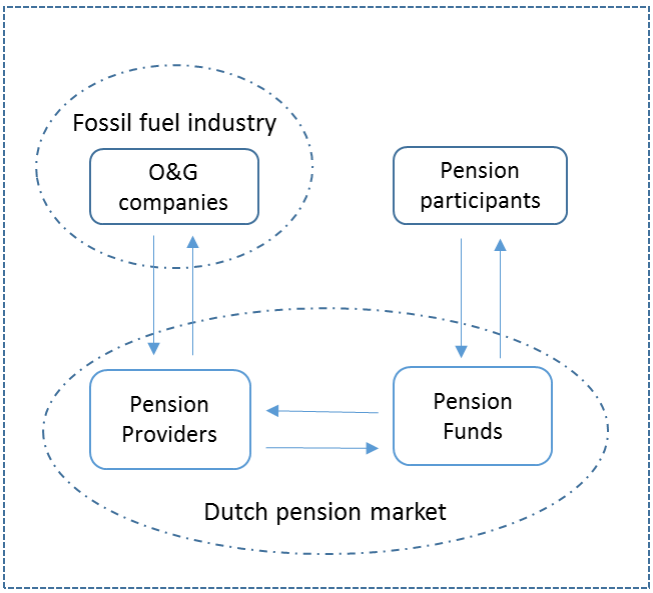

Figure 1: Overview of actors in the system investigated in this research

Table 1: Overview of the roles and relations of the actors in the system investigated in this research

Actor	**Primary function in this system**	**Relation to other actors**	**Exposure to carbon bubble risk**
O&G companies	Make profit & attract shareholders	Pays dividend to its shareholders, pension providers	Direct

[1] Emissions can be divided into three scopes. Scope 1, the emissions which are directly emitted by sources of a company. Scope 2, the indirect emissions related to the usage of electricity, cooling or heating of a company. Scope 3 includes all indirect emissions not related to the direct activities of the company, but related to the activities of the company. This is the biggest scope for the O&G industry and the financial sector. However, the least data is reported in scope 3 among most companies.

Pension fund	Administer the pension money of the practitioners	Receives/distributes money from/to pension participants Outsources the management of the pension capital to the pension provider	Indirect, via investments
Pension provider	Allocate the pension capital the most efficient given a certain risk/return profile	Invests money in O&G industry Allocates capital on behalf of its client, the pension fund(s)	Indirect, via investments
Pension participant	Saves money for pension	Pays money to pension fund & receives pension from pension fund	Indirect, via the pension fund

1.3 Research Question

Considering what is currently written in this field, the following research question is formulated:

"How should the Dutch pension funds and providers value the carbon bubble risks of Oil and Gas multinationals in their portfolio?"

To answer the main research question, sub-questions which will be answered via literature research, desk research and interviews are formulated. The methods and sub-questions used to structure the research are presented below in table 2.

Table 2: Research sub-questions

Research sub-question	**Methods**	**Chapter**
1. How do Dutch pension funds and providers currently value O&G companies?	Literature research & Interviews & desk research	3, 4
2. How is COP21 translated into the practices of the Dutch pension funds and providers?	Interviews & desk research	5
3. What would be the effects for the Dutch pension funds and providers if the O&G companies in their portfolio would decrease in value, due to a potential carbon bubble burst?	Interviews & desk research & scenario analysis	6
4. How do the Dutch pension funds and providers value the carbon bubble risk of O&G companies in their portfolio?	Interviews & desk research	7

Both interviews and literature research are used for sub-question 1. The aim was to identify indicators which determine valuation of the O&G companies for investors. It focuses on what KPIs they use, which data sources and what their methods for valuation are.

Sub-question 2 focuses on how the climate agreement of Paris is taken into account by these pension funds and providers. 144 Parties have ratified of the 197 Parties to the Convention in Paris in 2015. However, the National Determined Contributions (NDCs) submitted by these countries not always include binding legislative procedures in each country. This sub question also elaborates how the Dutch pension market matches the support of COP21 with their practices, and what progress is made regarding the regulatory changes of the IORP II Directive.

Sub-question 3 uses a hypothetical situation, where the O&G companies lose a percentage of their value, building upon previous carbon bubble scenario studies. Two scenarios are developed by assessing a sample of eleven large O&G companies. Elaborating on this, the effects and responses of the Dutch pension market to a potential carbon bubble burst are discussed. To triangulate the results of the interviews, desk research and scenario analysis are performed on the carbon bubble risk valuation of eleven big O&G companies.

Sub-question 4 elaborates on the valuation of the carbon bubble risk from the perspective of the Dutch pension market. This resulted in an overview of the different methods used to value the risk of O&G companies by the funds and providers. Cases of Arctic projects and high debt ratios of O&G companies are discussed, followed by discussion on the pricing of carbon bubble risk.

After answering these four sub-questions, the main research question is answered. By complementing the academic literature with the information from interviews with people with expertise on carbon risk and assets allocation, a comprehensive analysis is made on how these funds & providers value the carbon risk. Desk research will use data from the annual reports of pension funds and providers. The results of those data analysis will function as a benchmark. The combined methods of interviews, literature research and desk research are used to investigate the risks for oil & gas multinationals in the portfolio of Dutch pension funds & providers.

1.4 Research objective & deliverable

The objective of this research is to provide clearance on how Dutch pension funds and Dutch pension providers value the carbon bubble risk of oil & gas multinationals in their portfolio. The deliverable of this thesis is a comprehensive overview of the different practices on how the Dutch pension fund & providers value this risk. This overview can be used by the people working at the pension funds and providers. Moreover, this can be used by other institutional investors which invest in O&G companies and by pension participants to check if their pension fund is valuing the risks appropriately. This also contributes to the societal relevance of this research.

1.5 Theory & scientific relevance

The study of this thesis is built on three theories. First, the theory on strategic asset allocation (SAA) is used, to explore how pension funds manage the allocation of their assets. Factors such as risk tolerance, policy, the objectives of investment and time horizon are considered. SAA is described in the literature as a crucial aspect in portfolio management. Academic research finds that over 90% of the variance in portfolio returns is due to SAA (Brinson et al., 1986; Grinblatt et al., 1989; Brinson et al., 1991; Ibbotson et al. 2000). SAA can be defined as the usage of tools to achieve long term objectives. The type of objectives differs per type of asset owner (Guyatt, 2011).

Second, Asset Liability Management (ALM) is included. This is used by institutional investors to determine their optimal investment strategy (Dietz et al., 2016; Kleynen, 2015). This theory is used to

examine how carbon bubble risk of O&G companies can be valued by the Dutch pension market regarding potential stranded assets. ALM also provides insight in the future financial position of pension provides.

Third, the previous theories will be complemented with the theory on carbon risk valuation for institutional investors (Hultman et al., 2010; Dietz, 2016; Guyatt et al., 2011). To gain more insight into the valuation of oil & gas companies, additional literature will be used on O&G company valuation and carbon risk management (Branco et al., 2012; Levy et al., 2002; Osmundsen et al., 2006; Olsen et al 2011)

The scientific relevance includes the combination of SAA, ALM and theory on the carbon risk assessments. In the emerging theoretical field of carbon risks for corporates, this thesis contributes to the existing work of Subramaniam et al. (2015), Kolk et al. (2001), Bottelho et al. (2014) and Lucas et al. (2015). Building upon Schoenmaker et al. (2015), Dietz et al.(2016), and Van Tilburg et al. (2016), it can give new insights into the different ways of assessing carbon risk, the financial impact of a carbon bubble burst and the role for financial regulators in this. This research can also function as an example to set up similar studies focusing on the carbon bubble risk for pension funds and providers in other countries with the appropriate adjustments.

1.6 Societal relevance

For society an overview of the methods of risk valuation is relevant, since it can prevent the capital people saved for their retirement to evaporate due to wrong allocation of this capital. This research illustrates how much pension funds and providers would lose, focusing on a selected group of O&G companies, if these O&G companies would lose value. This information can be relevant for the Dutch pension participants in understanding to what extent their money is managed in a proper way. To make this more tangible, it relates to the effect is on the debt service coverage ratio, if the assets of oil and gas multinationals would become stranded due to environmental legislation or persistent low oil price on the market. This research is also relevant for pension funds and providers, since they can learn from the different methods used to assess this risk and see how they perform on this compared to the other parties in the market. Especially the risk departments of these organizations can use the information of this research. Regarding a transition towards renewable energy supply, it can incentivize oil and gas multinationals to shift towards more sustainable business practices. Once these institutional investors divest their money from these oil and gas companies, this could trigger them to operate in less carbon-intensive business models. Especially the pension market can have an impact, considering its sizeable investments in the energy industry.

1.7 Outline

As stated, the goal of this research was to investigate how the Dutch pension funds and providers should value the carbon bubble risk of the oil & gas multinationals in their portfolio. In chapter two, the methodology is discussed. An overview of the research methods is depicted, including the different steps in the gathering of the data, the steps in the data analysis and how this contribute to the research question. A literature review is presented in chapter three. This will focus on the carbon bubble and reasons which can cause assets to become stranded. A description of the Dutch pension market is followed by explanation SAA, ALM. Next, the characteristics of the O&G sector are explained, followed by indicators for O&G company valuation and risks. The fourth chapter describes the analysis of the important indicators for valuation of O&G companies. In the next section, chapter five, the implications of COP21 on O&G company valuation are discussed. This is complemented with explanation and implication of the change of the European Directive IORP II and the view of the respondents on the 1.5 ˚C and 2 ˚C target. Chapter six elaborates on two scenarios; *Business as Usual* and a *Carbon Bubble Burst.* Using data of eleven large O&G companies for different indicators, the companies most at risk are identified. This is followed by the results of the interviews on the impact of a carbon bubble burst

on the Dutch pension market and the response to such a bubble burst. In chapter seven, an overview of the risk valuation methods by the Dutch pension market is given followed by the perception of the carbon bubble risk by the Dutch pension market. Next, two cases on characteristics of a bubble are discussed, followed by a section on the pricing of the carbon bubble risk in financial markets. Finally, chapter eight will provide the main conclusions and implications of this thesis, followed by recommendations for public policy, the pension market and financial authorities. Chapter 9 will discuss the quality of the research, with its limitations, possible directions for future research and a personal reflection.

PART II

Conceptualization

2. Methodology

First, the research design of this thesis is discussed, followed by elaboration on the research sub-questions. Section 2.2 elaborates on the different research methods used, how the data was gathered and analyzed.

2.1 Research design

In figure 2, a schematic overview of the different research methods is presented. A literature review is used to define several key-concepts of this thesis. The literature review will include academic sources and elaborates on the relevant theory in this thesis. After the literature review, the scenario analysis was performed. The outcomes of the literature research functioned as a starting point for the scenario analysis. More data was obtained via desk research for this scenario analysis. Part of these first results of this scenario analysis were used for the interviews with the Dutch pension market. The desk research and orientation interviews were also used as input for the interviews with the Dutch pension providers and fund. This information was used to formulate the questions for the interviews and prepare each specific interview regarding data on carbon bubble exposure and risk valuation methods used per pension provider interviewed. Data from the reports obtained via desk research were also used as a context in answering the four different sub-questions. Below figure 2, the reasoning behind the choice of a method per sub-question is discussed.

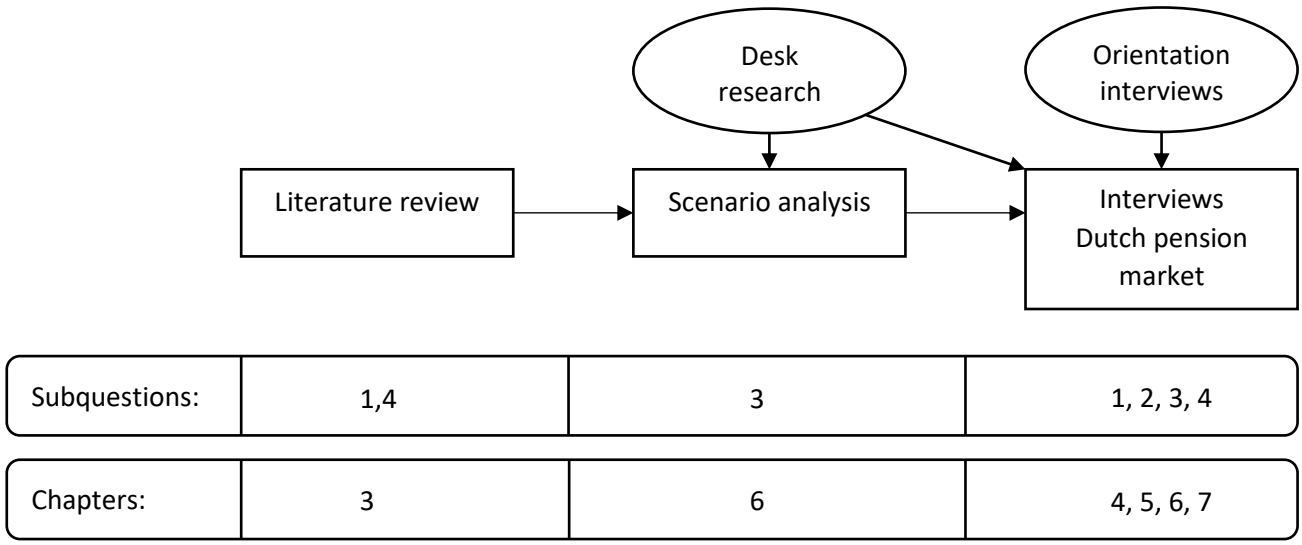

Figure 2: Schematic overview of research design

2.1.1 *How do Dutch pension funds and providers currently value O&G companies?*

To answer how is the risk of a carbon bubble burst currently valued, it is important to explore how and with which variables are O&G companies valued by investors. This was done via literature research and interviews. Literature research was done to obtain academic peer reviewed information on what the most important indicators are. The most comprehensive overview was found in the article *"Valuation of international oil companies"* from Osmundsen et al. (2006). The valuation model in this article was selected since it provides a concise overview of the traditional factors on which International O&G companies are valued. It was published in the *Energy Journal* in 2006. The Energy Journal is an authoritative source of all developments, reviews and info associated to energy[2]. Among the 45 citations, the critical reviews were limited, and not focused on the selection of indicators. The

[2] *The Energy Journal* has an impact factor of 4.29, which indicates an average importance. The impact factor of a journal is a proxy for its importance, based on the number of citations.

model is presented in section 3.7 and its indicators are further elucidated in section 4.3. These most important indicators for the value of an O&G company are also used as input in the scenario analysis. During the interviews these indicators were verified with the pension providers, but first the respondents were asked how they currently value O&G companies, to acquire unbiased information to answer the first sub-question.

2.1.2 *How is COP21 translated into the practices of the Dutch pension funds and providers?*

The second question was answered with desk research and interviews with the Dutch pension market, to see how COP21 is translated into their portfolio management. The annual reports of the pension funds and providers were analyzed, to acquire information on how COP21 was included in their business practices. For regulatory context, desk research focused on legislation in line with COP21, adaptation of EU directives focusing on ESG integration for European pension markets and specification of the French Energy Transition Law. Information obtained via the desk research was used as an input for the interview questions and verified during the interviews with the Dutch pension market. The combination of the desk research and interviews provided a solid combination of methods to answer this sub-question, since the latest data was combined with insights from practitioners in the Dutch pension market.

2.1.3 *What would be the effects for the Dutch pension funds and providers if the O&G companies in their portfolio would decrease in value, due to a potential carbon bubble burst?*

Sub-question three was answered through scenario analysis and interviews with the Dutch pension market. Literature review and desk research provided the necessary input for these methods. Scenario analysis was chosen since it gives an overview of different possibilities of the energy transition and the effects for O&G companies and the Dutch pension market. This is appropriate since this sub-question is based on the hypothetical situation of a carbon bubble burst. To acquire the exact effects for the Dutch pension market, interviews with the pension markets were the most suited to examine the effects. Interviews provided the most accurate information on exposure to O&G companies devaluation, effects and response to a carbon bubble burst, which could not have been available via desk research only. Surveys would have a higher risk of misinterpretation of the questions by the respondents, since explanation was required on the details of this subject.

2.1.4 *How do the Dutch pension funds and providers value the carbon bubble risk of O&G companies in their portfolio?*

The last sub-question was answered with literature research and interviews. Literature research focused on the external risks which can cause the assets of O&G multinationals to strand, and what the internal risks are important for these O&G multinationals. These risks form also the base for the institutional investors, hence the Dutch pension market. The interviews, again with input from desk research, provided the relevant information from the practitioners in the field. The important indicators, data and methods used for the risk valuation of these O&G multinationals were obtained via interviews.

2.2 Research methods

In this section, each research method is discussed, including the argumentation behind the choice of the research methods and how the process was executed.

2.2.1 Literature Research

The usage of academic literature benefitted the academic relevance of the thesis and contributed in identifying the research problem by exploring what research was already conducted before. The literature research was done by collecting articles via search engines Google Scholar and Scopus. Both empirical and review articles are used combining analysis of quantitative and qualitative nature. Search terms included possible combinations of:
fossil fuels, divestment, oil, gas, energy transition, carbon risk, carbon bubble, institutional investors, pension funds, oil and gas, strategic assets allocation, asset liability management, stranded assets.

Additional articles were found via the bibliography sections of those search results. Based on the results of those second search phase, new articles were found in the bibliography sections. This process was repeated until no new relevant literature resulted from these search activities. The articles used were predominantly published in journals focusing on energy, finance, climate change or business & economics. The articles used were analyzed using the computer program Mendeley, which helped to structure, highlight and add notes to the literature used.

2.2.2 Desk research

The desk research was of added value as its results provided the most recent information available on this topic. Regarding the rapid developments in this field, not all relevant information could be obtained via peer reviewed academic sources. The desk research consisted of research for both quantitative and qualitative data, in business reports, annual reports, energy outlooks from different agencies, or reports from data providers focusing on the energy and financial industry. Also information on relevant laws and regulations on national, European and global level was obtained via desk research. Data on actual price levels of commodities was found via renowned websites depicting the different levels at different periods in time. In the table below, an overview of the different reports used with desk research is presented. Reports obtained via the desk research differed in source. The distinction between academic literature and other reports research was made based upon the source of the report. Peer reviewed articles published in journals are categorized as academic literature. Also, white papers were categorized as academic literature. Table 3 provides an overview of report sources resulted from the desk research These reports were found via searching the web with the subject terms, via the references of other reports, or recommended by people who were involved during the writing process of this thesis.

table 3: Overview of the reports per subject resulted from the desk research

Subject	Report	Source
Financial data & ESG data	Annual reports of the interviewed pension providers	Websites pension providers
	Annual report of the interviewed pension fund	Website pension fund
	In the pipeline	CDP, 2016
	CSR reports and websites of O&G companies	Websites 11 O&G companies
	Financial data	Database Factiva, 2016
	Projected costs of generating Electricity	IEA, 2015
	Crude oil prices	Macrotrends, 2016

	Trends of the Dutch institutional market	Dutch investment management survey, 2015
	EFAMA Report on responsible investment	EFAMA, 2016
	Global Pension Assets Study 2017	Towers Watson, 2017
	Dubai doubling size of power plant to make cheapest energy	Bloomberg, 2016
	Pensioenfondsen; Financiele gegevens	CBS, 2016
	Benchmark Responsible Investment by Pension Funds in the Netherlands 2015 Bridging the Gap	Verstappen et al., 2015 (VBDO)
	Global Pension funds. Best practices in the pension fund investment process.	PWC, 2016
	Pension markets in focus	OECD, 2015a
Legal data	Resource Efficiency and Fiduciary Duties of Investors | ENV.F.1/ETU/2014/0002 DG Environment	European Commission, 2014
	Outcomes of the UN climate change conference in Paris	UNFCC, 2015
	IORP II Directive	Pensions Europe, 2016
	French Energy Transition Law	UNPRI, 2016
	Directive (EU) 2016/2341 of the European Parliament and of the Council	European Parliament, 2016
O&G industry data	O&G industry report	MSCI, 2016
	In the pipeline	CDP, 2016
	Annual report on form 20-F	Statoil, 2015
	Oil & carbon revisited - Value at Risk from 'unburnable' reserves	Robins et al., 2013 (HSBC)
	Upstream fundamentals	Accenture Consulting, 2016
	O&G; The Valuation Risks of 'Stranded Assets' are Much Exaggerated	Morgan Stanley, 2016
	Global implications of lower oil prices	Hussain et al., 2015 (IMF)
	Oil & Gas reality check	Deloitte, 2015
	BP Statistical review of World Energy 2016	BP, 2016
	Carbon Risk in O&G assets	Schroders, 2016
Energy outlooks & scenarios	World energy scenarios	World Energy Council, 2016
	BP energy outlook 2017	BP, 2017
	COP 21: het vervolg	BNP Paribas, 2016
	Climate change scenarios- implications for strategic asset allocation	Guyat et al., 2011 (Mercer)
	World Energy Outlook 2016	IEA, 2016
	Stranded Carbon assets	Generation foundation, 2013
	Pathways To Net-Zero Emissions. Better Life With a Healthy Planet; a new lens scenario supplement	Shell, 2016
	New lenses mountains and oceans	Shell, 2013
	Bloomberg Carbon Risk Valuation Tool In	Bloomberg, 2013

2.2.3 Scenario Analysis

Scenario analysis is a useful tool to assess the implications of future possible situations. Most of the climate risk assessments used by investors are based on backward looking data. However, this data does not accurately reflect the risks associated with climate change, since data on GHGs like CO_2 emissions is often lacking or not considered reliable. This increases the probability that climate risks are underestimated in the assessments of investors. Scenario analysis is a suited approach to assess risks like the impact of a potential carbon bubble burst on O&G companies, since it includes the implications of future possible risks.

Besides, it provides insight to the possible different development paths which lead to diverse future outcomes. Since it is not an extrapolation of certain trends, it can reveal scenarios which are normally underexposed or not taken into account at all. This scenario analysis contributed to identifying the relevant indicators and drivers in the case of a potential carbon bubble burst.

Different scenarios of the IPCC (2014) and IEA (2014) were studied before developing the two different scenarios. Two previous studies on the Value At Risk for O&G companies were compared, to distinguish important factors for the impact of a carbon bubble burst. Two scenarios were developed: The first scenario focused on a gradual energy transition without a carbon bubble burst. This was called B*usiness as Usual.* The other scenario assumed an abrupt energy transition and a *Carbon Bubble Burst*.

For the scenario analysis, a sample of 11 O&G companies was used. Since these 11 companies equaled to 25% of the market capitalization of all fossil fuel companies and roughly 25% of the global O&G supply, it provided a respectable sample size. Furthermore, pension providers mainly invest in large caps which are included in indices like the MSCI, which also contributed to the relevance of this sample.

The indicators were selected based on the key characteristics of each scenario, the outcomes of the literature reviews and interviews, and the availability of indicator data for the eleven O&G companies. The aim was to make the indicators per scenario mutually exclusive and collectively exhaustive. The eleven O&G companies were scored on each indicator between 1 and 11, indicating a low or a high risk per scenario. This resulted in a ranking of which O&G companies are most at risk per scenario. To correct for the weight of multiple similar indicators, the average ranking of these indicators was calculated[3]. From the average ranking of each scenario, the three O&G companies performing worst in class were marked as highest investment risk. An overview of the scenarios, important factors and indicators can be found in table 4. Elaboration on the scenarios, the key factors and the selection of the indicators is provided in chapter 6.

Why worst in class method?

In each of the two scenarios, the three worst performing O&G companies are selected. Since this research focuses on the carbon bubble risks in pension portfolios, this method of comparing was selected to show which O&G companies are the worst in class in both scenarios. The method was adapted from best in class method from Dym et al. (2014). A drawback of this method is that small differences between the O&G companies are not taken into account. This means that companies performing just a little bit better than the worst three in class are not marked with a high risk.

However, the method was chosen to obtain a clear overview of which O&G companies are considered high risk investments in each scenario. Since pension providers Identifying the worst performing

[3] For example the indicator Costs: a ranking on F&D costs and a ranking on O&M costs was constructed of the values of the 11 O&G companies, to develop the average ranking.

companies among its peers is also an investment strategy towards portfolio optimization (Black & Litterman, 1992). More recently, it became one of the dominant strategies for investors aiming for ESG integration (Andersson et al., 2015; Nagy et al., 2013; Peiró-Signes et al, 2012). Investors can use this to stimulate the other companies in their portfolio to strive for a lower carbon footprint or to be more cost efficient. According to Andersson et al. (2015), this does not necessarily propose exclusion. Underweighting of the high-carbon-footprint stocks is also an alternative. In both alternatives, this strategy facilitates a race towards sustainability among the companies in the portfolios.

Besides the academic literature, some asset managers are also applying this strategy to their portfolio to integrate ESG risks and stimulate ESG performance among companies. Robecosam (2016) uses the worst in class rank as one of the benchmarks in its sustainability practices to assess companies. ACTIAM excludes the *''worst* offenders'' which have high ESG risks related to for instance carbon emissions, and/or strategies which are not in line with the energy transition policy of ACTIAM (ACTIAM, 2016). This leads to decrease in carbon-related risks and stimulation of investments in the climate change frontrunners.

table 4:Overview of scenarios, key factors, and indicators used with source.

Scenarios	**Key factors of scenario**	**Indicators (source)**
1. Business as usual	- Ability of O&G company to fulfill rising fossil fuel energy demand	- Current production levels (CDP, 2016) - Proven reserves (CDP, 2016) - Reserve production ratio (CDP, 2016) - Reserve Replacement Ratio (CDP, 2016) - Return on investment (Factiva, 2016)
2.Carbon bubble burst	- Burnable carbon for O&G company	- Operation costs + Finding & Development costs (CDP, 2016) - Emission intensity per proven reserves per O&G company (MSCI, 2016) - Share of stranded assets in 1.5 ˚C temperature increase (IPCC, 2014; CDP, 2016; IEA, 2017). - Regulatory risk of geographical spread of proven reserves per O&G company (CDP,2016; MSCI, 2016)
	- Adaptability of O&G company	- Alternative energy assets & investments (CSR reports O&G company websites) - Proven Reserves (CDP, 2016) - Debt/equity ratio (Factiva, 2016) - Cashflow / CAPEX (Factiva, 2016)

2.2.4 Interviews

Respondents of the interviews

Interviews were used to obtain more information from experts in this field, essential in answering the research sub-questions of this thesis. To acquire more information on the carbon bubble risk in the Dutch pension market, seven interviews with people with expertise on this subject were carried out before the interviews with respondents of the pension fund and providers. The information from these preliminary interviews were also used to scope the sub-questions of this research, and test the questions which were asked during the interviews with the Dutch pension providers. Specifications of the seven preliminary interviews are depicted in table 5.

Table 5: Preliminary interviews with other relevant organizations

Organizations	**Expertise of organization**	**Function of respondent**
VBDO	Representation of sustainable investors	Senior Project Manager
DNB	Regulating financial entity	Program lead climate risk
Accenture (4 interviews)	Consultancy	Consultant Company Valuation (Brussel)
		Consultant Business Strategy (Amsterdam)
		Management Consultant Resources (Amsterdam)
		Consultant Company Valuation (Amsterdam)
Sustainalytics	Provider and analysis of sustainable data	Carbon Team Manager

Potential interview respondents in the Dutch pension market were approached via LinkedIn, email, telephone, at events related to climate risks for investors, or via other people. One-month free membership of LinkedIn premium allowed to send messages to potential respondents without the need for a direct connection to their professional network. The response rate was approximately 30%, approaching multiple potential respondents per organization. Most responses resulted in the contact information of a colleague who was then approached via email or telephone.

The five biggest pension funds in the Netherlands were approached multiple times, since these have most exposure to carbon bubble risk and the mandate of the pension money (DNB, 2016a). From ABP, Zorg & Welzijn, PMT and PME BPFBouw only one pension fund was open for an interview. The main response was that the pension providers had the relevant knowledge on this subject, or no response was provided.
Instead of the interviews with the pension funds, more pension providers were interviewed. Nine of the eleven biggest pension providers in the Netherlands were interviewed (DutchInvestor, 2015). Blackrock and Robeco (ranked 3rd and 6th based on Assets under Management (DutchInvestor, 2015), were not interviewed due to the time constraints of this research and a lack of response. Some of the interviewed respondents are asset managers, which have not only pension funds as clients. The total assets under management of the interviewed respondents comprised of 990 billion euros. Table 6

gives an overview of the interviewed organizations in the Dutch pension market. The name of the Dutch pension fund is not provided for confidentiality reasons.

Table 6: Respondents interviewed, pension providers & fund

Pension Provider	**Main Clients**	**Assets under Management (billions €)**
APG	ABP & BpfBouw	433
PGGM	PFZW	183
Achmea Investment Management	Achmea & others	100
MN	PMT & PME	92
Actiam	Various clients	52
TKPI [4]	Various clients	23
Aegon asset management	Various clients	58
NNIP	Various clients	61
Delta Lloyd asset management	Various clients	46
	Total	**990**
Pension Fund		
One large pension fund		

The interviewed respondents hold a variety of positions. In table 7 below, the functions of the nine providers and pension fund interviewed are depicted, in the order of the transcriptions in the additional report.

[4] TKPI is part of Aegon asset management, hence only TKPI is included in the sum of total assets under management.

Table 7: Overview titles and functions of respondents, their years in function, durations of the interviews and pages in the Transcription report.

Job title of respondents	**Years in current role**	**Function**	**length of interview**	**Interview date**	**Pages in transcription report**
1.Senior advisor investments 2.Senior policy advisor	3 4	1.Advice on investments decisions for portfolios 2.Managing development and implementation of responsible investment policy	34:14	15-12-2016	2-7
ESG analyst	4	Analyze ESG data of companies in portfolio, how these companies are improving and methodology for responsible investment	1:13:19	30-11-2016	8-17
Advisor Responsible investment	6	Advice and clients on responsible investment, monitor and develop internal ESG strategy and determine relevant instruments	56:24	7-12-2016	18-26
Responsible investment manager	2	Part of sustainable investments team, lobby for international climate regulation and contact person for engagement with O&G companies	46:43	12-12-2016	27-34
1.Senior account manager 2.Investment strategy analyst	6 2	1.Link between clients (funds) and organization, focus on desire and need of responsible investment 2.SAA & ALM analyses, advice on investment plans and risk monitoring	37:37	13-12-2016	35-40
Head risk analysis	8	Manage risk department, discuss risks with pension funds	1:03:08	14-12-2016	41-50
Senior portfolio manager energy	5	Manage portfolio of energy & utilities	45:59	16-12-2016	51-59
Senior Investment Analyst energy	8	Analyze energy market and advise portfolio manager on investment decisions	52:13	11-01-2017	60-66
Global Head of Responsible Investment	5	Focus on all sustainability related matters on global level	58:34	12-01-2017	67-76
Strategy consultant sustainability	3	Lead a project on how to integrate ESG data in financial portfolio and how to create a more sustainable portfolio with return.	42:50	19-01-2017	77-86

Relevance of respondents

Once the contact with an organization was established, the preference for a respondent with knowledge on O&G company valuation and carbon bubble risk expertise, was communicated to the contact person. This resulted in a group of respondents with diverse job titles. The functions of the respondents can be divided into four categories of specialization:

1. Responsible investments specialists (ESG analyst, Responsible investment manager/advisor, sustainability consultant, head of responsible investment, Project leader change management)
2. Risk specialists (Head risk analysis)
3. Financial specialists (Investment strategy analyst, Senior advisor investments, Senior account manager)
4. Energy specialists (Senior portfolio manager energy, Senior Investment Analyst energy)

Since each of these categories were important in the various sub-questions, the interviewed respondents provided a solid sample to answer the different interview questions. The interview question on O&G company valuation were most elaborately answered by the specialists in energy. Questions related to ALM and SAA studies were answered most in detail by the respondents with financial specialization. The risk specialists and energy specialists were most adequate in formulating the answers related to the carbon bubble risk. The responsible investment specialists were best informed on the impact of COP21 and the methodology and indicators for scoring O&G companies on ESG.[5] When answers to interview questions could not be answered during the interview, the specific questions were mailed to the respondent, so they could consult with one of their colleagues before answering the question via email.

Respondents with more years of experience did not necessarily provided better answers to the questions compared to less experienced respondents. From the interviews resulted that most responsible investment specialists (except one) were most critical about O&G companies and thought carbon risks were currently not priced into the markets. The other category respondents had a more return oriented view.

Analysis of interviews

The book ''Interview *in Qualitative research''* from Nigel King and Christine Horrocks was used as a handbook for conducting accurate qualitative research. Interviews with the Dutch pension market were recorded and transcribed before analysis. The preliminary interviews were summarized instead of literally transcribed, due to the lower density of relevant information.

Interviews were recorded with the app Smart Voice Recorder and transcribed in Microsoft Word before analysis. Subsequently, they were verified with the results of the literature research. The comment function in Microsoft Word was used for coding of the transcriptions. The coding scheme distinguished between the different types of answers provided, grouped per sub-question. Categories will be specified further after conduction of the interviews. The categories included:

1. O&G Valuation: Indicators, ALM/SAA, Investment view, Exposure O&G, Active/passive management
2. COP21: valuation change, Impact of COP21, Regulation effect, 1.5 & 2 ˚C target
3. Carbon bubble burst: Effect, Response Carbon Bubble Burst, Dividend and Debt , Arctic projects

[5] This is based upon the job title and function description of the respondents, the level of detail and comprehensiveness of the answers in the transcription report and the personal view of the researcher after conducting the interviews.

4. Carbon bubble risk: Carbon bubble risk valuation, risk methods, Risk indicators, risk weight, priced carbon bubble risk, improvements
5. Additional codes: Data, transition, fund vs provider, divestment time, model valuation Osmundsen.

The semi-structured interview list and an explanation of the codes can be found in Appendix I & Appendix II. The names of the respondents and companies are not presented with the quotes from the interviews in the result section, as agreed upon with the respondents. The full report with transcriptions and codes is, anonymized, available upon request. The summaries of the preliminary interviews can be found in the second part of that report. In chapters 4-7, the results and quotes are followed by page numbers, which refers to the pages in the report with the transcriptions. Four respondents emailed the answers to specific questions later, after consulting one of their colleagues. The answers to these questions are also added in the transcription report. The quotes used in chapters 4-7, were translated from Dutch to English and occasionally paraphrased to provide extra context of the specific question.

2.2.5 Case studies

During the interviews with the pension fund and pension providers, two concise case studies were done. This was to acquire more specific information on two characteristics which make bubbles prone for a financial crisis, as described in the literature (Schoenmaker et al. (2015). The role of the case studies was to examine to what extent the characteristics ''*capital intensive assets*'' and ''*high debt levels*'' are in line with the current trends in the O&G industry and what the view of the respondents was on this. To compare the views of the respondents and prevent too diverse and generic answers, the cases focused on one O&G company. Royal Dutch Shell was chosen, since most Dutch pension funds and providers have shares in Shell and to provide extra Dutch context to the cases. Besides, the two bubble characteristics were both applicable to Shell. In addition to its previous explorations in the Arctic with high associated costs and risks, Shell had a net debt of 70 billion euros and was lending money to pay a constant dividend to its shareholders. Both were discussed during an interview with the CEO of Shell, Ben van Beurden, in a Dutch Newspaper *''Het Financieel Dagblad''* in the month before the interviews (Van Dijk, 2016). The recent publicity increased the probability of obtaining specific information from the respondents on the two topics.

3. Literature Review

In this chapter, the carbon bubble risk is specified. The different reasons why assets of O&G companies can become stranded due to a carbon bubble burst is discussed, followed by characteristics of the Dutch pension market. Next, the academic literature on Strategic Asset Allocation is discussed, complemented with the theory of Asset and Liability Management (ALM) for pension funds and the determinants which determine the valuation of O&G companies. An overview of the different internal risks for O&G companies described in the literature is then presented. The final section summarizes the key findings of this chapter.

3.1 Climate risk: The carbon bubble

Climate risk is a systemic risk, since it can influence the complete financial system (Guyatt, 2011; Schoenmaker et al., 2015). Regarding the risk in the longer term, the risk-based approach should focus equally or even more on strategy of a company in the future compared to its current performance (Sorensen et al., 2011). Since the costs of climate change are postponed to future generations, the negative externalities of climate change are not incorporated in most of the current business models. According to the *Stern review* (2006), this makes climate change the greatest market failure of the history. The impact of the climate change risk for investors and the time span at which this will occur is also dependent on the implementation of a governmental regulation. If these negative externalities will be priced abruptly, assets can strand due to a loss in value (Schoenmaker et al., 2015; Ritchie et al., 2015). Battiston et al. (2016) did a climate stress-test on the financial system using data from the Euro Area. They found that direct exposures to the fossil fuel sector are minor (3-12%). The combined exposures to sectors susceptible for climate-policy are, however, large (40-54%). These effects are heterogeneous and enlarged by substantial indirect exposures via financial counterparties (30-40%) (Battiston et al., 2016). An overview of different types of climate risks and the related financial impacts identified by the Task Force on Climate-related Financial Disclosures of the Financial Stability Board[6] (FSB) is given in Appendix III.

The carbon bubble is a specific form of a climate risk. Carbon bubble risk can be defined as: ''*The financial exposure to fossil fuel companies that would experience impairments from assets stranded by policy, economics or innovation.''* (Ritchie et al. 2015. p.59). Economics can either include market forces of low fossil fuel prices, or divestments due to pressure from shareholders or the public.

Schoenmaker et al. (2015), investigated the different criteria present in different asset classes which affected the financial markets. Existing studies have been done regarding the housing bubble, shipping bubble and dotcom bubble. Based on literature research, they identified four asset criteria present in the housing bubble which induced the financial crisis, depicted in table 8 (Reinhart and Rogoff, 2009; Claessens et al, 2011). The asset criteria are: long-lived maturity, capital intensiveness, economic share and debt financed. All four need to be present to be crisis prone. The shipping bubble occurred after the financial crisis of 2008. Due to a collapse of global trade, the production of cargo vessels fell. The dotcom bubble burst between 1999 and 2001. Numerous companies emerged on the internet, but eventually many of these firms in the information and communication technology industry turned out to be overvalued.

Although the housing market and the fossil fuel market are not analogous, both asset classes have all the criteria which makes them crisis prone. The long-lived maturity of the asset shows a sudden change in the services can induce a price decrease, since services in the future will become less interesting.

[6] The Financial Stability Board is an international organization which monitors the global financial system and provides recommendations to decrease its vulnerabilities.

Capital intensive assets induce a reallocation in the economy once cost price exceeds the market price. The economic share of the asset class depicts what part of the economy is affected. The amount of debt-financed is the fourth indicator which makes an asset class sensitive to financial shocks. The pressure of low prices induces the cutting of costs, by trying to sell more of the asset which function as a backing of the debt (Schoenmaker et al., 2015; Domanski, 2015).

Table 8: Criteria for financial crisis sensitivity of asset classes. Source: Schoenmaker et al., (2015) p.16

Criteria	Housing	Shipping	Dotcom	Carbon
1. Long-lived	✓	✓	✓	✓
2. Capital intensive	✓	✓	✓	✓
3. Economic share	✓	×	✓	✓
4. Debt-financed	✓	✓	×	✓
Crisis prone	**Yes**	**No**	**No**	**Yes**

Guyatt et al. (2009) address the short-term perspective of the financial system, with the inappropriate pricing of negative externalities like climate change. Sethi (2005) & Reboredo et al. (2015), showed that the way future risks are assessed by these pension funds overlooks or underestimates the risks in the long term. This is explained by the natural short-term bias of the financial intermediaries, which are rewarded mainly on their short-term performance. In addition, they find divesting from weak performing companies difficult, regarding the consequences of destabilizing overall markets. Barton et al. (2014) found board members in financial markets have significant pressures to maximize results on the short-term. Among 1000 board members 44 percent declared to focus on a perspective less than 3 years to set the strategy, while 73 percent stated a perspective longer than three years should be pursued. This exemplifies that the short-term horizon present in the financial system, is far from optimal towards assessing the climate risks in the future. Next, the reasons why assets of companies operating in the fossil fuel industry can strand are discussed.

3.2 External risks which can cause stranded assets

An asset can be anything, tangible or intangible, of value for an individual, enterprise or country (ISO27000, 2014). When referring exclusively to carbon assets, this thesis focuses on the assets which contain carbon itself, the reserves, or the assets which are used to extract, process or transport the oil or gas products. This can be for instance surface facilities, equipment and infrastructure like pipelines and installations, systems and seismic data, off-shore drilling platforms, storage units or other carbon related infrastructures. OECD (2015b, p.5) uses the following definition for stranded assets: *"assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities''.*

If we take into account that not all the reserves can be burned, these assets of the O&G companies are overvalued and can hence strand. The studies estimating how much carbon can be burned, also referred to as the carbon budget, diverge. According to the IPCC, 275 Giga tonnes of Carbon is the maximum from the total reserves in the world of fossil fuels of 746Gt can only be burned this century to stay below the 2 ˚C (IPCC, 2013). Investigation among the proven reserves of companies that

produced 63 percent of the fossil fuels in the world between 1750 and 2010 (Heede, 2014) shows, that production of these reserves will result in 440 GtC of carbon dioxide. This corresponds to 160 percent of the burnable 275 GtC described by the IPCC (Heede, 2014). Other studies using data from 2013-2050 show, that the world's listed oil, gas, and coal firms have 1541 Gigatons of CO_2 in their proved and potential reserves, of which only 269 Gigatons can be burned securely for temperatures to have a 50 percent chance of not exceeding the 2 °C above the pre-industrial levels. Aiming for 80 percent certainty would relate to 225 Gigatones of CO_2 (Leaton et al., 2013). More recently, the research of McGlade et al. (2015) published in the journal Nature found via single integrated assessment modelling using scenarios for the geographical distribution, that 88% of coal reserves, 52% of the gas reserves and 35% of the oil reserves must remain in the ground before 2050. Robins (2014) and Andersson et al. (2015) state that climate targets, like the 2 ˚C limit, are not part of the market valuations of these O&G companies and these valuations under-price carbon risk. This results in a potential over-valuation of their assets, which can cause them to strand. Think tank Carbon Tracker initiative (2015) published a report which showed some of the major oil companies face the risk of losing collectively $2.2 trillion because of overestimated demands and surplus supplies driving down prices. Pemex has the highest risk, with a potential $77 billion loss over the next 10 years, after that Shell ($76.9 billion), Exxon Mobil ($72.9 billion), Rosneft ($53.3 billion), and BP ($45.5 billion). Companies in the energy sector from the United States are most exposed to this risk, with $412 billion of potential stranded assets by 2025, followed by Canada ($220 billion), China ($179 billion), Russia ($147 billion), and Australia ($103 billion) (Carbon Tracker initiative, 2015). These developments can have consequences for firms operating in the energy industry. For decades, these large enterprises supplied the increasing world energy demand of the growing population by extracting these depleting resources from the ground. However, if these O&G companies aim to continue their growth and existence, they need to ensure they have the appropriate strategies to mitigate these risks.

In the literature, four types of risk (regulatory, market, innovation and socio-political) are distinguished, which can lead to the stranding of the assets of coal, oil and gas companies. As shown in the following sup-chapters, the types of risks are interrelated. For example; regulations implemented have an effect on the market and the socio-political pressures as well (Generation Foundation, 2013; Halle et al., 2014; Helm, 2016; Sussams et al., 2015; Van der Ploeg, 2016; Weber et al., 2015).

3.2.1 Regulatory risks

First, regulation, in both a direct and indirect way. Direct regulation can be enforced by local, regional, national or supranational authorities and address the control of carbon emissions per corporation. Examples include the cap and trade mechanisms, like the Emission Trading System (ETS) used in Europe (Levy et al., 2002; Busch et al., 2006; Labatt et al., 2011). Indirect regulation can comprise pollution controls, renewable energy standards which need to be met, efficiency threshold regarding carbon foot printing and the control of water usage, which is predicted to be more scarce in the future and is used during the fossil fuel extraction process and operational processes of power plants. Other policies can be targeted at health concerns (Van der Ploeg, 2016; Sussams et al., 2015; Labatt et al., 2011).

3.2.2 Market risks

Market forces are a second type of risk described in the literature which can cause assets to strand (Helm, 2016; Lucas, 2016; Van der Ploeg, 2016; Weber et al., 2015). Oil prices reached a historic low price of $33.65 per barrel in January 2016 (Macrotrends, 2016). This is partly related to the development of competitive substitutes. Developments in the shale oil and shale gas sector regarding hydraulic fracturing and horizontal drilling the last twenty years caused an expansion of this market.

The rise of Liquefied Natural Gas (LNG) which can be transported costs efficiently without pipelines also contributed to the fact that some countries, like the US, can become a net energy exporter instead of net energy importer (van der Ploeg, 2016). The costs of extraction increase, as newer fields are located deeper under the crust of the earth and are becoming increasingly difficult to reach. Upstream capital expenditure by oil majors rose by 450% in the period between 2000 and 2012 (Weijermars et al., 2014). Lower demand in fossil fuels compared to expected levels, or over supply also effects the value of these assets. Besides, O&G companies might frontload their reserves more quickly, since the value they can get from it on the market now, is higher than in the future. In this case, the falling fossil fuel price due to oversupply will become self-fulfilling (Helm, 2016; Sinn, 2008). Other market forces, like geopolitical dynamics and competition can also influence the risk of stranded assets of an O&G company (Rubin, 2015; Van de Graaf et al., 2015).

3.2.3 Risk of technological Innovation

Technological innovation in substitutes or increasing the energy efficiency in sectors can lead to stranded assets for O&G companies. Renewable energy technologies are becoming competitive without subsidies and global installed capacity is growing (Hong et al., 2013; Van der Ploeg, 2016). China, estimated to contribute to 50% of the growth in global CO_2 emissions by 2035, has recently scaled up their renewable targets for 2020 to 150 GW of solar power, 200 GW of wind, 350 GW of hydro and their target of nuclear power to 58 GW (Hong et al., 2013). The Dubai Electricity and Water Authority (DEWA) announced they will have 1000 MW of solar energy installed by 2030. These increasing productions have led to significant scale and learning advantage. These developments have resulted in available electricity costs of 5.84 dollar cents per KWh, the lowest cost of electricity produced by photovoltaics so far (Bloomberg, 2016b; Juaidi et al., 2016). This is considered a major breakthrough, comparing it with the Levelised Costs Of Electricity production of conventional sources, with approximately 10 dollar cents for gas and 8.5 dollar cents for coal fired power plants respectively (EIA, 2015; IEA, 2015[7]). Besides other energy sources, innovation which increases the energy efficiency can reduce the demand for fossil fuels and lead to stranded assets. Innovations in the energy efficiency of sectors as materials and buildings, transportation and heavy industries could have significant impact on the fossil fuel demand (Johnson et al., 2015).

3.2.4 Risk of socio-political pressure

A fourth risk are socio-political pressures. Divestment campaigns are growing in size and quantity (Schneider, 2015; Ritchie et al., 2015). In the form of environmental protests and supports, these can result in a shift of the public opinion which in turn leads to a devaluation of these assets. The increasing need for transparency and global tendency towards corporate responsibility requires firms to be more conscious of the environmental impact of their activities. Large investment parties like pension funds, governments, investment funds, banks and insurers, are more and more aware of the pressure to have a sustainable and transparent portfolio (Ansar et al., 2013; Generation Foundation, 2013; Sussams et al., 2015, Van der Ploeg, 2016; Weyzig et al., 2014). In September 2014, 181 institutions, local governments and individuals in the United States pledged to divest fossil fuels assets worth 50 billion dollars, which equals to 81 percent of their total asset value (Schwartz, 2014). At the UN Climate

[7] Report Projected Costs of Generating Electricity(IEA, 2015). The LCOE calculations are based on a levelised average lifetime cost approach, using the discounted rate of 7 %. The calculations use a combination of generic, country-specific and technology-specific assumptions for the various technical and economic parameters, as agreed by the Expert Group on Projected Costs of Generating Electricity (EGC Expert Group).

Summit in 2014, both private and public investors collectively pledged to invest their assets with a combined total value of $24 trillion in preventing climate change (Kidney, 2015). In the US, the green bond market quadrupled to 430 million dollars from 2012 to 2013 (van Renssen, 2014). This exemplifies there is already a positive view of the world's largest investors in investing their capital in climate related bonds or projects as an opportunity, instead of fossil fuel related investments. Next to the opportunities of green investments, it is possible that the fear of asset managers will lead to large divestments (Kiyar et al, 2015). Figure 3 shows schematically the different risks which can lead to stranded assets for O&G companies, which can eventually lead to a carbon bubble burst.

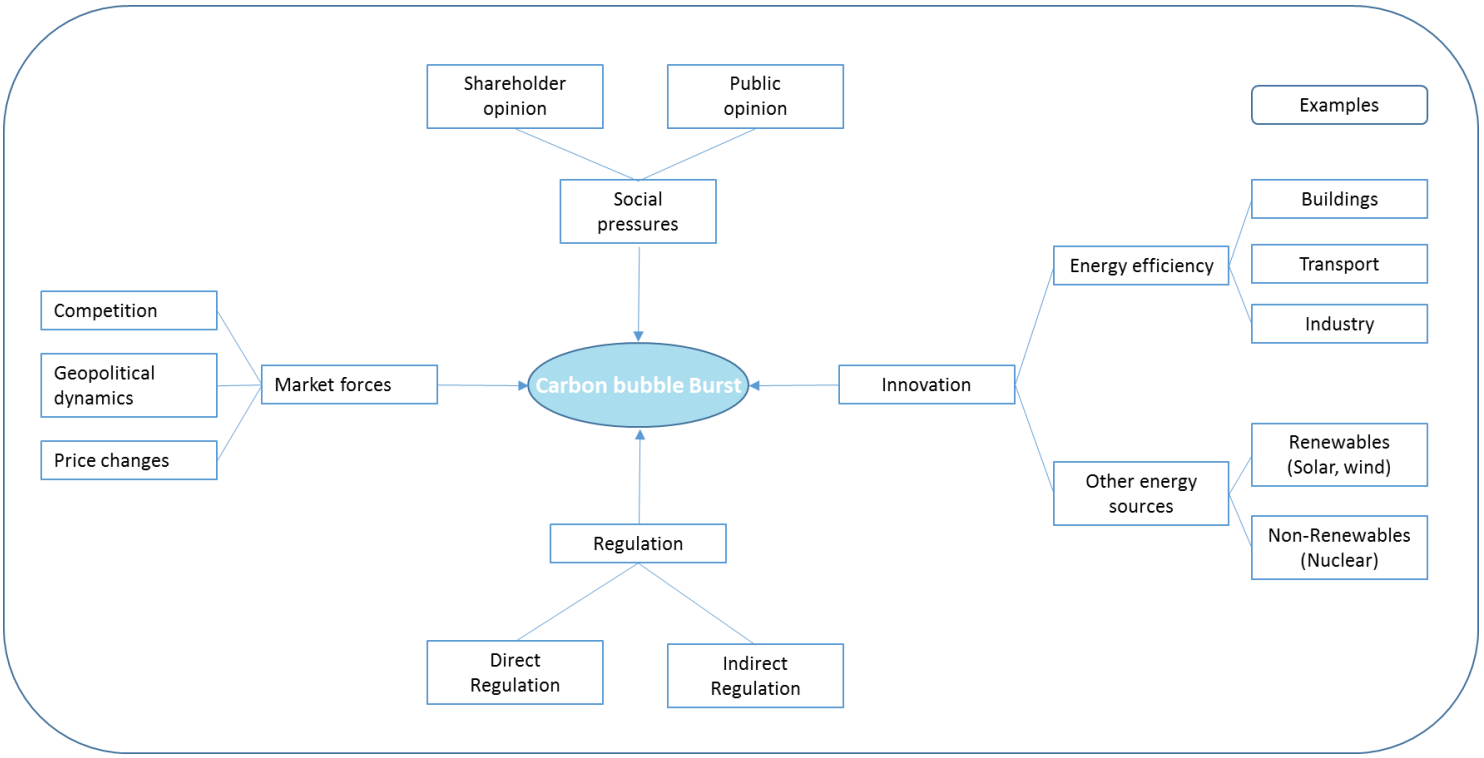

Figure 3: Overview of risk factors for stranded assets for O&G companies which can lead to a carbon bubble burst.

3.3 The Dutch pension market

Actors and regulation in the Dutch pension market

In this research, the Dutch pension market is defined as the pension funds and pension providers. The pension participants in the Netherlands pay a share of their income to the pension fund. Dutch citizens in the labor market[8] pay compulsory pension contributions via their employers. This implies they have no free choice regarding which pension fund administers their retirement money. While the capital is administered by the pension fund, the capital is managed by the pension provider of the fund. Different funds can have their capital managed by the same pension provider, which makes the investment decisions. Based upon own analysis and external information from data providers, the pension providers try to generate as much return for the lowest risk. Different interest groups serve the interest of the funds, providers or pension participants. These actors and the most important financial authorities which affect the Dutch pension market are depicted in figure 4 below.

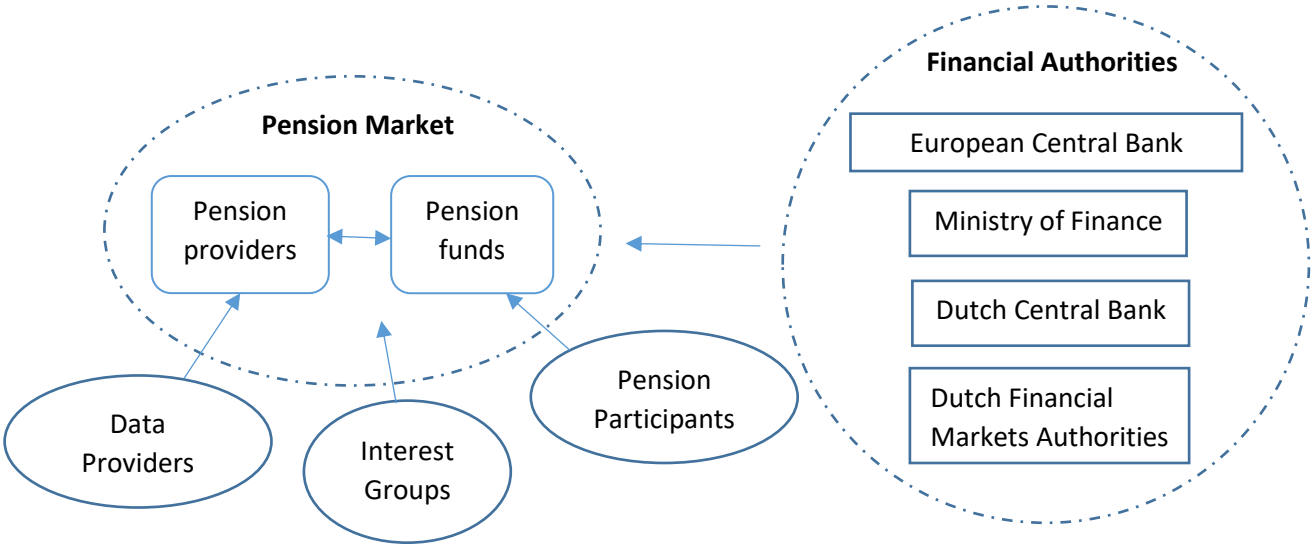

Figure 4:Overview of actors related to the pension market and the financial authorities

In the table 9 the most important roles of the different actors are described. The European Central Bank is the financial authority on the highest level. To ensure these pension funds and providers can meet their obligations to pay in the future, they are controlled by the DNB & AFM. The regulatory requirements for Dutch pension funds can be divided in three categories. The supervision related to the financial stability (prudential supervision), the provision of the information to the interested parties like insurers (behavioral supervision) and the monitoring of the statutes and pension regulations (material supervision). AFM is responsible for the behavioral supervision, DNB is responsible for prudential supervision and material supervision (DNB, 2014). To ensure these funds can comply with their future financial requirements, they must comply with a debt service coverage ratio, which is calculated monthly. There is no competition in the Dutch pension market. This implies citizens have to trust the pension funds and providers, assigned by sector or company, to invests their money safe and meet the fiduciary requirement to their clients based on the prudent person rule in Article 135 of the Dutch Pension Law (DNB, 2015).

[8] This excludes the self-employed

Table 9: Role of related actors in the Dutch pension market

Organization	Role
Pension Participants	Pays part of its earnings to the pension fund associated with its occupation
Pension funds	Administers pension money of its pension participants
Pension providers / asset managers	Manages the money of the pension fund
European Central Bank (ECB)	Supervision of financial sector on European level
Ministry of Finance	Responsible of the functioning of the Dutch financial system, for the laws and regulation in the Dutch financial markets.
Dutch Central Bank (DNB)	Prudential supervision of financial sector in the Netherlands
Dutch Financial Markets Authorities (AFM)	Supervises the transparency trustworthiness of processes in the Dutch financial markets
Data Providers	Provide data and analyses for the investment decisions of the asset managers
Interest groups	Serve the interests of organizations or people in the pension market

Asset allocation in the Dutch pension market

The total assets of Dutch pension funds comprised a total value of 1175.7 billion euros in 2015 (CBS, 2016). Research of Tower Watson presented a value over 1,300 euro in 2016 (Towers Watson, 2017). Research of the OECD showed that in 2014 among the global pension markets, the Netherlands had the highest asset-to-GDP ratio with 159.3% (OECD, 2015a). In the last 2 decades, the total capital of the Dutch pensions has been increasing while the number of pension funds decreased. This consolidation in the Dutch pension market is mainly driven by efficiency gains. Research of the last two decades in the Dutch pension market showed that more participants per pension organization lead to efficiency gains. This leads to lower costs of pension management, until 2.5 million participants per organization. On average, cost reduction of 0.25 percentage point over a period of 40 years lead to 7.5% more return per pension plan (Klopper et al., 2013). In figure 5 the average allocation of the different types of asset classes of the five largest Dutch pension funds[9] for the year 2015 is presented (PWC, 2016). In the last 5 years, the total assets of the funds increased to a total of 713 in assets under management in 2015. The average Compound Annual Growth Rate (CAGR) of the assets under management of these 5 pension funds was 11% over the period 2010-2015. The assets of these funds, managed by the pension providers, comprise mainly investments in fixed income and equity. Alternatives can include investments in real estate, hedge funds, commodities, opportunities or infrastructure. Other assets can be discount securities or derivatives. Fixed income investments are often in bonds, which does not include ownership of a company. Pension providers which buy equity (stocks of companies) includes a share of that company. This implies they do have ownership of the company and the ability to exert influence on the governance of the company. Engagement activities like voting at shareholder meetings can be applied in this case.

[9] Data of ABP, PFZW, PME, Bpf Bouw, and PMT. Total assets under management in 2015: 715 billion euros of which 80 % is invested abroad.

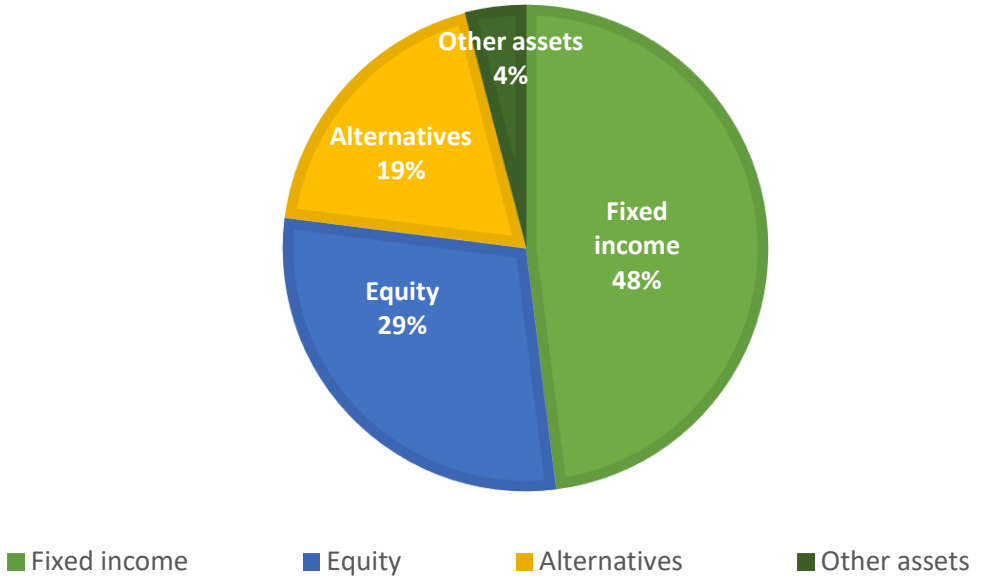

Figure 5: Calculated Average allocation per asset class of five largest Dutch pension funds in 2015. Source: PWC (2016). Global Pension Funds. Best practices in the pension fund investment process.

Responsible investments in the Dutch pension market & abroad

Dutch pension funds have incorporated CSR & ESG in their business practices. 94% of the Dutch pension funds and providers currently apply ESG criteria to some extent in their investment analysis. However, research of the VBDO indicates that the overall score of all pension funds applying responsible investment practices are not showing improvement (Verstappen et al., 2015). More integration of ESG data on investment decisions is key. To increase the validity and reliability of such data, the measurement and control of the data should be increased. ESG data can then play an important role towards constraining companies to invest in carbon-intensive industries and switch to renewables instead (Busch et al., 2016). The challenges are to specify on a greater scale the responsible investments practices required to address climate change (Sievanen, 2013). By developing and applying the accounting and reporting of natural capital[10] methodologies, the pension market and the whole financial system could also act as an agent of change in mitigating climate change and accelerating the energy transition (Van Tilburg et al., 2016).

Foreign pension markets are leading by example, by allocating their investments away from assets with high climate risks, towards green assets. The Norwegian Pension Fund, the Danish National pension fund, The French Fonds de Réserve pour les Retraites (FRR), UK's Environment Agency pension fund and The Swedish government pension fund AP4 are already severely lowering their exposure or completely divesting from fossil fuel in their portfolios (MSCI, 2015; Mooney, 2017).

Besides the ethical motivation against fossil fuel investment, these funds and providers should hedge for the financial risks, such as the risk of a carbon bubble burst, according to the principle of a prudent person standard of care (The European Commission 2014; Schneider, 2015). Sarang (2015) states divestment from fossil fuels can be already seen as the fiduciary duty, and addresses the role the court can play in this debate. Schneider (2015) shows that not divesting can also create significant reputational risk for pension funds. Fossil fuel investments generate sufficient returns now, but these

[10] Natural capital can be defined as: ''*the stock of natural resources on which human well-being and the economy depend*'' (page 4, Van Tilburg et al., 2016). Accounting of carbon is an example of natural capital accounting.

returns can fall if a carbon bubble will burst. Divestment at the right time is crucial to deflate such a carbon bubble. It remains difficult to estimate when the appropriate time for divestment is, as stated by the report *Too late, too sudden: Transition to a low carbon economy* of the European Systemic Risk Board (2016). If the transition would occur abrupt due to sudden constraints on carbon-intensive energy sources, the costs will be significantly higher (ESRB, 2016).

3.4 Strategic Asset Allocation

As all institutional investors, Dutch pension funds have interest to allocate their assets in a strategic way, given the risks and returns. Francis et al. (1987) already discovered strategic pension funding is complex due to the tradeoffs between the different incentives for funding. Since over 90% of the variance in portfolio returns is due to SAA, it is an important aspect (Brinson et al., 1986; Grinblatt et al., 1989; Brinson et al., 1991; Ibbotson et al. 2000). Asset allocation indicates how investors decided to spread their investments among different asset classes and how much they hold in each of these classes. This can include for instance equities, bonds, property and cash. Strategic asset allocation is defined as by Guyatt et al. (2011) as: ''*The use of optimization tools by asset owners to determine long-term asset allocation benchmarks to achieve their long-term objectives. The objectives vary depending on the type of asset owner and its obligations to beneficiaries or other stakeholders.*'' (Guyatt et al., 2011. p.5)
The research of Weyzig et al. (2014) analyzing European pension funds found out that the exposure to the fossil fuel industry was 256 billion euros in total, with 196 billion in equity and 60 in debt. For the Dutch pension funds, DNB (2016a) analyzed 699 billion euro in assets under management. 37.8 billion was exposed to fossil fuels. The exposure compared to the total assets under management of the Dutch pension funds consisted of 2.1% in loans, 2.3% in commodities 0.5 % in bonds and 0.6% in other types of assets.

Guyatt (2011) used a representative portfolio mix to estimate risks, assuming an allocation of 34% developed large-cap equities, 13% emerging-market equities, 18% global government bonds, 26% investment-grade credit and 9% property. It showed Equity Risk Premium (ERP) contains most of the risk (72%) in such a portfolio. Illiquidity premium (5%) and the credit risk premium (12%) are both lower. The risks of policy and technology in this model are estimated at approximately 10% and 1% respectively. This indicates the pension funds with their sizeable investments in equity are subject to significant carbon bubble risk.

The ERP stands for the compensation for taking the risk to invest in equity, compared to the risk-free rate. It reflects how the market risk is perceived and the price attached to that risk (Damodaran, 2009a). Factors influencing the ERP which are related to climate change include the uncertainty related to the different scenarios of climate change. Other factors are the reliability of the information, overall risk aversion and the risk of an event are also contributing to the risk premium (Guyatt, 2011). The way the ERP is affected by the carbon bubble risk is essential for the SAA of these funds and providers. Andersson et al. (2015) developed different investment strategies using options as a solution for investors regarding the climate risks uncertainty. They distinguish between two types of portfolios which can mitigate the risks of climate change. The pure-play green portfolios and the less carbon-intensive portfolios. So far, little is written in the academic literature on SAA for pension funds related to the O&G companies in their portfolio.

3.5 Asset Liability Management

Research found that ALM is one of the more effective strategies to construct portfolios which minimize the risk (Vrontos, et al., 2013). Kleynen (2005) p. 531 identifies ALM as:

''*The ALM process is intended to generate risk/return profiles that match the predefined risk attitude. If this match is accomplished, the risk return profile is efficient. Efficiency is thus generated if the resulting risk/return profile coincides with the predefined risk attitude taken by the pension fund.*'' (Kleynen, 2005. P. 531)

Kleynen (1996) investigated how risk management fits within ALM for pension funds, and more recently performed a case study on ABP with ALM (Kleynen, 2015). Risk identification and quantification is used to make the appropriate investment decisions for the fund. These investment decisions have to match with the predefined risk appetite of the fund. This is illustrated in figure 6, where the blue line represents an efficient risk profile, since it stays below the risk attitude in the ten year forecast.

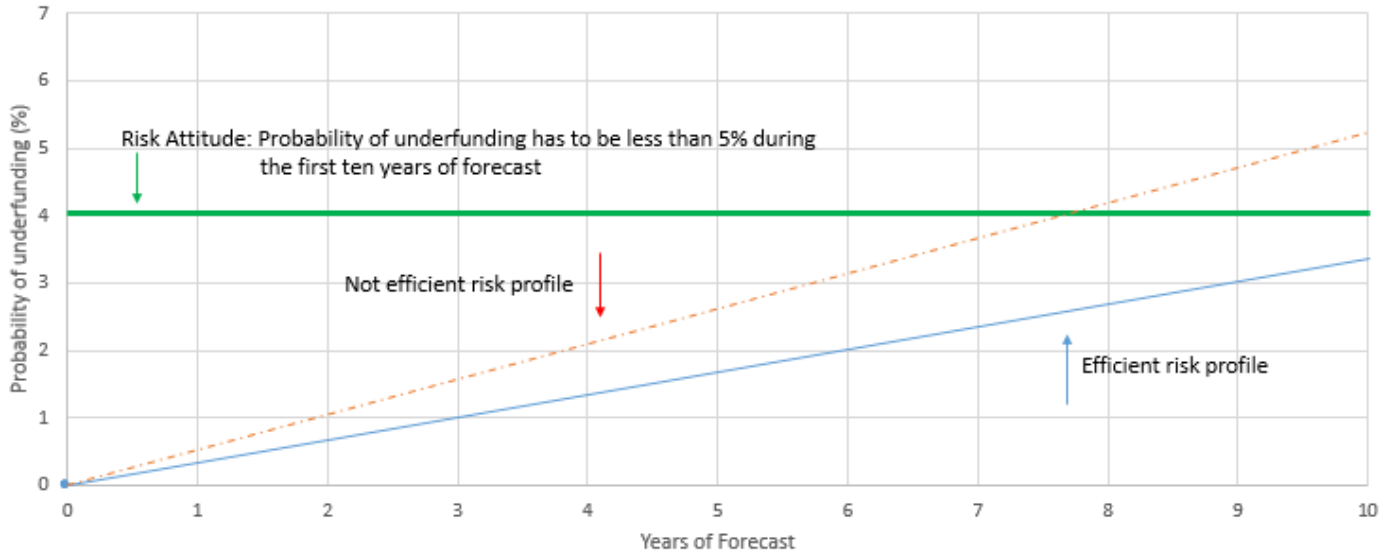

Figure 6: The relation between risk attitude, risk profile and efficiency with concern to the probability of underfunding. Source: Kleynen (2015). ALM for pension funds p.531

Typical risks for pension funds include the investment risk, wage growth/inflation risk, political risk, actuarial risk and pension financing risk. The investment risk includes to what extent the financial position is sensitive for investment decisions. The wage growth/inflation risk deals with an index which determines how salary changes or inflation affect the financial position of the pension fund. To what extent the pension funds financial position is sensitive to the changes of the state is called the political risk. The value of the fund is the present value of the accumulated pension benefits of the current population. This is based on the demography and the actuarial rules. These rules include for instance assumptions on discount rates and asset valuation. The actuarial risk is defined as how the financial position of the fund is sensitive to modification in the actuarial rules applied. The fifth risk is the financing risk, more viewed from the sponsor's perspective. The cost of labor includes the cost of the pension scheme. According to the operational management, the contribution rates should not be volatile over time (Kleynen, 2015).

The risk of climate change or the carbon bubble is not explicitly mentioned in this study. ALM can be used to determine what the risk profile of O&G companies is, taking into account which assets have the highest risk to strand. These assets can become liabilities for these O&G companies, due to the reasons mentioned in section 3.2. There will be investigated how this risk can be included in the risk

assessments of the Dutch pension funds and providers, which will result in an overview of the common practices of risk valuation.

3.6 The O&G sector

3.6.1 Types of ownership

The terminology of oil & gas companies is used for conceptual demarcation in this thesis. Regarding ownership, three types of companies within the oil industry can be distinguished. International Oil companies (IOCs), listed on stock exchanges and 100% owned by the public. These comply to regulations of stock exchange listing. National Oil Companies(NOCs), which are completely owned by the state and are not obliged to disclose information regarding production, profits, and reserves. These types control more than 75 % of the global oil and gas reserves. The third and increasingly popular type, are the Government Sponsored Enterprises (GSEs). These O&G companies, like Gazprom, Petrobas and Statoil are partly owned by the state and partly by the public (Kaiser et al., 2012).

3.6.2 The Oil & Gas value chain

Companies in the oil and gas industry distinguish between upstream, midstream and downstream (Howard et al., 2009). The upstream phase is more focused on the exploration and production (E&P) of the resources. Main activities in this part include the rig operations, feasibility studies, machinery rental and extraction of the resources. Midstream deals with the transportation and storage. Downstream operations comprise refineries and marketing, which convert the crude resource into the finished products like gasoline or other fossil fuel products. Subsequently, these are sold to businesses, retailers or consumers (Howard et al., 2009). Figure 7 displays an overview of the different activities in the O&G value chain and the different products from oil and gas (Wolf, 2009).

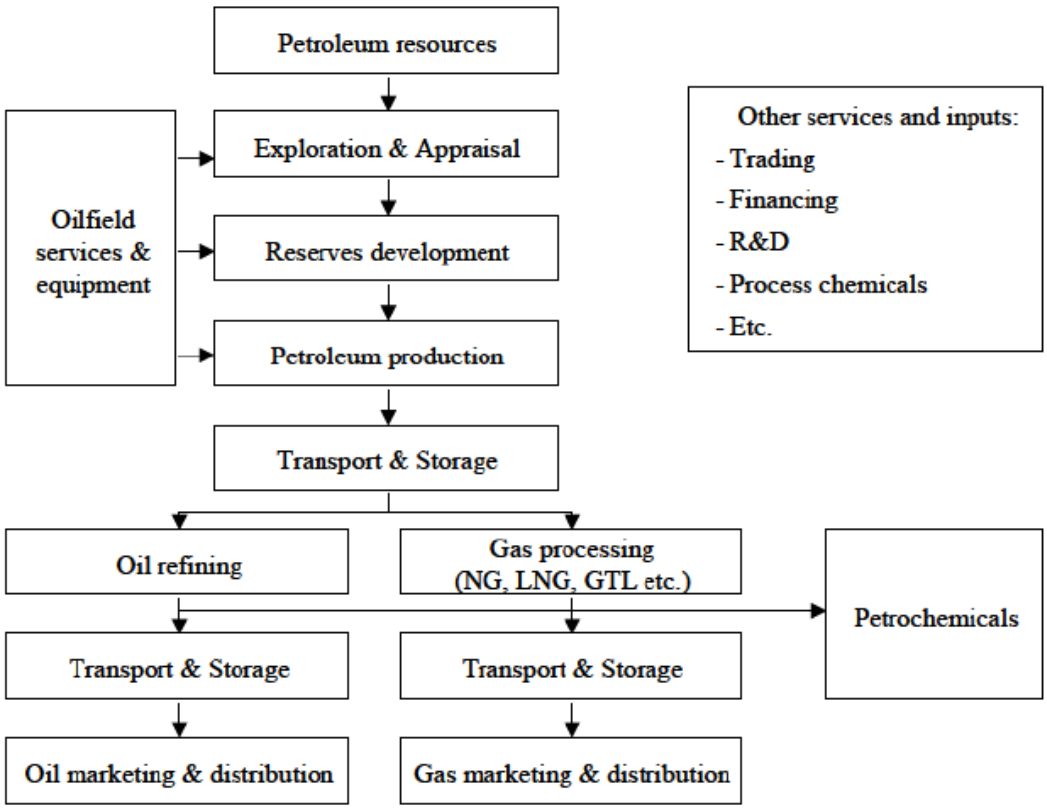

Figure 7:Value Chain of O&G industry. Source: (Wolf, 2009)

3.6.3 Scale advantages & disadvantages

Perhaps more than other industries, the O&G sector utilizes sourcing on global level, integration and international coordination to realize economies of scale and lower costs Large scale production can result in lower cost of capital, lower operation costs, lower F&D costs, division of labor and lucrative sale contracts due to high production levels. All these factors can lead to competitive advantages (Levy et al. 2002). However, scale disadvantages can also apply to these O&G multinationals. Large scale companies can suffer from a lack of adaptability. This inflexibility can result in higher risk of over-production. Adapting to new business models is also harder, since large shares of its capital are already invested. This indicates larger O&G companies have risk on more stranded assets, if they are required to shift their core business away from hydrocarbon production (Caldecott et al., 2015).

3.6.4 Oil demand per sector

The total primary energy supply was 1370 MToe in 2014. 31% of this was supplied via oil, and 21% with natural gas (figure 8). Oil is a mixture of hydrocarbons and the separation leads to different petroleum products. The main products of one barrel of crude oil are: gasoline, diesel fuel, jet fuel, heating oil, Liquefied Petroleum Gas, heavy kerosene, feedstocks for petrochemicals, waxes, lubricating oils and asphalt. The total oil demand in 2014 was 92.98 million barrels of oil per day. Figure 9 shows the breakdown of the oil and gas demand per sector.

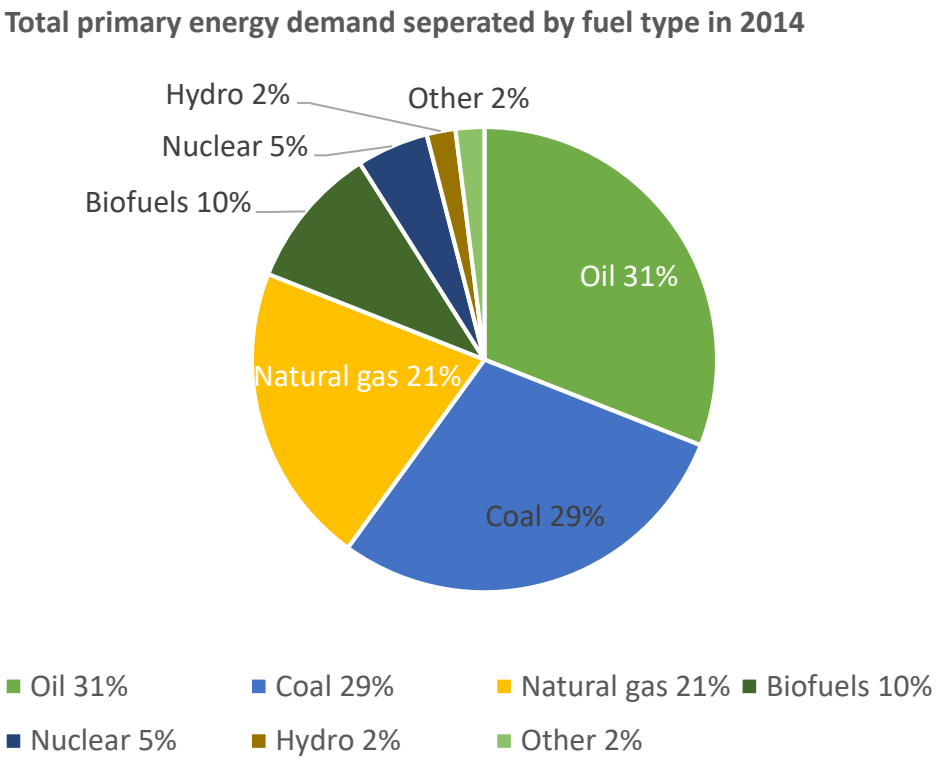

Figure 8:Breakdown per fuel type of total 1370 MToe demand in 2014. Source: World Energy Outlook, IEA 2014 (p.101)

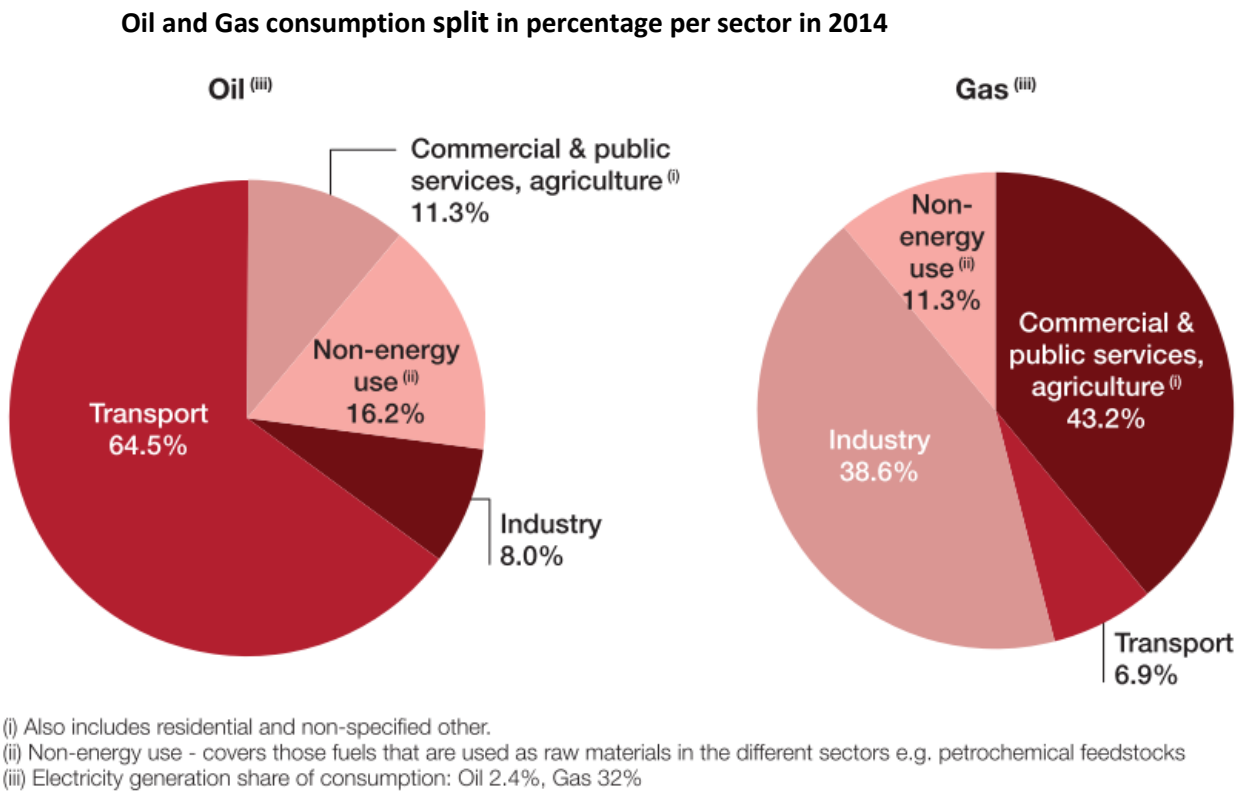

Figure 9: Oil and gas consumption per sector in percentage in 2014. Source: IEA Key world energy statistics (2016).

3.6.5 Peak oil demand instead of peak oil supply

In the past, the assumption was that the peak of oil supply would be key for the lifetime of O&G markets. The main concern was when a shortage of oil supply would occur. Instead, the peak of the oil demand is now to an increasing extent gaining support as a crucial driver, regarding the restrictions imposed to mitigate climate change (Bentley, 2002; Owen et al., 2010; Verbruggen et al.,2013). For the carbon bubble discussion, it is key when global oil demand will peak (Van de Graaff et al., 2015). Numerous studies are devoted to the projections of future oil demand. Three scenarios on the future oil demand of the IEA (2014) are shown in table 10 and figure 10. The Current Policy Scenario assumes no regulation is implemented. This has most overlap with the pathway of a temperature increase of 6 °C compared to pre-industrial levels in 2100, and crosses the 2 °C target in 2035. The New Policies scenario assumes adoption of new regulation, and overlaps with a pathway related to 4 °C temperature increase compared to pre-industrial levels in 2100. In both scenarios, oil price is expected to increase, which will increase the viability of unconventional oil projects for O&G companies. The 450 scenario gives a 50% probability of staying within the 450 ppm concentration of carbon in the atmosphere associated with 2°C compared to pre-industrial levels in 2040. Various drivers which can influence this future oil demand are depicted in Appendix V.

Table 10: peak oil demand predictions per scenario (IEA, 2014).

Organization	Scenario	Projection of peak oil demand	Level of production in 2040 (million barrels/day)
IEA 2014	Current policy Scenario	After 2040	117
IEA 2014	New policies scenario	Around 2040	103.5
IEA 2014	450 scenario	2020	93.7

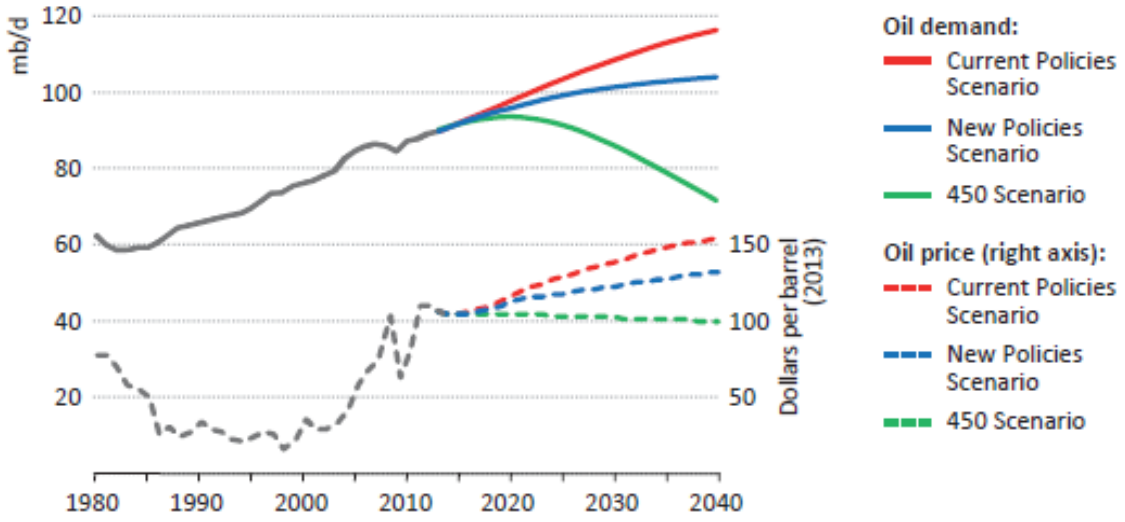

Figure 10: Predicted world oil demand and oil price per scenario. Source: World Energy Outlook p.97 (IEA, 2014).

3.6.6 Reserve valuation

For investors, the balance sheet of a company is important. A company's balance sheet displays its financial position at a certain point in time, including the assets, liabilities and equities of the O&G companies. The oil or gas is not considered an asset of the company if it is still in the ground. Hence, the reserves are not valued on the financial balance sheets of the O&G companies, and are not recognized statistics according to the General Accepted Accounting Principles (GAAP). The reserves of O&G companies are often reported annually, additional to these balances (Kaiser et al., 2012). Although not on the financial balance sheets, the reserves are of significant value for the O&G companies and its investors, since it is a sign of future production, which provides a larger potential return on equity for shareholders.

The main components which determine the value of an oil or gas company are its reserves, the level of production, and the price of the commodity at the time of assessment (Kaiser et al., 2012). One of the primary asset of the O&G companies, are their hydrocarbon reserves (Howard et al., 2009). The Petroleum Resources Management System (PRMS) framework displayed in figure 11, shows the relation of the resource classifications for minerals. This classification framework is defined by the Society of Petroleum Engineers (SPE, 2007). Two axes categorise the reserves. On the vertical axis the commercial feasibility, the probability that a project will reach commercial producing status. On the horizontal axis the geological and technical uncertainty (for instance from undiscovered via Possible and Probable to Proven reserves). The total Petroleum Initially In Place (PIIP) includes all discovered and undiscovered resources at a certain moment in time. The discovered PIIP can be divided the production, reserves, contingent resources and unrecoverable resources. The undiscovered PIIP are differentiated by the prospective and unrecoverable resources (SPE, 2007).

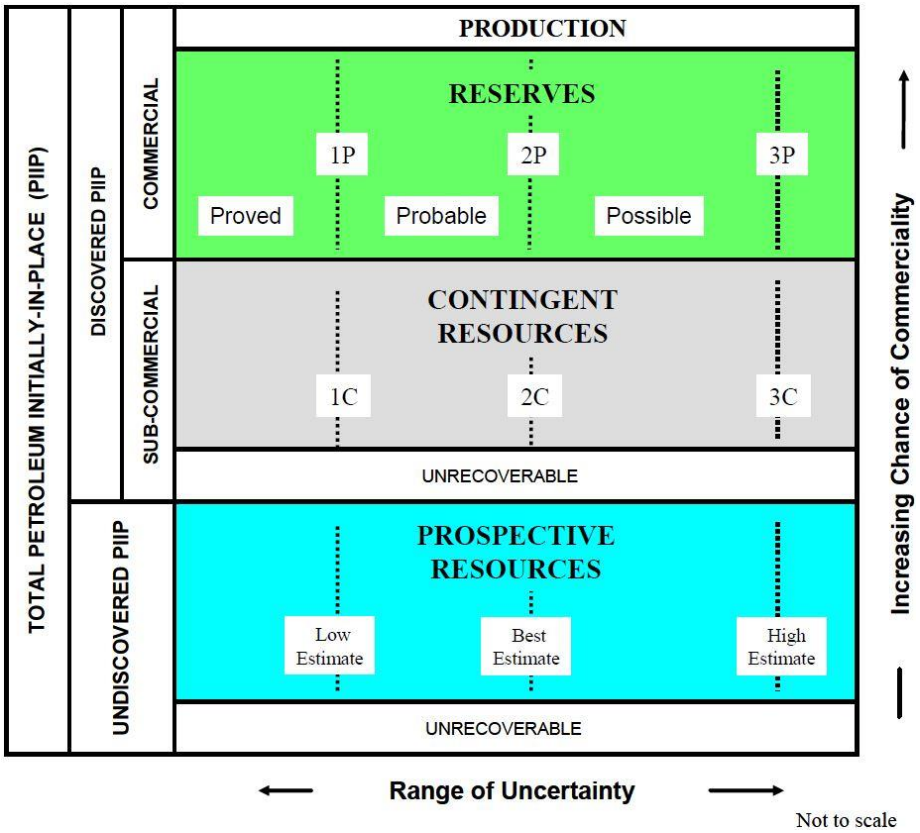

Figure 11: Visual presentation of the Petroleum Resources Management System (PRMS) (SPE, 2007)

The values of these resources are subject to uncertainty, depending on regulatory and financial uncertainty developments, unknown prices and cost, and variable production rates. The reserves of an O&G company are an important indicator of its future production. In the oil and gas industry, proved reserves are defined as: ''*The estimated remaining quantities of oil and gas anticipated to be economically producible, as of a given date, by application of development projects to known accumulations under existing economic and operating conditions.''* (p.2 Kaiser et al., 2012).

In general, three categories are distinguished (Oslo Børs, 2013), where P stands for inclusion of the classes.

- 1P: Proved reserves. Indicating a reasonably certain estimate, most likely to be discovered
- 2P: Proved plus Probable reserves. indicating a reasonably probable estimate.
- 3P: Proved plus Probable plus Possible reserves. Indicating a highly uncertain estimate.

This means that the proved reserves, 1P, are also part of 2P and 3P. In turn, 2P is included in 3P. The categories are also referred to as follows, considering P as the probabilistic degree of relative uncertainty in the estimates (Oslo Børs, 2013):

- P90 (reasonably certain estimate)
- P50 (reasonably probable estimate)
- P10 (relative highly uncertain estimate)

In each country or continent, a regulatory entity provides guiding principles on the resource classifications and company requirements to list on their stock exchanges. In the US this is the Securities and Exchange Commission (SEC), in Europe this is the European Securities and Market

Authority (ESMA) which supervises that the companies evaluate, control and report their assets and cash flows. The SEC obliges that US O&G companies listed on the US stock market, report proved, developed & undeveloped, total proved reserves, production volumes and other data on company performance on a regular basis. O&G companies disclose information in their 10-K reports within 60, 75 or 90 days after the ending of the fiscal year, depending on the size of the company. The transparency of NOCs and GSEs diverges significantly (Kaieser, 2012; Oslo Børs, 2013). Arnot (2004) focused on role of reserves reporting in the communication with the financial sector. This reporting is an important aspect for investors, since it determines what the production potential is for an O&G company. Arnot (2004) advocates for more disclosure of reserves, since it is now subjective which reserve are ''*reasonable commercial*''. Olsen et al. (2011), also state that Exploration & Production (E&P) companies frequently overestimate their own reserves. Since this is of interest of the estimators, managers, investors, creditors and regulators, it is difficult to change. Linnenluecke et al. (2015), agree on this and proposes adaptations in accounting for the organizational adaptation to climate change via risk assessment function, valuation function and a disclosure function.

3.7 O&G company valuation model

Osmundsen et al. (2006), constructed a model to estimate the enterprise value of an International O&G company. Although it is very difficult to predict the exact value of a company, it can provide insight in what the most important indicators are to determine the value of the company.

Specification of the model:

$$M_{it} = A_i + \alpha P_t + \sum_{i=1}^{n} \beta_i KPI_{it} + \gamma R_{it} + u_t$$

M= EV/DACF= Enterprise Value/Debt-adjusted Cash Flow

A= company-specific dummies (or fixed effects)

P= crude oil price. Barrel of Oil Brent

R_{it} = Return on Average Capital Employed

KPI= Vector of the Key Performance Indicators, which include:

- *OGP=Oil and gas production, as reported to SEC 10K reports*
- *RRR= Reserve Replacement Ratio. Sum changes proved reserves/production*
- *UPC= Unit Production Costs of operation and maintenance. Production costs/Production*
- *FDC= Finding & Development Costs. Sum of costs for exploration & development*

a, β and y are the parameters to be estimated, and u_t is an error term with the white noise characteristics (p. 57 Osmundsen et al., 2006).

This model is used as a starting point to get an overview of the important indicators which determine the value of an O&G company. This The *a, β and y* parameters are not the same for all companies. This model is typical for an O&G company active in the exploration & production side of the O&G value chain[11]. O&G companies with more focus on downstream activities like refinery, are less dependent

[11] See figure 7: Value Chain of O&G industry (Wolf, 2009)

on the indicators used in this model. The negative effects of a low oil price are more a concern of companies focused on exploration and production, since their production costs are more fixed. This means their profit margin is more affected if they can get a lower price for their products. Downstream focused companies have less negative effects of low oil prices, since they purchase the crude oil for a lower price, while their revenue is more stable since they sell at a premium. The results of the numerical values found per indicator with this model, based on the data set of the article for 14 O&G companies from 1990-2003, are not taken into account since the individual effects of financial indicators on the enterprise value are outside the scope of this research. Endogeneity[12] in the econometric model is tested, which contributes to the reliability of the selection of the indicators which determine the company value. Section 4.3 elaborates on the indicators discussed in the model.

3.8 Company Risks in O&G sector

From the perspective of investors, it is important that an O&G company will generate stable return. For pension funds and providers, the focus lies on the long term valuation predictions, regarding their long term return on investment profile (Della Croce et al., 2011). When the future risks are minimized, this provides more certainty to the investors. In the field of carbon risk for O&G companies, Botelho et al. (2014) used the O&G reserve profiles to make a forward looking risk assessment for exploration and production activities. They found that O&G companies with heavy oil reserves report more exposure to the risks of climate change. Companies with more bitumen and natural gas reserves, are more sensitive for water scarcity. Branco et al.(2012) elaborated on the different types of carbon risks, investigating six O&G majors to their exposure on carbon risk. The five categories used for carbon risk exposure were: market share, carbon emissions, energy efficiency, corporate aspects and resource funding. The exploration of unconventional reserves is considered an important factor for future production. Weijermars et al. (2014) however, states these future productions in more complex fields with high development costs require a high oil and gas price to be viable. This poses an extra risk on O&G companies operating in unconventional complex fields.

Based on the different risk factors described in the articles found via the literature review focusing in on risk, five risk factors for O&G companies are categorized:

1. Water resilience
2. Capital flexibility
3. Climate governance & strategy
4. Emissions & resource management
5. Fossil fuel asset mix

These risk factors exclude external factors which can cause assets to strand, like the development of alternative clean energy sources, implementation of regulations or socio/political factors, as described in section 3.2. In table 11, an overview is presented of risk factors on O&G company level, as discussed in the literature.

[12] Endogeneity is a term used in econometrics, when the explanatory variables have a correlation with the error term. The error term is the deviation from the observed value compared to the real value. Endogeneity should be tested for, since it can be the effect of a measurement error.

Table 11: Overview Risk factors for O&G companies in literature

Author	Methods used	Identified climate risk factor(s)	Risk category
Botelho et al. (2014)	Future risk assessment via content analyses of 24 O&G companies	Fossil fuel asset mix	5
		Water scarcity	1
		Access to reserves	5
		Governance of board	3
		Emissions	4
		Leakages/spills	4
Branco et al.(2012)	Multi-criteria approach via Analytical Hierarchy Process	Intensity of heavy oil reserves	5
		carbon emissions	4
		energy efficiency	4
		corporate aspects	3
		market share reserves	5
		Fossil fuel asset mix	5
		resource funding	2
		Water scarcity	1
Weijermars et al. (2014)	25 years of operational & financial performance data of 10 largest O&G majors	High F&D costs	2
		High production costs	2
		Capital flexibility	2
Levy et at. (2002)	Case study, data on 4 O&G majors.	Governance	3
		Reputational risk	3
Arnot (2004)	Desk research	Reserve mix	5
Domanski (2015)	Financial data O&G sector 2006-2015	Debt burden	2
		Capital flexibility	2
		Financial constraints	2
Hussain et al. (2015)	IMF data on O&G sector	Volatile break-even of capex intensive projects	2
Osmundsen et al. (2011)	Data of 14 international oil and gas companies in 1990-2003	Financial flexibility	2
Caldecott et al. (2015)	Data on capex of 10 projects O&G companies	CAPEX	2
		Financial flexibility	2

Water resilience is a separate factor, mentioned in several sources. All the financial risks, like high F&D costs, high operation costs, high debt burden are included in capital flexibility. Climate governance & strategy includes the transparency and direction of the strategy and the targets formulated by the board of the company. This also related to reputational risk of an O&G company. Factors like leakages, spills and energy efficiency are included in emissions & resource management. The fossil fuel asset mix includes the mix between types of fuels in reserves, the accessibility of the reserves and the carbon intensity of the proven reserves.

3.9 Key findings of the literature review

Based on the literature review, some first conclusions are made. This thesis focuses on the carbon bubble risk, which is a specific type of climate risk. External risks why assets of O&G companies can strand can be divided in 3 types; regulatory risks, market risks and socio-political pressures. Little is published in the academic literature so far on the practice of ALM and SAA to hedge against climate risks or carbon bubble risk in the pension market. The O&G industry is a capital intensive industry, where companies have to distinguish themselves by allocating their capital in the most efficient way. Indicators which determine the value of O&G companies are the market price of oil, the proven reserves, return on average capital employed, O&G production, Reserve Replacement Ratio, unit cost of production and finding and development costs. Risk factors on O&G company level can be divided into five categories, namely: water resilience, capital flexibility, climate governance & strategy, emissions & resource management and fossil fuel asset mix.

Based upon these findings in the literature, sub-questions one and four can partially be answered. The first sub-question: *How do the Dutch pension funds and providers currently value O&G companies?*

In the literature the direct motivations for the Dutch pension market were not found. From the literature can be concluded that, from an investors perspective, important indicators for O&G company valuation are:

- production levels,
- reserve replacement ratio,
- unit production costs,
- finding and development costs
- oil price

The fourth sub-question was: *How do the Dutch pension funds and providers value the carbon bubble risk of O&G companies in their portfolio?*

From the literature review it resulted little is done on ALM studies and SAA to assess the risk on O&G sector level at pension funds. The Dutch Central Bank found in 2016 that in the financial sector, the pension funds have the highest exposure to a carbon bubble risk with 5.4%. This indicates that the pension market not considers it a significant risk, since there are still substantial investments in O&G companies.

PART III

Results

4. Factors of O&G company valuation for investors

In the chapters 4-7, the page numbers after the quotes in the text boxes, and in the footnotes after the results refer to the page numbers of the report with the transcriptions of the interviews. In this chapter is discussed what the factors for the valuation of O&G companies are for the pension providers. In 4.1 an overview of the investment strategy is presented. 4.2 Provides an overview of the indicators mentioned during the interviews. 4.3 Gives the specifications of the indicators from the valuation model from Osmundsen et al. (2006), and 4.4 the view of the respondents on the model. The final section summarizes the key findings of this chapter.

4.1 Investment strategy of Dutch pension providers

All providers have multiple portfolios. Per portfolio it differs whether they are actively or passively managed. In case of passive management, an index is followed. In case of active management portfolio managers decide which companies to invest in and how big these positions are[13].

Most pension providers compare their results with a benchmark from an index. These benchmarks can be per region or sector and are based on the expectations and requests of the client. The provider can under- or overweigh different industries or companies compared to this index[14]. Most of the mid & large caps are included in these indices. If a portfolio manager decides not to invest in a company in the benchmark, since they believe it is overvalued for instance, they weight their position at zero, and invest in other companies [15]. This is easier for smaller position than for bigger ones, since the larger the company the more deviation from the benchmark.

> *'Some companies are so big, that it would be extreme if we would not invest in them. If we would not invest in Exxon Mobil, for instance, it would be an extreme position, since it is about 14% from our Oil & Gas benchmark.''* Interview with Senior portfolio manager Energy - p.53 of the transcription report.

Normative view versus the financial risk view

The investment strategy depends per pension provider. Respondents indicate the distinction between the financial choices and the normative choices of investment[16]. Financial performance is often measured quantitative and the pension provider has the responsibility to assess the financial risk and returns of companies in their portfolios. The fundamental view on where a company is heading, includes the moral aspect and is often based on qualitative data [17]. This is more based on where the company is going and how that matches with the beliefs of the client, the pension fund. The normative choice to not invest in a company lies with the pension fund.

[13] Page 10, 82 of the Transcription report
[14] Page 19, 53 of the Transcription report
[15] Page 53 of the Transcription report
[16] Page 11 and 26 of the Transcription report
[17] Page 82 of the Transcription report

> *'In the end, we have been appointed to generate the highest rate of return for a certain level of risk, given the arrangements we have made with the pension funds. Making the normative choices is not up to us, that is up to the client (pension fund). The client can make the decision to divest.''* Interview with Responsible investment manager - p. 26 of the transcription report.

To determine if an investment in shares of a company is valuable, the cash flow is an important metric. For most companies, Discounted Cash flow is calculated to measure if the company is a valuable investment. This is done via DCF models. Section 4.2 discusses the most important indicators which determine the value for an O&G company.

4.2 Indicators & methods O&G valuation from interviews

Here the various indicators mentioned are discussed and ranked on how often they were mentioned.

From the interviews with the pension providers resulted that Discounted Cash flow(DCF) is the most important method to value O&G companies. However, this is just a tool and not an indicator on itself. Various indicators are included in this DCF method. What specific elements are in the discounted cash flow models was not be disclosed by the respondents. Still, the proven reserves of an O&G company are considered an important indicator by the pension providers. The consensus among the providers is, these reserves will be exploited in the coming 10-15 years[18]. Table 12 indicates how frequent the indicators were mentioned by the respondents.

Table 12: Frequency of indicators for O&G valuation during interviews

Method/Indicator important for valuation O&G company	**Frequency**
DCF	6
1P reserves	4
Exploitability of reserves	3
RRR les important	3
Oil price	2
Value creation	2
F&D costs &capex	2
Future projects	1
Horizon of investments	1
Values after taxes	1
Dividend	1
Assets of company	1
Governance of the company	1
Specific info on the fields	1
Producition volumes	1
$ marge/barrel of oil	1
Cost of capital	1
Opex	1
Profit & losses	1

[18] Page 4 of the Transcription report

''Cash flow is the most important indicator. The problem with value of O&G companies is, a lot is dependent on the oil price. Another difficult thing is: if you put a dollar in the ground now, it takes at least 5 years before you see return. This makes it more difficult to model and to predict.'' Interview with Senior Investment Analyst energy - p.60 of the transcription report.

There is no standard list the portfolio managers use with different indicators on O&G company valuation[19]. A wide variety of indicators determines the value of an O&G company. Most of the large O&G companies are included in the MSCI index.

''*It is not like we have a concrete list with some indicators for the valuation, we work closely together with the portfolio managers (…) there is a wide variety of indicators on which the valuation is based.''* Interview with Responsible investment manager - p.27 of the transcription report.

Other elements which drive these O&G valuations are to what extent they believe these reserves can be exploited, mix between oil and gas reserves, the risks involved[20], what kind of projects are planned, what is the horizon of the investment, will those investments be profitable[21].

''We do not value on the base of proven reserves only (…) Cash flows follow from the activities a company executes, and one of the most important activities of O&G companies, is pumping up oil and gas and sell it.'' Interview with Senior portfolio manager Energy - *p.51* of the transcription report.

Most of the pension providers interviewed, managed portfolios for different clients. The strategy per portfolio differs and can have different views on what the important aspects in the portfolio are and the weight of the corresponding ESG-scores.

''*In the end, the valuation of O&G companies increasingly depends on the vision of the management and what they are currently doing or planning to do with their money.''* Interview with Strategy Consultant sustainability - p.78 of the transcription report.

''If companies are valued based on their reserves, I don't think that is a correct indicator, since you don't know if that will still deliver return in the future.'' Interview with ESG analyst - p.13 of the transcription report.

[19] Page 27 of the Transcription report
[20] Page 9 of the Transcription report
[21] Page 35 of the Transcription report

During the preliminary interviews with consultants specialized in the O&G industry and company valuation, the following indicators were mentioned: Cashflow, Return on Capital Employed, Reserve Replacement Ratio, Gearing (Debt/equity), O&M costs, F&D costs and the oil price[22].

4.3 Analysis of indicators of the model from the literature

Osmundsen et al. (2006) developed a model to estimate the value of an O&G company. Respondents were asked if they would add or replace one of the indicators, or if it was a complete approach. Below an explanation of the indicators is provided. Some of the respondents emailed their view on the model later, after consulting one of their colleagues. These suggestions are discussed after the elucidation of the indicators.

Specification of the model:

$$M_{it} = A_i + \alpha P_t + \sum_{i=1}^{n} \beta_i KPI_{it} + \gamma R_{it} + u_t$$

M= EV/DACF= Enterprise Value/Debt-adjusted Cash Flow

A= company-specific dummies (or fixed effects)

P= crude oil price. Barrel of Oil Brent

R_{it} = Return on Average Capital Employed

KPI= Vector of the Key Performance Indicators, which include:

- *OGP=Oil and gas production, as reported to Securities Exchange Commission 10K reports*
- *RRR= Reserve Replacement Ratio. Sum changes proved reserves/production*
- *UPC= Unit Production Costs of operation and maintenance. Production costs/Production*
- *FDC= Finding & Development Costs. Sum of costs for exploration & development*

α, β and γ are the parameters to be estimated, and u_t is an error term with the white noise characteristics (p. 57 Osmundsen et al., 2006).

4.3.1 Oil Price

Higher oil prices deliver higher revenues for O&G companies and often result in an increase in the value of O&G companies (Husain et al., 2015). Damodaran (2009b) also stated that for cyclical and commodity companies, like O&G companies, the earnings and cashflows of those companies follow the price of the commodity. Listed companies must disclose information according to specified standards.

[22] Page 89-91 of the Transcription Report

> ''*Recent developments with a rise from 44$ to 55$ per barrel is a threshold in which O&G companies can breakeven again. This implies it can be a total different picture for a company like Shell in just 6 weeks.''* Interview with Senior Investment Analyst energy - p.64 of the transcription report.

Several respondents confirm the price of oil is a very important indicator. A barrel of crude oil Brent is one of the dominant standards for this price volatile commodity[23]. Several factors influence the price. Supply and demand are important factors. 40% of the oil supply in the world is controlled by the Organization of Petroleum Exporting Countries (OPEC). Over-supply and lower demand are two of the many factors which can lead to lower oil prices. Similarly, rising demand for fossil fueled energy in emerging economies can lead to higher oil prices (BP, 2017).

Other factors include the cost of production. Higher cost for the extraction of the oil can result in higher prices. Two respondents indicate it will be the question if current investments in new reserves and CAPEX will remain low if oil price rises again and more expensive fields become profitable[24]. If this happens, this will result in higher valuation of these O&G companies. On the other hand, it will be more attractive to invest in alternatives like solar.

4.3.2 Return on Average Capital Employed

RoACE is defined as: *''Net income adjusted for minority interests and net financial items (after tax), as a percentage ratio of average capital employed. Capital employed is the sum of shareholders' funds and net interest-bearing debt. EV, or Enterprise Value, is the sum of the company's debt and equity, at market values. DACF or Debt-Adjusted Cash Flow, reflects cash flow from operations plus after-tax debt-service payments.''* (Osmundsen et al., 2006. p. 53)

> ''*Return on Average Capital employed is also an indicator we take into account. The problem with ROACE is that the definitions used by different companies varies a lot, so it takes some time if you want to level that.''* Interview with Senior Investment Analyst energy - p.60-61 of the transcription report.

This is a financial measure indicating the efficiency of the capital employed. The higher the ratio the better the company is in generating profit from its capital. In capital-intensive industries like the O&G sector this is an important indicator. To acquire a better ratio on their capital employed, O&G companies sometimes take impairments on their assets. The lower the capital employed, the higher the return ratio will be.

[23] Besides North Sea Brent, West Texas Intermediate (WTI) is another dominant standard for crude oil, mainly used in the US. Dubai crude is also a popular benchmark. All standards have different costs specifications.
[24] Page 6, 44, 47 51, 57, 64,73 of the Transcription report

4.3.3 Oil & Gas production

The production determines how much the company can sell. Each O&G company reports its production of oil and gas, via the Securities and Exchange Commission. Eleven of the large O&G companies have a total production of 23,85 million boe/day, on average between 2013 and 2015 (CDP, 2016). Since the production volume determines the cashflow, it is an important indicator for O&G companies[25]. Although some respondents mention the O&G companies claim they have focus on value creation, volume is still an important indicator of future revenue.

> *''O&G companies claim they are focusing on value creation, value over volume. But the question remains if you have to believe that. We do see that the production volume targets for the boards of these O&G companies are less present than before.''* Interview with Senior portfolio manager Energy - p.54 of the transcription report.

4.3.4 Reserve Replacement Ratio

This ratio is used to measure the capability of a company to find new hydrocarbons which are depleted in a certain time. It is calculated by dividing the sum of changes in proved reserves by production of that period. The changes in proved reserves include discoveries plus revisions plus purchases, minus the sales reported via the Statement of Financial Accounting Standards. Changes in reserves can also occur due to acquisitions of other companies.

> *''We take into account, but more as a crosscheck instead of an important indicator. We see it more as a warning sign if they will not be able to keep producing for the next 10 years.''* Interview with Senior investment analyst energy - p.60 of the transcription report.

Two respondents mentioned that the reserve replacement ratio is becoming less and less important[26]. In the past companies like Exxon Mobil were focusing in the past 20 years on an RRR of more than 100%. Since 2015 this was not the case anymore. Two others indicated it concerns them if O&G companies still take this into account.

> *''I don't care if the RRR of a company is above 100%. We also communicate that to those companies, that Reserve Replacement Ratio is not important for us. It is not a value driver.''* interview with Senior portfolio manager Energy - p.54 of the transcription report.

Five other respondents did not have a specific opinion about RRR.

4.3.5 Unit Production Costs

The unit cost of production is a measure to determine the operational cost. This is calculated by dividing the cost of operation and maintenance of the operating wells and other facilities and equipment, by the production. Companies which are able to operate at lower costs will be able to perform better under lower oil prices. The average operating costs of the eleven big O&G companies

[25] Page 51, 85 of the Transcription report

[26] Pages: p.13, 27 RRR is a bad indicator. P. 54, 60 RRR less important. of the Transcription report

between 2013 and 2015 is 11.32 $/boe (CDP, 2016).

4.3.6 Finding and Development Costs

Finding and Development costs are the sum of the costs the O&G company makes for the exploration and development activities of new oil and gas fields, divided by the total proved reserve additions.

> *''Finding & development cost is an important indicator for O&G companies. Capital expenditures are included in this metric, how much does it costs to find a barrel of oil and to build an installation which extracts it. (…) Besides these indicators, we look at risks, operational excellence, those kinds of things, but these will eventually translate into the F&D costs.''* Interview with Senior portfolio manager Energy - p.51 of the transcription report.

4.4 View of the respondents on the model

Four respondents declared they had not enough specific knowledge in O&G company valuation to give comments on the model and mailed their responses after consulting a colleague. None of the respondents recognized the valuation model of Osmundsen et al. (2006). Six respondents emphasized this is not the way they worked. Two stated that this was more or less complete and most important drivers are included for an E&P company in the O&G industry. One of those two stated that if a company would be actively involved in downstream activities, other drivers would be more important[27].

> ''*This is not the way we value those companies. For me, the value of a company is in the cash flow. Oil price, company specific dummies, F&D costs, all comes back in the cash flow. I would not use this model, it is only an academic exercise.''* Interview with Senior portfolio manager Energy - p.59 of the transcription report.

> *''I think this is over-engineered and these kinds of models give a fake representation of the value of a company. The world is much more complex than this. (…) The predictive value of this model is close to zero.''* Interview with Head risk analysis - p.49 of the transcription report.

4.5 Reflection on the interviews

From the interviews, it became clear mainly the energy portfolio manager or energy investment analyst could answer these questions. Other respondents lacked specific knowledge on O&G company valuation indicators. Also, the exact importance of indicators in those DCF models could not be derived from the interviews. Either because they did not know that, or because it was classified.

[27] Page 66 of the Transcription report

4.6 Key findings

The first sub-question was: *How do the Dutch pension funds and providers currently value O&G companies?*

Based on the interviews and desk research, the most important findings are that the pension funds have little knowledge of the valuation of O&G companies, this is done by the pension providers. These providers do not work with lists of indicators to value O&G companies. Many more factors, both normative and financial are taken into account by pension providers. Discounted cash flow is the most important method used. The discussed indicators in this section all have influence on the discounted cash flow models. Still, it was not disclosed how important the indicators which drive the DCF models are.

Most providers take an index as a starting point and make adaptions to under/over weigh specific companies or sectors. The billions in the portfolios and the number of companies in the investment universe are too large to value each company intensively, so largely following an index is considered most efficient.

Oil price is important for O&G companies, since it affects the revenue of the company and changes the breakeven price of different projects. However, companies can exert little influence on it. The O&G production of a company and its proven reserves are important determinants in the cash flow models. RoACE O&M costs, F&D costs are all indicators of financial performance and are taken into account during the investment decisions. The RRR is to lesser extent important for pension providers.

The normative choice not to invest in a company lies with the pension fund. To exclude a company based on its financial risk, is up to the pension provider.

5. Influence of COP21 on valuation of O&G companies

The implications of COP21 for the valuation of O&G companies in the pension portfolios will be discussed in 5.1. Section 5.2 elaborates on the effects of new regulation regarding climate risk assessments for the European pension market, IORP II. After that, the feasibility of the 1.5 & 2 ˚C target from the perspective of the Dutch pension market is discussed in 5.3, followed by the difference between those targets according to the literature. In 5.4 is reflected on the interviews. The final section, 5.5, summarizes the key findings of this chapter.

5.1 COP21 implications

COP21 has not changed valuation of O&G companies by pension providers. Eight of the nine providers point out that the Paris agreement has not changed the way O&G companies are valued[28]. The main reason is there is not enough binding legislation in place yet which would force the O&G companies to change their operations or would have a strong impact on the market value of O&G companies[29]. Some providers indicated they were already calculating with different climate scenarios and estimating the carbon footprint of their portfolios. The effect of the Paris agreement mainly contributed to more awareness of the topic of global climate change. It is perceived as a marking point, a confirmation in what direction future regulations are going.

> ''*Paris is not that far-reaching that we needed to change our financial models on it.''* Interview with Global Head Responsible investment - p.68 of the transcription report.

> ''*The fact that Paris is an agreement with large support, has the consequence that investors can make more clear decisions in their investments. The more uncertainty, the less clear you can make an investment decision. Paris facilitated investors can make more obvious choices, which can accelerate the energy transition.''* Interview with Head Risk Analysis - p.43 of the transcription report.

What changed for the pension providers is that it gave them more leverage towards companies in their portfolio to ask for data regarding carbon emissions in the scopes and other ESG related activities. If companies are not showing enough progress or transparency, investors have more leverage to convince them to change. They can make more clear choices in their investments since it is supported by so many countries and a part of the uncertainty is eliminated.

> ''*Since Paris the discussion is more focused. Teams like ours have a stronger mandate to discuss with the O&G companies what is their transitions potential. If we have our concerns with a company, there is more willingness for transparency and a dialogue of what needs to change.''* Interview with Responsible Investment Manager - p.29 of the transcription report.

[28] Pages 13, 20, 29, 36, 43, 55, 62, 69 & 79 of the Transcription report.

[29] Corporate Average Fuel Economy (CAFE) standards are another example of regulation which influences the overall oil demand and O&G companies. These standards are one of the leading mechanisms to improve the fuel efficiency of vehicles and lower GHG emissions. Originally they were put in place to reduce the US dependency of foreign oil, but after COP21 new targets were set. However, the fuel economy standards were not mentioned during the interviews.

5.2 New Directive: IORP II

An example of new regulation in line with the Paris agreement, is the new directive accepted by the European Parliament, which requires European pension funds to assess ESG risks of their investments. After the law is explained, the view of the pension providers is presented on this law and its importance.

On November fourth 2016, the Paris agreement came into force. This was one month after at least 55 countries have placed their instruments of ratification, acceptance approval or accession with the Depositary. These countries together account for at least 55% of global greenhouse gas emissions (UNFCCC, 2017).

Although not all 197 countries have made specific what their National Determined Contributions will be in the terms of regulation in their own country, progress is made via new policy implementations. An example of this, is the new directive IORP II, accepted by the European Parliament in November 2016.

IORP Directive is the European prudential framework for Institutions for Occupational Retirement Provision (IORPs) or pension funds. The pension funds hold approximately 2.5 trillion euros of around 75 million European citizens. The goal of this Directive is to deliver a prudential framework for pension funds based on mutual recognition and minimum harmonization. It specifies that pension funds should (European Parliament, 2016):

I. Have enough assets to cover the commitments of the pensions
II. Own professionally qualified governing bodies, adequate internal control mechanisms and sound administrative procedures
III. Be transparent towards plan members by communicating clearly the target level of benefits, risk exposure and investment management costs.

The new Directive (EU) 2016/2341 overhauls existing national regulation, and introduces new requirements for risk management and reporting standards, aiming to make the retirement income of citizens in the EU safer. These new adaptions include (Pensions Europe, 2017):

I. New requirements for governments
II. New rules on the risk assessment of IORP
III. New requirements regarding depositary usage
IV. More power for supervisors

Moreover, it will facilitate activities of IORP across borders and extra incentives to invest more in long term growth, and investments which benefit the environment and employment through economic activity. This is stimulated by the need for transparency regarding risk management and investment decisions regarding ESG factors and how they are part of the risk management system (European Parliament, 2016). Risk management systems should be as adequate for ESG factors as for operational risks, ALM and others (Directive (EU) 2016/2341, page 63).

Specifically, on page 43:
''It is essential that IORPs improve their risk management while taking into account the aim of having an equitable spread of risks and benefits between generations in occupational retirement provision, so that potential vulnerabilities in relation to the sustainability of pension schemes can be properly understood and discussed with the relevant competent authorities. IORPs should, as part of their risk management system, produce a risk assessment for their activities relating to pensions. That risk assessment should also be made available to the competent authorities and should, where relevant,

include, inter alia, risks related to climate change, use of resources, the environment, social risks, and risks related to the depreciation of assets due to regulatory change ('stranded assets').'' (Directive (EU) 2016/2341, page 43)

The Directive came into force on January 12th 2017. In line with Article 66, member states have two years from this date to put the national laws, regulations and administrative provisions in place which are needed to comply with this Directive.

5.2.1 Status quo Dutch pension providers on IORP II

In the Directive is specified the Dutch pension providers, as financial service providers of the funds, will need to comply with this new legislation as well. Among the respondents, there was little awareness of this new Directive. The question was asked whether the ESG risk factors were already equal important compared to other risk factors.

> ''*Financial return is for us equal important compared to non-financial return. We often get those questions. You see in France investors need to disclose their carbon impact. In England, similar things are happening.''* Interview with Sustainability strategy consultant- p.79 of the transcription report.

Two respondents[30] mentioned they were already taking ESG risk factors equally into account. Four indicate [31] that this is a point of attention already, but ESG factors are not yet as important as other types of risk factors like operational risk or liquidity risk. However, they weigh ESG factors in their investment decisions and look how CO_2 intensive companies can have an impact on their portfolio.

Two respondents[32] indicate they do not belief the standardization of ESG risk management should be stricter regulated. From their point of view, it is too much dependent per investment decision on a variety of factors to be captured in additional regulatory initiatives. One refers to a report of the European Fund and Asset Management Association(EFAMA) in 2016 on Responsible Investment. One of the conclusions is there should not be more regulation and standardization of ESG risk management (EFAMA, 2016).

> ''*I believe there are other risk factors than ESG which deserve more attention. From the perspective of materiality... You can say something should deserve more attention, but it is also up to the portfolio manager/ analyst who makes those decisions. I think it is a little weird how it is sometimes imposed.''* Interview with Global head Responsible investment - p.69 of the transcription report.

The EFAMA report continues with:
''There is no statistically relevant outperformance or underperformance of Responsible Investment strategies. (…) Given that responsible investment strategies are neutral to performance, it follows that fiduciary duty does not present an obstacle to responsible investment. Therefore, EFAMA does not see

[30] Page 43, 79 of the Transcription report
[31] Page 21, 36, 63, 69 of the Transcription report
[32] Page 55, 69 of the Transcription report

any necessity for policymakers to clarify fiduciary duty in order to promote responsible investment. EFAMA also recommends that no further obligatory exclusions be drawn up in legislation, given their likelihood to harm returns.'' (EFAMA, 2016. P. 5).

This contradicts with results of a meta study analyzing over 200 academic sources, books and industry reports, where is stated that investors should incorporate ESG standards into their decisions regarding the economic impact, and 88% of companies implementing solid ESG practices have higher operational performance (Clark et al., 2015).

As long as studies like these contradict each other, it will be uncertain for investors and boards of the pension funds what strategy to follow. Four of the respondents believe the Dutch government could do more according to the pension providers. Especially the Ministry of Finance, which can play a more active role in shaping regulation and providing clearance on long term climate goals. An Energy Transition Law as in France could work in the Netherlands as well, according to three pension providers. An overview of this law is presented in Appendix IV.

''*Transparency is key towards achieving the long term climate goals. (…) I think DNB is already doing a lot. The Ministry of Finance could do more. I think it is important more specific transition pathways are developed on national and sector level. This would make it easier for us, if we know what role the government will play.*'' Interview with Responsible Investment Manager - p.33 of the transcription report.

''*In France they have the Energy Transition Law. Investors with more than 500 million euro have to specify their carbon impact and how they contribute to a 2 degrees scenario. Those are the important steps which we need to see from the governments. There will always be pioneers and laggards. Some of the actors in our financial system will only change if the law changes.*'' Interview with ESG analyst - p.14 of the transcription report.

During the interview with the DNB the status quo of a Dutch Energy Transition Law was discussed, but the information was too classified.

'' *I cannot disclose to you if we are currently considering an Energy Transition Law similar to what is implemented in France, or if we are already working on this. That kind of information is too sensitive.*'' Interview with Program lead climate risk DNB - p. 89 of the transcription report.

5.3 The 1.5 & 2 ˚C target

This section presents the view of the respondents on the 1.5 and 2 ˚C scenario.

Six of the nine respondents explicitly stated their organization supports the Paris agreement with the 1.5 & 2 ˚C target. The other 3 indicate the support is not explicit in such a way it will result in completely different portfolio management if the target seems out of reach [33].

> *''We are just a service provider; it is not up to us. I would definitely say we would support the 2 ˚C target, but that does not matter that much. Actually, the boards of the pension funds should support it. They have not really expressed whether they support it or not.''* Interview with Senior Account Manager - p.36 of the transcription report.

Reflecting on the feasibility of a 1.5 & 2 ˚C scenario, six respondents expressed their personal concerns regarding current temperature increase or the parts per million CO_2 already in the atmosphere. Two others indicate this more a political question and too difficult to say. One respondent is still optimistic, but declares the coming four years will be crucial. Overall, the respondents were not positive the world would stay within 1.5 or 2 ˚C scenario, but indicate it is not their main task to realize this.

Does it matter? The difference between a 1.5 ˚C versus a 2 ˚C temperature increase

Since temperature increase of more than 2 ˚C compared to pre-industrial levels will have detrimental consequences for the planet, there is aim to limit the temperature increase to 1.5 ˚C above pre-industrial levels. The difference of this 0.5 ˚C is substantial (Rogelj et al., 2012; Rogelj et al., 2013; Schleussner et al., 2016).

The probability of staying within the aimed limit is higher when focused on 1.5 ˚C. The more the temperature exceeds this limit, the lower the certainty of reaching future targets. The impacts and associated costs for mitigating climate change also become higher as the temperature increases further (Rogelj et al., 2013). Key uncertainties as geophysical, technological, political and social factors play an important role in this.

A recent study of Schleussner et al, (2016) indicated more explicit that the difference between 1.5 and 2.0 ˚C also would generate significant effects on the water availability, degradation of coral reefs, extreme drought, precipitation-related effects and extreme temperatures per region. Tropical areas like North of South America, Central, South-East Asia and West Africa will be affected by more severe losses on agricultural yields. Scenarios on sea-level rise indicate 10 cm difference in 2100 between 1.5 and 2 ˚C increase.

Besides the probability and the magnitude of these effects increases significantly in the 2 ˚C scenario, the report of the Structured Expert Dialogue from the UNFCCC also concluded a higher risk regarding irreversible changes of some physical and ecological systems compared to 1.5 ˚C target (SED, 2015). Moreover, these predictions overestimate the carbon we have left staying within this temperature limit, since temperatures would continue to rise approximately 10 years after emissions are stopped (Frölicher, et a., 2014; Schleussner et al, 2016).

Considering these analysis, limiting global warming to 2 ˚C above pre-industrial levels does not indicate a safe level per se. Additionally, in order to stay within the carbon budget associated with the 1.5 ˚C target, immediate mitigation actions are required.

[33] Support: page. 4, 12, 30, 44, 70, 81. No explicit support: 21, 36, 62 of the Transcription report

5.4 Reflection on the interviews

Multiple respondents pointed out the need for further regulation, before changes in the financial valuation of O&G companies would occur. This indicates the pension market currently perceives carbon risks of O&G companies not critical enough from a financial risk perspective, to thoroughly act up on them. This also strengthens the need for more regulation, since most investors acknowledge it can help them in obtaining more data and knowledge. Since COP21 did not change the valuation methods of O&G companies, this does not benefit the probability of staying within a 1.5 or 2 ˚C temperature increase compared to pre-industrial levels. Current efforts are not enough to meet these targets; Hence more binding regulation is needed and/or a change in current risk assessments towards more focus on climate risks.

5.5 Key Findings

The second sub-question was: *How is COP21 translated into the practices of the Dutch pension funds and providers?*

COP21 has not changed the way O&G companies are valued by Dutch pension funds and providers. Mainly, because there is not enough binding legislation in place yet which affects the O&G companies. Besides creating more awareness, one of the more important implications of the climate agreement is that institutional investors have more leverage to ask the O&G companies for more transparency and progress towards an energy transition. Since the direction of the policy is confirmed, part of the uncertainty is eliminated and it gives pension providers more leverage to favor sustainable investments. Three of the nine pension providers mentioned they not explicitly support COP21, via changing their portfolio management to foster realization of the two ˚C target.

The absence of data on climate risks is an important obstacle for pension providers to make low carbon investments decisions. An Energy Transition Law implemented in France can accelerate this process of more data and disclosure on climate impact of the financial sector. Support should be created in the financial sector for such a law. The adaption of IORP II by the European Parliament is another regulatory change which aims to foster knowledge, data and methods on climate risks in the European pension sector. Among the respondents, it differed whether they were on track regarding ESG integration and data on climate risk assessment. Some were already giving equal attention to climate risks compared to other investment risks. Others lacked confidence in the effectiveness of such additional regulatory means or carbon foot printing as an investment tool.

6. Effects of O&G devaluation in pension market due to carbon bubble burst

In this chapter the effects of the carbon bubble burst are assessed. 6.1 provides a recap from the literature review on the different drivers which can lead to a carbon bubble burst. 6.2 Describes two earlier studies on the value at risk of O&G companies due to climate change. 6.3 Introduces and discusses the key factors which determine the impact of a carbon bubble burst on O&G companies. These factors are used in the scenarios Business as Usual (6.4) and a Carbon Bubble Burst (6.5), where data of 11 of the largest O&G companies are used as a sample to see which of these companies would be most at risk in each scenario. Data from the CDP, MSCI and Factiva is used. 6.5 discusses the exposure and effects of a carbon bubble burst from the interviewed pension providers, followed by the response to this situation in 6.6. In 6.7 is reflected on the interviews. The final section 6.8, summarizes the key findings of this chapter.

6.1 Factors leading to a carbon bubble burst

From the literature review resulted four main factors which can lead to stranded assets for O&G companies and eventually a carbon bubble burst. These are depicted in figure 12. A lower demand in fossil fuels is the main driver for a potential carbon bubble burst. Considering this, it is key when oil demand will peak (Verbruggen et al., 2013). In case of regulation, it is also possible a limit on fossil fuel supply is a contributing factor. However, this requires high level of cooperation between authorities, which seems unlikely (Sinn, 2008; Nordhaus, 2015).

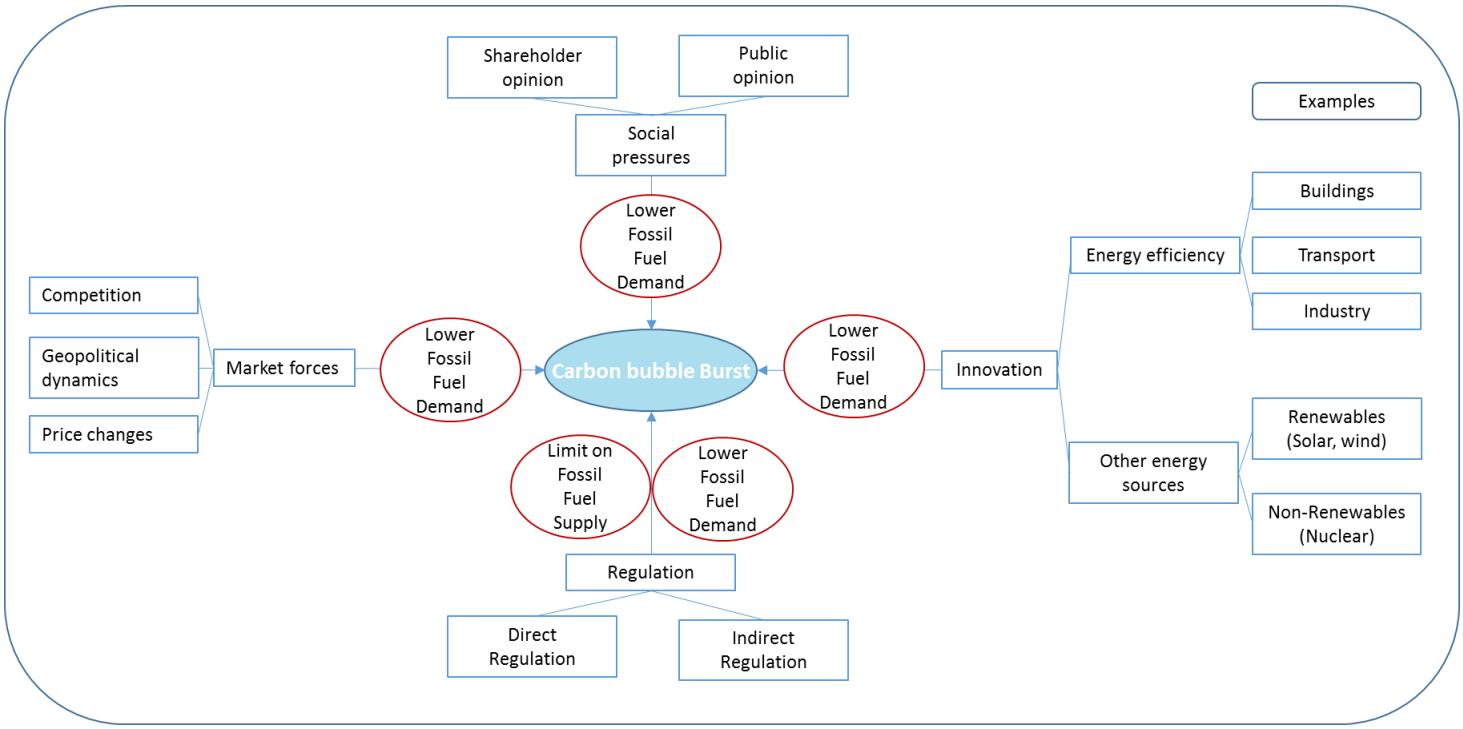

Figure 12: Factors which can lead to stranded assets of an O&G company and a carbon bubble burst, via lower fossil fuel demand or a limit on the fossil fuel supply.

6.2 Earlier studies on the value at risk of O&G companies due to climate change

Several analyses have estimated the value at risk for O&G companies if a carbon bubble would burst. Two business reports are discussed in more detail here. The Carbon Trust & Mckinsey (2008) published a report on how climate change could result in a loss of company stock value of 30-40 %. Robins et al. (2013) investigated for HSBC what the value at risk would be from unburnable reserves. They found fossil fuel companies could lose 40-60% of their MCap if a 2 ˚C scenario would be enforced. Although these reports are not the most recent, these are selected since they provide a thorough analysis of how the carbon bubble risk could materialize and are prominent reports in the carbon bubble discussion.

6.2.1 Carbon Trust - *Climate change – a business revolution?* (2008)

Carbon trust was one of the first to start the carbon bubble discussion. In the report several mitigation scenarios are presented, based on assumptions in a carbon-constrained world and the associated effects on the MCap of companies. The report distinguishes four types of business outlooks resulting from decarbonization, with high or low risk to climate change, and high or low opportunities of value creation due to climate change. The main impact trends are volatility, demand increase, transformation and demand decrease, as depicted in figure 13.

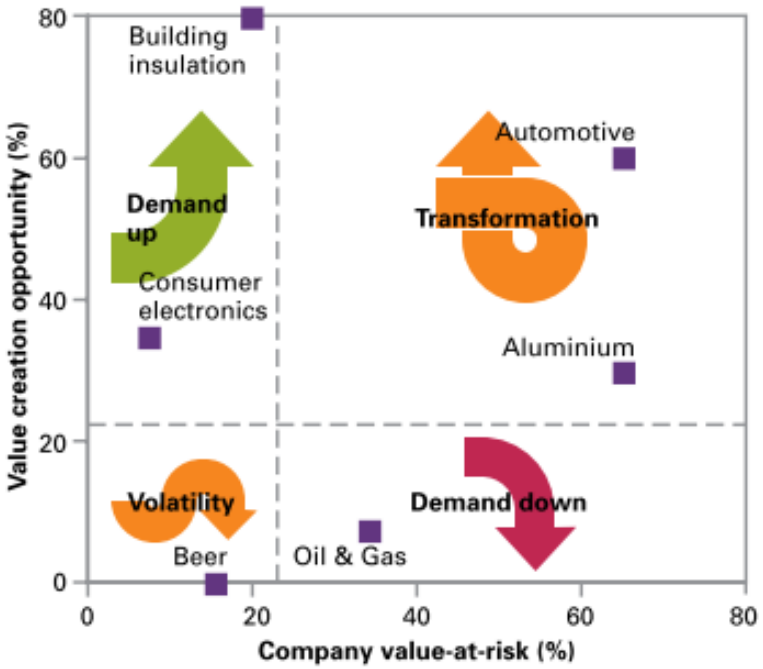

Figure 13: Calculated value creation and transition value-at-risk for different sectors. Source: Carbon trust & McKinsey (2008)Climate change – a business revolution ? ''How tackling climate change could create or destroy company value'' (p.3)

The section on the O&G sector differentiates between two components which can affect the value at risk for O&G companies failing to adapt to the transition.

1. The risk of less revenue due to a decrease in demand
2. The risk of extra adaption costs because they fail to adapt

The percentage value of risk of the O&G companies depends on multiple factors. For the E&P companies, Carbon Trust includes:

- the year the demand of oil and demand of gas falls
- peak reserve ratio (reserves/production)
- shift in O&G prices

Implications for O&G companies

This could lead to a value of risk of 15% if oil demand falls after 2020. If price effects are also included, this could lead to 30-35% value at risk of these companies.

6.2.2 HSBC - *Oil & carbon revisited -Value at risk from 'unburnable' reserves* (2013)

The report of HSBC written by Robins et al. (2013), focused on potential loss of European O&G majors and focused on two effects:

1. the MCap loss due to unburnable proven and probable reserves (2P)
2. the price effect on the MCap due to a lower demand

Especially this price effect could cause significant losses for these companies. 90% of the world's O&G reserves are owned by governments (IEA, 2014). These fields, for 70% in hands of OPEC, are often also cheaper to exploit. This implies that the projects which will be cancelled first when price falls due to lower demand, are most likely the more expensive projects in hands of the O&G majors.
HSBC found that gas reserves would be less at risk than oil and coal, considering its lower carbon content. For the analysis, they used a ceiling price of $50 per barrel of oil Brent and $9 million British thermal units which equals $55 per barrel of oil in oil parity.

Implications for O&G companies

In 2013, BP had most reserves(2P) which would be unburnable 25%. However, Statoil had the highest loss in MCap with 17%, since the reserves of BP were for the majority lower margin than those of Statoil. Combining the effect of unburnable reserves with the price effects, all companies would be substantial at risk. Shell and Total are on the lower range, with 40% loss of MCap, Statoil would be most at risk with 60%. Analysts of HSBC hold the opinion that most investors still need to price in these risks, probably because these risks seem long term. They conclude that companies with high cost future projects, like oil sands, and deep water projects, form the highest risk for investors.

6.2.3 Comparing earlier studies

From these studies two important factors are distinguished which determine the impact of a carbon bubble burst on O&G companies:

1. The amount of unburnable carbon for the O&G company
   A lower fossil fuel demand leads to less reserves which can be exploited and sold, resulting in less revenue. This lower demand will be followed by price-effects, which also lead to less revenue due to lower price per barrel of oil sold. Besides, lower oil prices imply less projects are breakeven, which also affects the cashflow.

2. The adaptability of O&G companies to these effects
   Companies which lack the ability to adapt to these changes in demand, market price, number of breakeven projects and revenue, will have the highest risk of losing value.

6.3 Defining the scenarios

6.3.1 Important factors per scenario

To assess the potential effects of a carbon bubble on the value of O&G companies, two scenarios were developed. If a potential carbon bubble would burst, this depends on whether the energy transition will go gradually or abruptly (Busch et al., 2006; Schoenmaker et al., 2015; DNB, 2016). In a gradual energy transition, there is assumed O&G companies have the time to adapt and no unanticipated devaluation of assets would occur. The additional costs of such a gradual energy transition are considered manageable (Stern, 2008). This scenario is called *business as usual* in this thesis. In this scenario, the important factor for O&G companies is to what extent they can fulfill the growing fossil fuel demand.

If the energy transition will go abrupt, a carbon bubble could burst due to the sudden, unanticipated devaluations of assets. This sudden reallocation of capital in carbon-intensive sectors due to an abrupt energy transition will not only hit fossil fuel companies, but also the financial system. Besides devaluation of the carbon-intensive assets in their portfolios, it can cause a negative shock in economic growth for all sectors. It will include high costs of adaptation, high market uncertainties and possible shortages in energy associated with unexpected high prices (Busch et al., 2006; Battiston et al., 2016 ESRB, 2016; FSB, 2016).

Based on previous studies, two factors are considered to assess the impact of a carbon bubble burst on O&G companies:

1. The amount of unburnable carbon
2. The adaptability of the O&G company

How much carbon is unburnable affects the value of O&G companies, since its reserves are an important determinant for future cash flow. The less reserves are exploitable, the higher the loss of MCap of the O&G company. The better an O&G company can adapt to this abrupt energy transition, the lower the risk of devaluation. A schematic overview of this is depicted in figure 14.

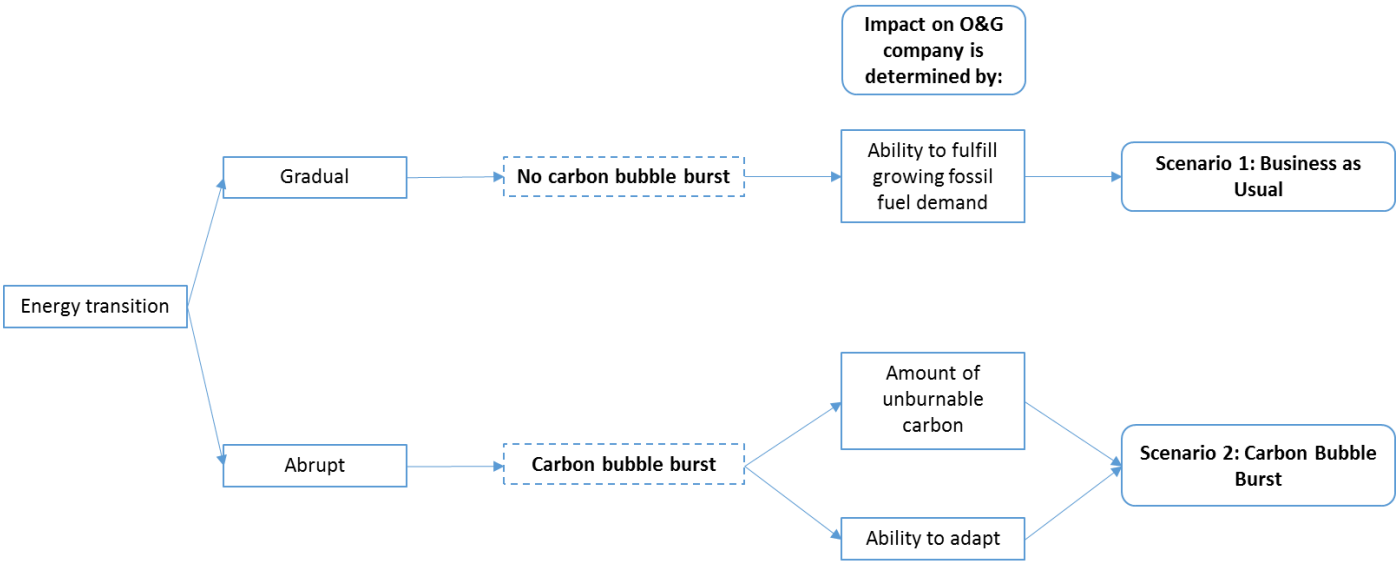

Figure 14: Overview of the two scenarios and the factors determining the impact on the value of O&G companies

The goal of these scenarios was not to assess how much each company could lose exactly in value per scenario, but to assess how much it is at risk compared to its competitors. From an investors perspective, this provides insight in which companies are most at risk in their portfolio. Excluding the worst in class per portfolio can then lead towards portfolio optimization.

6.3.2 The Carbon Budget

Considering a carbon bubble burst scenario, the level of impact of the factors ''*unburnable carbon*'' and ''*adaptability*'' on O&G companies, is determined by the carbon budget. This is the amount of carbon which is left to be burned staying within a threshold of global temperature increase. The IPCC (2014), calculated the carbon budget in Gt CO_2 for staying below 1.5 ˚C, 2 ˚C and 3 ˚C temperature increase compared to pre-industrial levels at different levels of probability. Focusing on the values with 66% of the simulations within the threshold, the remaining carbon budget after 2016 is depicted in table 13. A more extensive explanation on the carbon budget and the simulations is given in Appendix IX.

Based upon the findings of McGlade & Ekins (2015) on the distribution for a < 2 ˚C threshold, and the different types of Proven fossil fuel reserves, the 11 O&G companies would have on average 42% of their proven reserves stranded. An overview of these calculations is presented in Appendix X.

Table 13: Carbon budget after 2016 per temperature threshold for 66% probability, based on simulations of IPCC (2014) and IEA (2017) emission data from 2011-2016. The distribution of fossil fuels was approached by McGlade & Ekins for a 2 ˚C threshold (2015).

Temperature threshold	**Gt CO_2 Left to be burned after 2016** [34]	**Effect of Unburnable carbon & Adaptability on O&G companies**	**Distribution of unburnable fossil fuel reserves**
Carbon bubble burst < 1.5 ˚C	239	Highest	-
Carbon bubble burst < 2 ˚C	839	High	Oil: 35% Gas: 52% Coal: 88%
Carbon bubble burst < 3 ˚C	2239	Medium	-
Business as Usual	∞	Low	-

The lower the carbon budget is, the more important the effects of unburnable carbon and adaptability are for O&G companies, since they can exploit less reserves. The question remains: which companies will be able to use more of this budget than others? The scenario analysis compared 11 O&G companies on relevant indicators which affect their position relative to their competitors. Next, the sample of O&G companies used in the scenarios is discussed.

[34] The Gt CO_2 emissions of the carbon budget after 2011 from the IPCC (2014) are reduced by 161 Gt CO2, the total CO2 emissions from 2012-2016, (IEA, 2017). See also Appendix IX

6.3.3 Sample of O&G companies

The effects of each scenario are assessed on O&G multinationals. 11 of the largest O&G companies were selected, based on their MCap in 2016, depicted in table 14.

Table 14: overview MCap of 11 large O&G companies. Source: Factiva financial data (2016)

O&G company	**MCap 2016 in billion US $**
Exxon Mobil	356
Shell + BG	194
Chevron	185
Total	116
BP	101
Occidental	55
ConocoPhillips	52
Statoil	50
Eni	54
Petrobras	44
Suncor	43
Total MCap	**1250**

Although Rosneft, PetroChina and Saudi Aramco have a high market capitalization, these companies are not included in the sample due to a lack of data availability. The total estimated MCap of fossil fuel companies is 5 trillion US $ (Dietz et al., 2016). Hence this sample of eleven companies represents 25% of the total market value of all companies in the fossil fuel industry. Also, these companies produced together 23.85 million boe/day on average between 2011 and 2015, which is approximately 25% of yearly global oil demand. This makes it a reliable sample for the O&G industry.

6.3.4 Ranking the O&G companies

Depending on the data of the indicators per scenario, the O&G companies were given a rank from 1 to 11 for each indicator. Next, the sum of the different ranking scores divided by the number of indicators, showed the risk position of that O&G company relative to its competitors. The worst three in class were marked red per scenario, as indication which O&G companies should be excluded first by investors in that scenario.

6.4 Scenario: Business as Usual

The first scenario, *Business As Usual,* assumes no carbon bubble burst, since the energy transition will go gradually. Regulations will not have sufficient impact on O&G companies to limit their production or reduce the fossil fuel demand. The main drivers are the rising fossil fuel energy demand. In the coming decades, the global population and primary energy demand is expected to increase. Besides, 2 billion people from low income group are expected to enter the middle class in 2025, indicating a higher average energy demand per capita. The exact years differ per energy outlook (BP, 2017; IEA, 2016; World Energy Council, 2016; Shell, 2016). The future of the global energy picture is dependent on many factors and difficult to predict. An overview of important energy drivers shaping the future energy system is presented in Appendix V.

6.4.1 Selection of indicators | Business as usual

In this scenario, the ability of the O&G companies to meet the growing fossil fuel energy demand is most important. This scenario uses five indicators to assess this ability, depicted in figure 15.

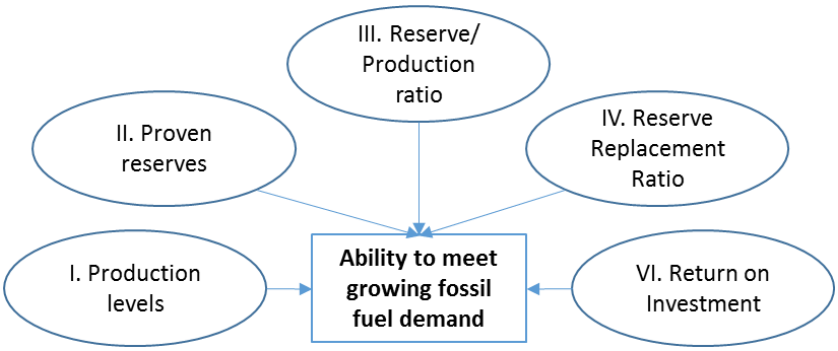

Figure 15: Indicators used in the Business as Usual scenario

The average production levels from 2015 were taken into account in million boe/day, taking the average value of the period 2011-2015 (CDP, 2016). The oil industry is characterized by significant effects of economies of scale, which can lead to cost advantages. O&G companies which can produce at high levels to fulfill the growing fossil fuel demand are considered good investment, low production levels indicate higher investment risk.

An important indicator for future production are the proven reserves of a company. This was measured in billion boe, as reported to the Securities Exchange Commission for the year 2015 and retrieved from CDP (2016). For the same reason, companies with high reserves are expected to flourish in this scenario considering the scale advantages. Companies with the lowest proven reserves, have little proof to produce or increase production in the future, so low levels of reserves are labeled as high risk.

To assess how well the companies will be able to continue producing O&G with their current reserves, the Reserves to Production ratio (R/P) is used. It is calculated by dividing the proven reserves of a company by its current production levels, presented in years. The median of the period 2011-2015 was used to eliminate yearly outliers (CDP,2016). A high reserve to production ratio indicates the company can produce for many years with current reserves, which generates future cashflow. High R/P ratio indicates upstream exploration efficiency, so low levels are considered most at risk.

The fourth indicator is the replacement ratio of reserves (RRR), representing the ratio of exploration of new reserves versus its current reserves. Data was retrieved from CDP (2016) and is an average of

the period 2011-2015. A high RRR is considered positive, since it indicates the O&G company will be able to meet the growing energy demand via exploring new reserves. Table 15 depicts the data of the indicators for the 11 O&G companies.

Return on investments (%) is an indicator which measures the effectiveness of a company's investments. This indicator is a good indication of how efficiently a company allocates its money. This gives also an indication on how well a company can allocate its capital in the future in the O&G business and whether it will maintain sufficient return on capital (Levy et al., 2002). Besides, it provides more detail than the basic profit margins of companies and is used by investors to assess the financial conditions of a company and its capability to generate more profits in the future. The database Factiva was used to retrieve the data of the 11 O&G companies on this indicator. The average of 2012-2016 was used to eliminate possible yearly outliers. The most recent range of five years was chosen to acquire the most recent data value.

These five indicators were also mentioned during the preliminary interviews and the interviews with the pension providers as traditional indicators for O&G company valuation. Other indicators mentioned during the interviews were not included due to a lack of data availability. The production levels of O&G companies and RRR were also included in the model of Osmundsen et al (2006) obtained via the literature research.

6.4.2 Results

The O&G companies were ranked per indicator. For all indicators, high values were positive for O&G companies in this scenario and low values implied high risk. Hence, companies with the lowest value were marked as the highest investment risk in this scenario[35]. The columns are split per indicator. The left column presents the actual value, the right column below each indicator the rank of the O&G company.

table 15: Development status & Reserve production ratio. Per indicator: Left column: value, Right column: rank. Source: CDP (2016) In the pipeline. P.14-18. Factiva company data (2012-2016).

11 Large O&G companies	**Production levels 2011-2015 (million boe/day)**		**Proven Reserves (2015) (billion boe)**		**Reserve to Production ratio 2011-2015 (years)**		**Reserve replacement ratio 2011-2015 (%)**		**Return on investment 2012-2016 (%)**	
Statoil	1.8	*7*	5.1	*9*	16.1	*11*	93	*7*	13.14	*7*
Eni	1.7	*8*	6.9	*8*	11.3	*10*	100	*4*	5.96	*10*
Total	2.3	*5*	11.6	*3*	13.5	*5*	122	*2*	7.98	*3*
Shell + BG	3.7	*2*	15.3	*2*	12.1	*7*	56	*9*	6.17	*3*
BP	2.3	*5*	10.4	*6*	13.1	*6*	10	*11*	3.98	*5*
Occidental	0.67	*10*	2.2	*11*	11.4	*9*	81	*8*	0.14	*11*
Petrobras	2.6	*3*	10.5	*5*	14.8	*3*	52	*10*	3.91	*9*
ConocoPhillips	1.6	*9*	8.2	*7*	14.3	*4*	97	*6*	3.77	*6*
Chevron	2.5	*4*	11.2	*4*	11.8	*8*	115	*3*	0.96	*2*
Exxon Mobil	4.1	*1*	24.8	*1*	16.1	*2*	100	*4*	1.45	*1*
Suncor	0.58	*11*	4.7	*10*	22.2	*1*	178	*1*	3.1	*8*

[35] So for Production levels for example, Exxon Mobil had the highest value and ranked 1st, while Suncor ranked 11th with the lowest value.

The average rank of each O&G company over all indicators, gives an indication of which companies would perform best and which are most at risk in a Business as usual scenario. This is depicted in table 16.

Table 16:Ranking of companies in Business as Usual scenario. The three companies most at risk are marked red

11 Large O&G companies	Average rank of the five indicators	Companies at risk (1=least at risk, 11 most at risk)
Statoil	*8.2*	*10*
Eni	*8*	*9*
Total	*3.6*	*2*
Shell + BG	*4.6*	*4*
BP	*6.6*	*8*
Occidental	*9.8*	*11*
Petrobras	*6*	*5*
ConocoPhillips	*6.4*	*7*
Chevron	*4.2*	*3*
Exxon Mobil	*1.8*	*1*
Suncor	*6.2*	*6*

Occidental, Statoil and Eni are the three companies most at risk in this scenario, on average scoring worst on the five indicators relative to their competitors. Hence, these form the highest investment risk for pension providers. Exxon Mobil, Total and Chevron are least at risk, and most likely to outperform their competitors in meeting the growing fossil fuel energy demand in the future.

6.5 Scenario: Carbon Bubble Burst

This scenario assumes an abrupt energy transition, and a carbon bubble burst. The O&G companies are assessed on indicators which effect how much carbon they cannot burn, and indicators on their ability to adapt to this situation. First, the indicators for unburnable carbon are discussed, then the indicators for adaptability.

6.5.1 Unburnable Carbon

To determine which O&G companies will be able to exploit more than their competitors of the carbon budget using their proven reserves, the companies are compared on four important indicators (Figure 16)

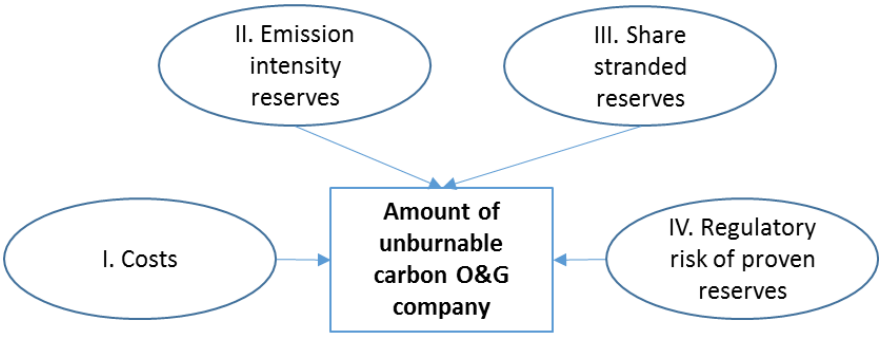

Figure 16:Indicators used for amount of burnable carbon O&G companies

I. Costs

Leaving less reserves exploitable, there can be argued the cheapest reserves will be exploited first. Figure 17 presents the O&G industry production curve with the average breakeven value in US$/boe for different types of reserves on a 75% confidence interval. There are multiple reasons presented in the literature which are in favor of cost as a dominant driver:

1. More environmental legislation.
    - This can lead to higher costs for fossil fuels companies, making costs important (Levy et al., 2002; Busch et al., 2006; Labatt et al., 2011).

2. More competition leading to accelerated expropriation of reserves.
    - Since the value companies can get from their reserves now, is higher than in the future regarding future policy restrictions and technological developments. This could lead to oversupply, leading to lower market prices, making costs important (Sinn, 2008; Van der Ploeg, 2016).

3. Lower demand for oil due to social pressures
    - Changing consumer behavior and pressure from shareholders can affect the amount of reserves exploited or sold of an O&G company, making costs important (Bokenkamp et al., 2005; Kiyar et al, 2015; Schneider, 2015; Ritchie et al., 2015).

4. Innovations in alternative energy sources or sector efficiencies
    - This will lead to lower demand for oil, lower market prices, making costs important (Juadi et al., 2016; Hong et al., 2013; Helm,2016).

Moreover, the chance that IOCs will be the ones hit the most by these cost effects is high, since most of the cheaper reserves are owned by NOCs. IOCs are to an increasing extent exploring unconventional fields, associated with higher costs (Robins et al., 2013; Weijermars, 2014).

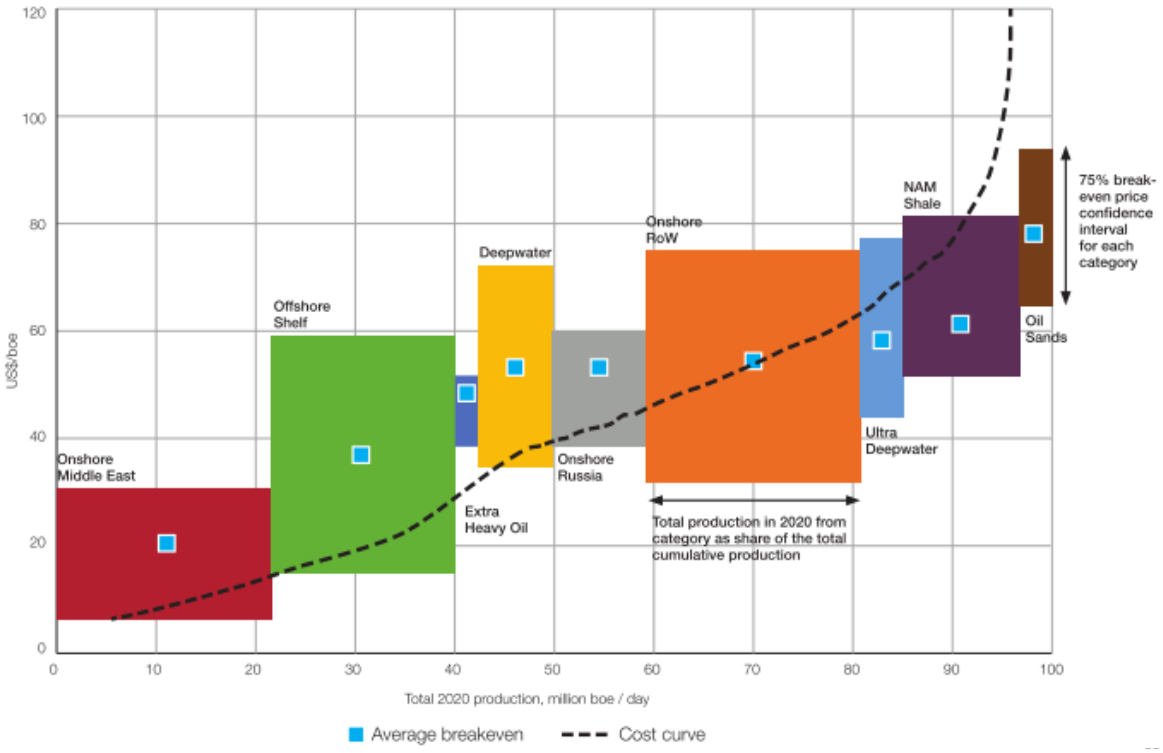

Figure 17: Industry production cost curve. Source: Deloitte (2015) report Oil & Gas reality Check (p.12)

Metrics

To assess the cost of operation and maintenance (O&M) during the production process of the O&G company, the operational costs in US dollar per boe are used from CDP (2016). The finding and development(F&D) costs of the O&G companies are used to capture the costs of their exploration activities, also in US $/boe. For both indicators, the data from the CDP (2016) was used, taking the average value of the period between 2011 and 2015 to eliminate possible yearly outliers. Both F&D and O&M costs were mentioned as important indicators for the valuation of O&G companies during the interviews.

Results

Looking at the average ranking of the costs in table 17, Petrobas Shell and Chevron are worst performing. These companies have the highest costs to find a find new reserves, develop the field, and produce a barrel oil or gas from it. These data also give an interpretation of which companies are located at the most expensive fields.

Table 17: Overview financial data O&G companies. Source: CDP (2016) p.14-18.

11 Large O&G companies	**Production Costs, 2011-2015 ($/boe)**	**Ranking** (lowest cost=1, highest =11)	**F&D Costs 2011- 2015 ($/boe)**	**Ranking** (lowest cost=1, highest =11)	**Average rank costs**
Statoil	5.9	*1*	26.8	*6*	*3.5*
Eni	9.3	*3*	19.4	*3*	*3*
Total	6.7	*2*	27.9	*7*	*4.5*
Shell + BG	13.2	*9*	33.7	*8*	*8.5*
BP	10.1	*4*	40.9	*10*	*7*
Occidental	11.6	*6*	33.7	*8*	*7*
Petrobras	12.8	*8*	47	*11*	*9.5*
ConocoPhillips	12.5	*7*	22.9	*4*	*5.5*
Chevron	13.4	*10*	25.2	*5*	*7.5*
Exxon Mobil	10.6	*5*	19.1	*2*	*3.5*
Suncor	18.4	*11*	13.8	*1*	*6*

II. Emission intensity of reserves

To stay within the given carbon budget while exploiting the most reserves, it would be most efficient that the least polluting reserves are exploited. Although it is unlikely O&G companies would make this moral decision themselves, regulation could give them an incentive for this. A tax on carbon is an example of such regulation, so O&G companies have an economic stimulus to leave their most Carbon or GHG intensive reserves in the ground. This approach does not consider that O&G companies with high average carbon intensity of reserves, could still extract less polluting reserves than O&G companies with a lower average carbon/GHG intensity of reserves. Nevertheless, it provides a first overview of which companies have the most polluting reserves in their portfolio which could be affected by a carbon tax.

Metrics

Focusing on all GHGs, this is measured in the reserves emission intensity in (GHG ton/boe). This data is obtained from the Oil & Gas Industry report of MSCI ESG (2016). Table 18 depicts the CO_2 content per GJ of the fossil fuels. Besides CO_2, the other GHGs are taken into account in figure 18, like CH_4, N_2O and others. Fuels like natural gas, which have a relatively low CO_2 content, are not necessarily of less impact on climate change. Leakages of the GHG Methane (CH_4) in the atmosphere are associated with the production of natural gas. Methane has 23 times as much impact on global warming over a period of 100 year, compared to the same mass in CO_2 .This is an important threat for the atmosphere and diminishes the advantage of the low CO_2 content of natural gas (Tollefson, 2013).

Table 18: CO_2 content of fossil fuels. Source: IPCC (2014)

Fuel	**CO_2 content (kg per GJ)**
Oil sands and oil shale	106.7
Thermal coal	96.4
Metallurgical coal	94.6
Crude oil	73.3
Natural gas	56.1

Results

In figure 18, the GHG intensity of the Proven reserves of the 11 companies are ranked. Suncor has highest risk exposure, followed by Conoco Phillips and Exxon Mobil. These companies are higher at risk, assuming most CO_2 intensive types of reserves will be the first to remain into the ground, via prohibitions due to binding environmental legislation or high carbon taxes.

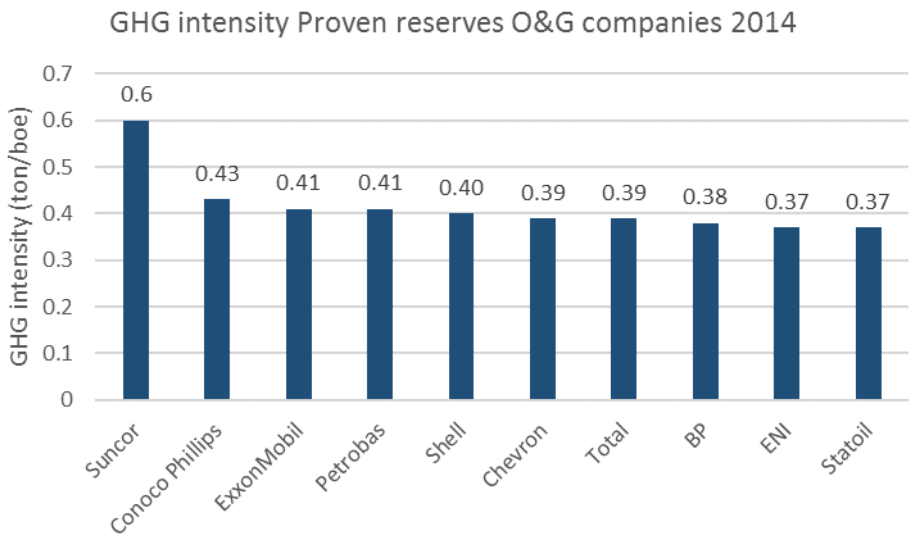

Figure 18:Emissions embedded in hydrocarbon reserve portfolios. Source: MSCI ESG (2016) Industry report Oil & Gas p.33. & Schroders (2016) Carbon risk in Oil & Gas assets p.12.

III Share of stranded assets at 1.5 ˚C carbon budget

To approach the amount of stranded assets for each company, the carbon budget associated with a 66% probability of < 1.5 ˚C temperature increase compared to pre-industrial levels is selected. This value was selected, since for the carbon budget associated with < 2 ˚C, also parts of the 2P reserves of the companies needed to be included. Data on this 2P reserves was not available. Besides, it is difficult to determine how much these 2P reserves contribute to the value of an O&G company. The amount of stranded reserves compared to its proven reserves approaches how much a company will suffer from a potential carbon bubble burst.

Metrics

The share of stranded assets of a company is defined as the stranded reserves/Proven reserves.
The stranded proven reserves of a company are:

$$Stranded\ Proven\ Reserves = Proven\ Reserves - Burnable\ Proven\ Reserves$$

The Proven reserves are known (CDP, 2016). The burnable reserves associated with < 1.5 ˚C threshold are for a company in the sample are approached via this formula:

$$Burnable\ proven\ reserves = \left(\frac{CarbonBudget}{YearlyEmissions}\right) * \left(\frac{Yearly\ Global\ O\&Gproduction}{share\ oilproduction\ O\&Gsample}\right) * Share\ production\ of\ O\&G\ company\ from\ sample$$

Dividing the carbon budget by the yearly emissions, gives the years left of producing for the O&G companies. This is multiplied with the yearly oil production, divided by four, since the sample of O&G companies comprise 25% of global production. To obtain how many billion boe each company can produce of this, it is multiplied by the share of the current production of the company compared to the yearly production of the sample.

This approach makes multiple simplifying assumptions. First, that the yearly global emissions (32.2 Gt CO_2) and oil global production (35 billion boe/year) remain constant (IEA, 2017). Second, that the share production of the O&G companies compared to global production remains 25%. Third, the share of production of the 11 O&G companies remains the same (23.85 million boe/day) (CDP, 2016). Also, it assumes the companies do not see the end of production coming and that only the GHG CO_2 affects the years of the reaming carbon budget. The carbon budget after 2016 for a 66% probability of < 1.5 ˚C temperature increase, is set at 239 Gt CO_2. Although this is a simplified approach it gives an indication of which shares of the O&G companies proven reserves can become stranded.

Results

Suncor, Exxon Mobil and ConocoPhillips would have the most stranded reserves in this approach (table 19). This gives an indication these companies are also most at risk in a < 2 ˚C target.

table 19: Approximation of stranded reserves per company within 1.5 ˚C target

11 Large O&G companies	**Share of production to sample production**	**Burnable reserves (billion boe)**	**Stranded Reserves (billion boe)**	**Share of proven reserves stranded (%)**	**Ranking** (lowest share=1, highest share =11)
Statoil	0.08	4.94	0.16	3.18	*1*
Eni	0.07	4.66	2.24	32.41	*4*
Total	0.10	6.31	5.29	45.61	*8*
Shell + BG	0.16	10.15	5.15	33.66	*5*
BP	0.10	6.31	4.09	39.33	*7*
Occidental	0.03	1.84	0.36	16.45	*2*
Petrobras	0.11	7.13	3.37	32.07	*3*
ConocoPhillips	0.07	4.39	3.81	46.47	*9*
Chevron	0.10	6.86	4.34	38.77	*6*
Exxon Mobil	0.17	11.25	13.55	54.65	*10*
Suncor	0.02	1.59	3.11	66.15	*11*

IV Regulatory risk of proven reserves per region

Although lower fossil fuel demand is most likely to be the factor which could trigger a carbon bubble burst, a limit on supply is also possible. Regulation could lead to a prohibition on the exploitation of reserves in a specific country. This could lead to stranded assets for an O&G company once its reserves are in areas where such legislation is implemented. Although the oil business of these majors is global oriented, some companies tend to be concentrated in specific regions. This can make these O&G companies a high investment risk if regulations are implemented.

Metrics

To distinguish more specifically between the 11 O&G companies on how they are exposed to the regulatory risks of climate regulations, the areas where the 11 O&G companies are producing hydrocarbons were linked to the regulatory risk levels. Current production levels were taken as a proxy for the proven reserves of O&G companies (Kaiser et al, 2012). Hydrocarbon production levels per region were adopted from CDP (2016). Results of analysis of MSCI (2016) report on O&G industry on the regulatory frameworks per country related to GHG emissions were used. This analysis focused on the carbon emission reduction targets for GHGs, including base and target years and internal analysis of MSCI on the regulatory frameworks per country. This information was verified for countries with the most proven oil and gas reserves per region, based on the proven reserves information from the BP statistical review of World Energy (2016). The exact targets per (I)NDCs were verified via the Climate Action Tracker (2017) and the UNFCCC (2017). Each region was scored on the ambition of the targets in combination with the base and target year. High, ambitious[36] targets of more than 25% reduction were labeled as higher risks. Second, countries which had not yet submitted (I)NDCs, or had no clear base years for their targets were labeled with a lower risk. Finally, the regions of production per O&G company were linked to the risk levels of the regions.

Results

In figure 19, the hydrocarbon productions of the 11 O&G companies are presented per region. Exxon has highest production levels, about eight times more million boe/day compared to Suncor, which is the smallest producer.

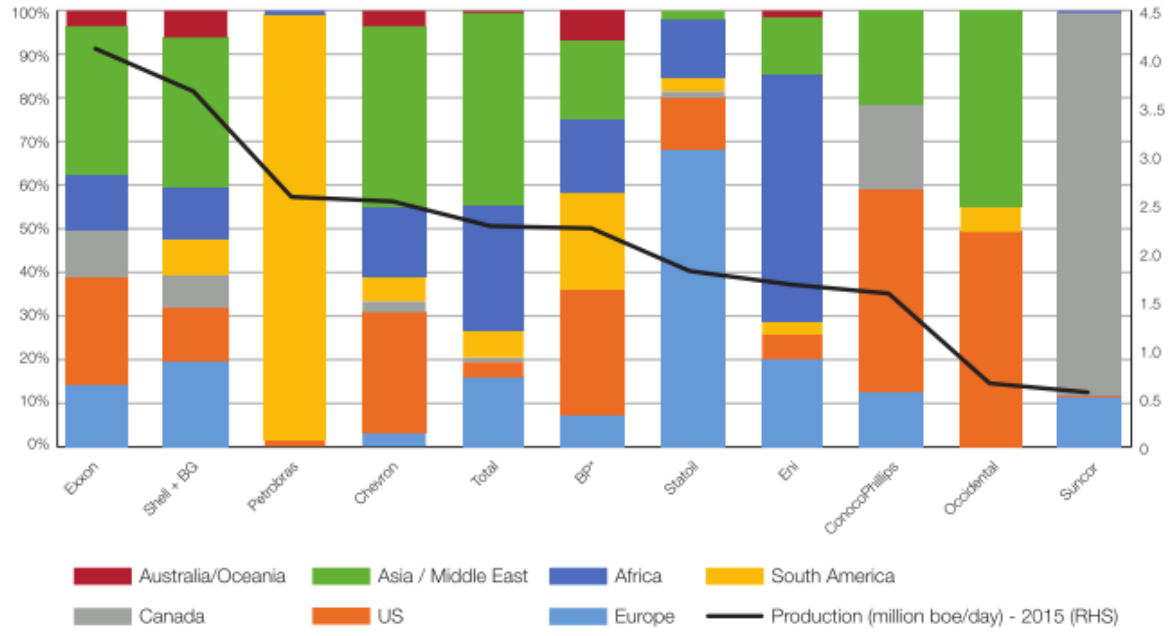

Figure 19: O&G companies' hydrocarbon production per region. Source CDP (2016) In the pipeline p. 35

[36] Ambitious implies no dynamic baselines or BAU scenarios as base year.

MSCI (2016) classified the risk of strict environmental regulation per region, based on the emissions targets set and analysis of the regulatory frameworks. This is shown in figure 20.

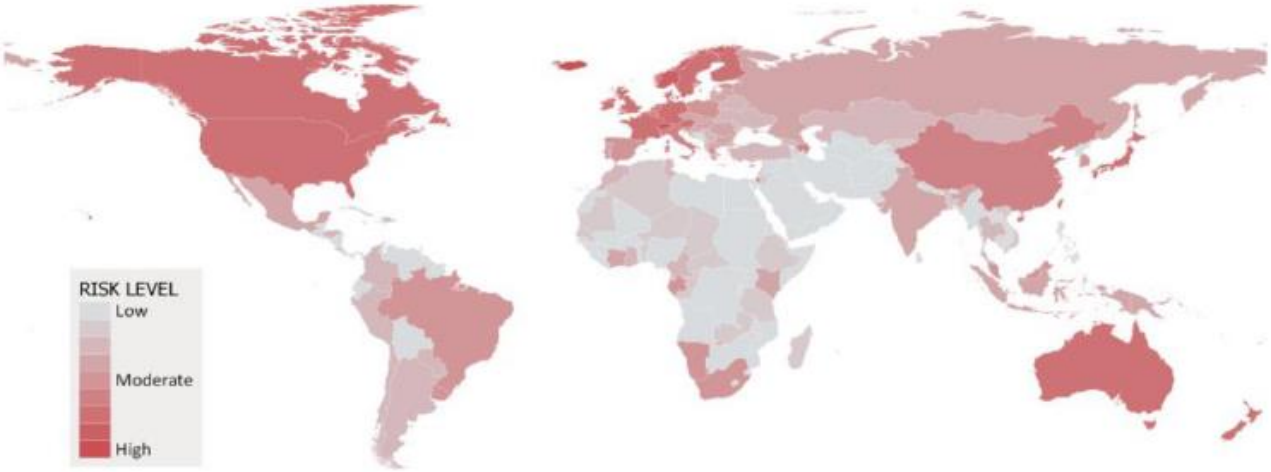

Figure 20:Overview regulatory frameworks of Global GHG emissions. Source MSCI (2016), Industry Report O&G, p.35.
(NB: not all regions are scored appropriate by MSCI based on the emission reduction targets. Targets of countries like China & India were compared to GDP intensity for example.)

In table 20, the (I)NDCs for the regions used in figure 19 are presented. Per region, the carbon emissions targets are presented if available. These reduction targets are used as a proxy for future environmental regulation which could affect the reserves of O&G companies. For the regions Africa, Asia/Middle East and South America, the three countries are selected with the highest number of proven oil reserves and proven gas reserves to obtain their emission reduction targets (BP, 2016). These countries are the most important for O&G companies, since their regulation can potentially have the most impact on the future production of the O&G companies.

Table 20: Emission reduction targets from (I)NDCs per country/region and associated risk levels. Source: Climate action tracker (2017) and UNFCCC (I)NDC Registry (2017).

Country[37]	**Carbon emission target**	**Base year**	**Target year**	**Overall regulatory risk per region**
Canada	-30%	2005	2030	High
USA	-26-28%	2005	2025	High
Australia	-26-28%	2005	2030	High
EU	-40%	1990	2030	High
Africa - **Libya*** - **Nigeria*** - **Algeria**	 No INDC submitted 20% -7%-22%	 No data Compared to BAU Compared to BAU	 No data 2030 2021-2030	Low
Asia & Middle East - **Russia** - **Saudi Arabia**	 -25-30% Annual abatement of 130 Mt CO_2	 1990 Dynamic baseline of 2 scenarios	 2030 2030	Low

[37] *Not all countries have already submitted NDCs at the UNFCCC. Nigeria, Iran and Venezuela only submitted their INDCs and still need to register their NDCs. Libya has not submitted its INDCs yet.

- **Iran***	-4% (GHGs)	Compared to BAU	2030	
South America				Moderate
- **Venezuela***	-20%	Compared to BAU	2030	
- **Brazil**	-37%	2005	2025	
- **Mexico**	- 25%	Compared to BAU	2030	

Canada, US, Australia, and Europe are categorized as regions with the highest risk of climate regulation implementation which could affect O&G companies. All these regions have submitted their NDCs and all targets are above 25%. South America[38] is scored with moderate risk level. Although not all countries submitted their NDCs, emissions reduction targets are 20% or higher. Africa and Asia & Middle East have the lowest regulatory risk. Not all with most countries submitted their (I)NDCs and reduction targets are not ambitious or compares to arbitrary dynamic baseline scenarios.

Assuming current production locations are a good proxy for an O&G companies proven reserves (Kaiser et al, 2012), Petrobas, ENI and Total are least exposed to the potential environmental regulations with the majority of their reserves in low or moderate regulatory risk areas. The total percentage in areas with high risk is lower than 30% in this group. Hence, investment in these companies is considered less risky based on the regulatory risk of stranding of assets. Chevron, Shell, Exxon, Occidental and BP are moderately exposed, with better geographical diversified reserves over different regions. Still the percentage of reserves in regions ranked with high regulatory risk ranges between 50% and 65%. Three companies are most at risk, with more than 75% of their reserves in high regulatory risk areas. ConocoPhillips (78%, in US, Canada, EU), Statoil (82%, in EU, US, Canada) and Suncor (99%, in Canada, EU) have the highest regulatory risk for assets to strand, with the majority of their reserves in high risk areas. The risk levels and overall ranking is depicted in table 21.

table 21: Risk level per O&G company regarding reserves in environmental regulatory regions

IOC	**Level of regulatory environmental risk exposure per O&G company proven reserves**			**Rank** (1=low risk, 11= high risk)
	Low	Moderate	High	
Statoil			**x**	*10*
Eni	**x**			*3*
Total	**x**			*2*
Shell + BG		**x**		*6*
BP		**x**		*4*
Occidental		**x**		*8*
Petrobras	**x**			*1*
ConocoPhillips			**x**	*9*
Chevron		**x**		*5*
Exxon Mobil		**x**		*7*
Suncor			**x**	*11*

The worst performing companies on unburnable carbon per indicator are depicted in table 22.

[38] Mexico is included in South America, since US & Canada are already categorized as separate regions.

table 22:O&G companies most at risk regarding unburnable carbon

Costs	**Emission intensity**	**Share of stranded assets**	**Regulatory risk of reserves**
Petrobas	Suncor	Suncor	Suncor
Shell	ConocoPhillips	Exxon	Statoil
Chevron	Exxon	ConocoPhillips	ConocoPhillips

6.5.2 Carbon bubble Burst | Adaptability O&G companies

Adaptability of O&G companies was the other defined important factor, which determines what the impact of a carbon bubble burst would be. Adaptability of the O&G companies focusses on its current alternative energy assets & investments, its size and its capital flexibility. Capital flexibility is considered important since it determines how well a company can financially adapt to shocks. Since the O&G companies must shift away from their core business abruptly, the companies with inflexible capital allocations comprise higher investment risks. Regarding high level of capital intensity in the O&G industry, the capital is often allocated for a longer period (20-30 years) for large projects (Busch et al., 2006; Weijermars, 2014). The capital flexibility of O&G companies is tested via the ratios of debt / equity ratio and Cashflow/ Capital Expenditures. The indicators for adaptability are depicted in figure 21.

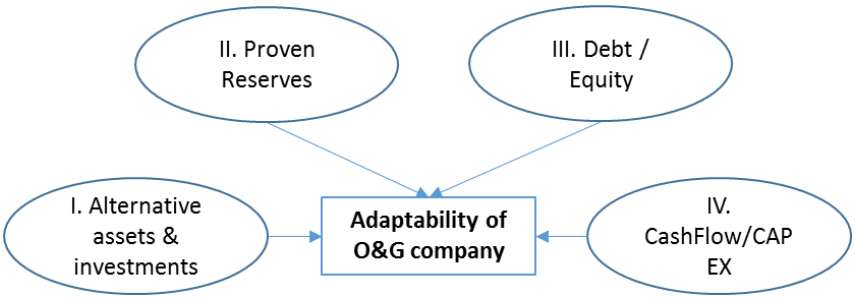

Figure 21: Indicators used for adaptability of O&G companies

I. Alternative assets & investments

O&G companies which can participate in the energy transition by gradually shifting to renewables are more likely to survive in a carbon-constrained world (Weijermars et al.,2014; Levy et al.2002; Van der Ploeg, 2016). The O&G companies which do not shift towards renewable assets, can be a higher investment risks for investors.

Metrics

The O&G companies were scored on the presence of alternative energy assets and investments in low-carbon technologies. Qualitative and quantitative data on alternative energy assets and investments was retrieved from CSR reports of companies and company websites. Companies with no alternative energy assets were labeled with the highest risk. Companies with ambitious and concrete targets for renewable investments were ranked as less at risk (table 23).

Results

Table 23: Overview alternative energy assets & investment of O&G companies. Source: CSR reports & company websites.

11 Large O&G companies	**Alternative Energy assets & investments**	**Rank** (1=low risk, 11= high risk)
Statoil	Projects in offshore wind, New energy investment fund of 200M US$	*4*
Eni	Solar projects planned (350MW capacity) 1 billion investment planned in 3 years	*5*
Total	Acquired Sunpower solar company. Aim 20% of portfolio invested in low-carbon by 2035	*1*

Shell + BG	Wind energy (500MW cap) Raizen Biofuels project, 1 billion liters in 2015. Plan to invest 200M / year.	*3*
BP	Onshore wind (1556 MW cap) Biofuels 795 million liters 2015 invested 8 billion 2005-2013	*2*
Occidental	No alternative energy assets, focus CCS	*10*
Petrobras	Low-carbon R&D, interest in onshore wind and biofuels	*8*
ConocoPhillips	No alternative energy assets, invest in couple energy start-ups	*11*
Chevron	Geothermal 1300 MW capacity, wind 16.5 MW	*7*
Exxon Mobil	No alternative energy assets, focus on CCS	*10*
Suncor	Wind (144 MW capacity), biofuels, 400m liters/year	*6*

II. Proven reserves

The more proven reserves a company has, the bigger its size, and the larger the risk of overproduction (Caldecott et al., 2015). Large companies tend to adapt less quick to changes. Although these scale advantages can lead to cost reductions in business as usual scenario, it leads to scale disadvantages in a carbon bubble burst scenario. Data from CDP (2016) was used in billion boe for the year 2015 as a proxy for size.

III. Debt / Equity ratio

The debt/equity ratio is retrieved from database Factiva, using data of fiscal year 2016 in line with International Financial Reporting Standards (IFRS). The debt-equity ratio is calculated by dividing the total liabilities by the value represented in the shareholder's equity of the company.

$$Debt/Equity\ Ratio\ =\ Total\ Liabilities\ /\ Shareholders'\ Equity$$

The debt/equity ratio gives an indication of the financial stability of the company. High ratios indicate a higher risk, since it implies financing large shares of its assets with debt. This further implies aggressive leveraging practices and financing growth with debt. This can result in volatile earnings or payment problems due to the additional interest expenses and financial instability. The higher the debt ratio of a company, the higher its risk when it needs to adapt to new circumstances, like shifting away from its core business towards a new lower-carbon business model. Companies with high debt ratios are less likely to survive when adaptation is required (Kaiser et al. 2012; Domanski et al., 2015).

IV. Cashflow/CAPEX

To assess how much of its available cashflow a company invests in new capital, the ratio Cashflow/CAPEX is used. This ratio is calculated as follows:

$$CF/CapEx\ =\ Cash\ Flow\ From\ Operations\ /\ Capital\ Expenditures$$

Data was used from Factiva over the period 2014-2016. Low CF/CAPEX ratios are often considered positive, since it is an indication that a company can acquire long term assets using free cashflow. In this scenario, high CAPEX values, hence low CF/CAPEX ratios for O&G companies are labelled as high

risk, since this makes them less flexible and adaptable. Assuming the capital expenditures involve O&G assets, these can become stranded in a carbon bubble burst scenario. Companies which high CAPEX over a period, form a higher risk in a carbon-constrained world (Caldecott et al., 2015).

The values and rankings of Proven Reserves, Debt/Equity and Cashflow/CAPEX are presented in table 24.

Table 24: Values and ranks of Proven reserves (CDP,2016), Debt/Equity and CF/CAPEX (Factiva, 2016)

11 O&G companies	Proven Reserves (billion boe)	Rank	Debt/equity (2016)	Rank	Cashflow/CAPEX 2014-2016)	Rank
Statoil	5.1	*3*	90.31	*10*	0.89	*9*
Eni	6.9	*4*	51.36	*6*	1.05	*5*
Total	11.6	*9*	57.75	*7*	0.89	*10*
Shell + BG	15.3	*10*	49.55	*5*	1.11	*2*
BP	10.4	*6*	61.18	*8*	1.05	*4*
Occidental	2.2	*1*	45.68	*4*	1.05	*6*
Petrobras	10.5	*7*	190.93	*11*	0.92	*7*
ConocoPhillips	8.2	*5*	77.99	*9*	0.90	*8*
Chevron	11.2	*8*	31.69	*2*	0.78	*11*
Exxon Mobil	24.8	*11*	25.56	*1*	1.29	*1*
Suncor	4.7	*2*	39.05	*3*	1.06	*3*

The high debt ratios of some O&G companies can be explained by the fact they are partially owned by the state as Government Sponsored Enterprises (GSEs). Statoil (67%), Petrobas (61%) and Eni (30%) are partly government owned. This allows them to have higher debt ratios. Nevertheless, these high debt ratios indicate high investment risks. High debt ratios and capital intensive industries were also categorized as crisis prone by Schoenmaker et al. (2015) (see section 3.1), which is alarming.

Taking the average ranking of the O&G companies for adaptability gives the following results (Table 25).

Table 25: Average rank of adaptability indicators

11 O&G companies	**Average rank 4 indicators Adaptability**	**Rank** adaptability
Statoil	6.50	*7*
Eni	5.00	*2*
Total	6.75	*8*
Shell + BG	5.00	*2*
BP	5.00	*2*
Occidental	5.25	*5*
Petrobras	8.25	*10*
ConocoPhillips	8.25	*10*
Chevron	7.00	*9*
Exxon Mobil	5.75	*6*
Suncor	3.50	*1*

Combining the burnable carbon & adaptability rankings, ConocoPhillips, Chevron and ExxonMobil would be most at risk in a carbon bubble burst scenario, because of unburnable carbon and a lack of adaptability skills (table 26).

Table 26: O&G Companies most at risk in carbon bubble burst scenario marked red.

11 O&G companies	**Rank Burnable carbon**	**Rank Adaptability**	**Average rank carbon bubble burst**	**Finanl rank Carbon bubble Burst**
Statoil	*2*	*7*	*4.5*	*3*
Eni	*1*	*2*	*1.5*	*1*
Total	*3*	*8*	*5.5*	*5*
Shell + BG	*7*	*2*	*4.5*	*3*
BP	*5*	*2*	*3.5*	*2*
Occidental	*8*	*5*	*6.5*	*7*
Petrobras	*4*	*10*	*7*	*8*
ConocoPhillips	*10*	*10*	*10*	*11*
Chevron	*6*	*9*	*7.5*	*9*
Exxon Mobil	*9*	*6*	*7.5*	*9*
Suncor	*11*	*1*	*6*	*6*

6. 6 Effect carbon bubble burst for Dutch pension market

In this section, the results of the impact of a carbon bubble burst among the interviewed pension providers is discussed.

DNB (2016a) found that the carbon bubble exposure via fossil fuels on the assets for pension funds was the largest, with 0.4 % in bonds, 2 % in equity, 2.5% in commodities and 0.7% in other types of assets. This exposure to fossil fuels was in total 5.4% (DNB, 2016a).

The interviewed respondents in this research have a total of 990 billion euros in assets under management. The exposures to O&G industry of the interviewed pension providers ranged from 15% to less than 2% of their portfolio[39]. The average share in O&G in the portfolio of the pension providers is 7.45 percent. For the asset managers, this only involves the share of O&G position in their pension portfolios.

Total exposure to O&G industry among the interviewed respondents is 73.76 billion euro. Assuming the total Dutch pension market of 1300 billion euros equals the exposure of 7.45% to O&G companies, the total exposure is 96.85 billion euros. This is a substantial amount, considering this excludes coal companies and utilities. Multiple explanations are possible for the difference between the outcome of this research and the outcome of the DNB report (DNB,2016). A possibility is that the research of DNB included different respondents who were less exposed, or the respondents of the DNB research disclosed lower values than the actual exposure. Another reason could be that respondents interviewed for this research provided not the accurate data, since they had not the right numbers in mind, or mentioned their exposure to the effect in multiple industries if the carbon bubble would burst and not only O&G multinationals would go bankrupt. It is also possible that the respondents increased their positions in O&G companies recently, moving away from coal while maintaining the advantages of investments in fossil fuel companies.

> *''Let's say 15% of our portfolio is in O&G companies. If these companies lose 40% in value, that means we would have to write off (XXX) billion euros and the debt-coverage ratio falls by 6 points. That implies we would have to make substantial reductions on the pension payments, instead of 500 euros a month only 475 euros.''* Interview with Head Risk Analysis - P. 44-45 of the transcription report. (*NB: Number of billions loss is erased for confidentiality reasons)*

Much more Impact than only the O&G sector

If the 2 ˚C scenario is realized and companies will have 42% of unburnable reserves as calculated for the eleven O&G companies in Appendix X, the lost value of the Dutch pension market of only O&G companies could comprise 40.68 billion euros[40]. This is a substantial amount, but not as big as the 25% loss in pension portfolios of the financial crisis according to respondents[41]. However, this does not imply the impact of the risk can be considered low or less essential to avoid. Moreover, the impact of a carbon bubble burst on the whole portfolio would be even larger, since it will have consequences in multiple sectors which all would lose value, such as utilities, transport and manufacturing (Andersson et al., 2015; Batiston et al., 2016; ESRB, 2016; DNB, 2016). The respondents acknowledge it is a broader

[39] Pages: 55, 23, 28, 36, 42, 62, 78 of the Transcription report
[40] This does not consider a discounted factor of the stranded assets on the Mcap loss.
[41] Page: 5 of the Transcriptions report

issue than the just O&G sector, but most still consider a carbon bubble burst improbable. Section 7.2 elaborates on these reasons.

6.6 Response to carbon bubble burst of Dutch pension market

The respondents had different views on whether they would sell their positions if a carbon bubble would burst. The majority, six of the respondents, states the situation will be analyzed again to explore what is most likely to happen. If it is expected the company will be able to create shareholder value in the future, the positions would not be sold[42]. One respondent mentions that if it is a real bubble burst, they will step out of O&G since they don't believe the companies would increase in value again[43]. One respondent stated they would not sell their positions, since selling positions when they declined in value is usually a bad investment decision[44]. At a pension provider where the majority is passively managed, it would depend on the rate of the decline in value and the level of the company value compared to the threshold which is determined in advance by the portfolio manager[45].

Divestment time

The time it would take to sell the positions also differs per provider. One provider mentioned it can be done within 24 hours. One provider indicated it can take up to six weeks, since large institutional investors neither want to have too much impact on the market or make it obvious they want to sell their positions, since this can alarm other investors to do the same.

> *''We could instantly sell our O&G positions overnight. Our portfolio is not rigid. We can adapt many things. We know that something is coming in 10-15 years which will impact the O&G industry. The information is direct available on the market and once the risks increase the positions will be slowly phased out.''* Interview with Advisor responsible investment - P. 23 of the transcription report.

It mainly will depend on how many other investors want to sell their positions, majority respondents stated. In a case of a bubble burst, this will be the case since all investors would want to sell their positions.

> *'If the bubble bursts, like what happened with Volkswagen, it takes 2-3 months before you sell all your positions. Mainly because everybody wants to get rid of them.''* Interview with Strategy Sustainability Consultant - P. 82 of the transcription report.

[42] Page: 14, 23, 31, 45, 55, 63 of the Transcription report
[43] Page 72 of the Transcription report
[44] Page 38 of the Transcription report
[45] Page 81 of the Transcription report

6.7 Reflection on the interviews

Reflecting on the interviews, it is worrying the risk is being downplayed by some respondents. Although the impact of a carbon bubble burst via O&G companies could be less than that of the financial crisis, the impact in multiple sectors will be much larger and all means are required to avoid this. Also, after the financial crisis the value did come back. Regarding the response of the pension providers if a carbon bubble burst would occur, the value of O&G companies would not come back if this happens. This makes the strategy which most pension providers mention incompetent. Unless these companies could participate via alternative energy sources or negative emission technologies (CCS), the investments in the O&G companies will lose their value. Another critical remark is required considering the divestment time. If divestment procedures are started when the bubble bursts, they will be too late. All investors would sell their positions at that moment, resulting in a lower price per share and a loss for the pension providers.

6.8 Key Findings

The third sub-question was: *What would be the effects for the Dutch pension funds and providers if the O&G companies in their portfolio would decrease in value, due to a potential carbon bubble burst?*

This chapter focused on the effects of devaluation of O&G companies. First, scenario analysis focused on two scenarios and the effects on 11 large O&G companies. In the first scenario, companies could continue to exploit their reserves, since rising fossil fueled energy demand was the dominant driver. Occidental Statoil and Eni are most at risk in this *Business as Usual* scenario. Assuming an abrupt energy transition, ConocoPhillips, Exxon Mobil and Chevron are most at risk in a *Carbon Bubble Burst* scenario.

From the interviews with the respondents resulted that the average total exposure to O&G companies in the different portfolios is 7.45 %, which is an average of the different portfolios and different clients of the pension providers. This equals to 96.85 billion euros for the complete Dutch pension market. The effect of the financial crisis (25%) in 2008 had more impact. However, the effect of the carbon bubble burst would have effect in multiple sectors than only O&G. The response to a carbon bubble burst differed per pension provider. Most of them would reevaluate to see if the impacted companies would be able to increase in value over the long term. However, if a bubble burst would occur, this value would not come back which implies a loss for these O&G investments. The time to divest the O&G companies could range between 24 hours and three months, depending on how the market responds.

The effects of a carbon bubble burst would be substantial according to the Dutch pension market, considering the effect on their portfolio, which will be more than just the exposure of O&G companies. However, the pension market values the probability of a carbon burst unlikely. Chapter seven elaborates on this.

7. Risk valuation of a Carbon bubble of O&G companies in the portfolios

This chapter discusses how the respondents value the carbon bubble risk of O&G companies in their portfolio. In 7.1, the data sources of the pension providers are discussed, followed by the indicators and methods they use for risk valuations. 7.2 elaborates on how the pension providers value the risk of a carbon bubble burst. A critical reflection on their reasons is provided after these reasons. To further examine the link between a bubble and the O&G industry, 7.3 discusses two cases, on high debt levels and capital intensive assets in the O&G industry. Both are characteristics of bubbles defined in the literature. 7.4 elaborates on whether the carbon bubble is currently priced in the financial markets or not. In section 7.5 deals with the issue on how to deflate the potential carbon bubble. The final section summarizes the key findings of this chapter.

7.1 Data, indicators & methods for valuing the carbon bubble risk

Here the data sources of the pension providers are discussed, followed by the indicators and methods they use to score the carbon (bubble) risk of O&G companies.

7.1.1 Data

The main argument against carbon accounting of an investment portfolio is the lack of sufficient data. Pension providers buy data and analyses from different companies. MSCI[46] is considered the leading provider for data and analyses for institutional investors and hedge funds. Other data providers are Trucosts, Sustainalytics and Wood Mackenzie[47]. O&G companies also disclose directly to their investors, but the level of in-depth information differs per company.

> *''MSCI & Sustainalytics are our data providers. MSCI delivers the most quantitative data in this field. We look at what is our exposure. For our specific more sustainable fund for instance, we had globally 1600 companies in the MSCI world fund. This implies 100% carbon exposure, since you invest based on weighted average globally.''* Interview with Sustainability Strategy Consultant - P.83 of the transcription report.

The data reports are specified per sector, dependent on the important ESG subjects. In table 28, an overview from Clark et al. (2015) on ESG themes is depicted. The carbon bubble can be categorized as a specific type of climate change risk.

[46] MSCI stands for Morgan Stanly Capital Index, but the data providing company is no longer part of Morgan Stanley.

[47] Pages: 10, 20, 32, 36, 53, 74, 83 of the Transcription report

Table 27:Overview examples ESG factors. Source: Clark et al. (2015) p. 12

Environmental (E)	Social (S)	Governance (G)
Biodiversity/land use	Community relations	Accountability
Carbon emissions	Controversial business	Anti-takeover measures
Climate change risks	Customer relations/products	Board structure/size
Energy usage	Diversity issues	Bribery and corruption
Raw material sourcing	Employee relations	CEO duality
Regulatory/legal risks	Health & safety	Executive compensation schemes
Supply chain management	Human capital management	Ownership structures
Waste and recycling	Human rights	Shareholder rights
Water management	Responsible marketing and R&D	Transparency
Weather events	Union relationships	Voting procedures

7.1.2 Indicators

A variety of indicators is taken into account for the risk analysis of an O&G company. An overview of the important indicators mentioned by the respondents is presented in table 29. Pension providers with clear sustainability targets, value carbon foot printing as a useful tool. The indicators used by the pension providers are divided in the categories: financial data, CO_2 emission intensity of the production process, specifications on fossil fuel reserves and governance of the company. Although these indicators were mentioned by respondents, not all are considered risk indicators.

Table 28: Overview of indicators mentioned for risk analysis of O&G companies by respondents & categories

Indicators	Category
historical data cost overruns on projects	financial data
cashmargin/oil price	financial data
efforts for risk mitigation,	governance
track record	historical safety data
safety trends	governance
transparency on assumptions before starting project	governance
how laws are taken in account	governance
governance of the company	governance
regulation of company	governance
fracking activities	CO_2 intensity activities

geographical spread of fields	geographical spread of fields
most vulnerable fields cost	fossil fuel asset mix
unconventional oil/gas	fossil fuel asset mix
minimum water usage	water usage
Spills: oil, methane	emissions & leaks in process
spills trends	emissions & leaks in process
CO_2 intensity	CO_2 intensity activities
carbon footprint	CO_2 intensity activities
MSCI determined indicators	MSCI external

At the same time, it resulted from the interviews carbon foot printing is not specific enough. Especially since most of the emissions fall in scope 3, which are often not included.

> *''The production side includes 15% of the emissions. O&G companies can perhaps reduce CO2 emissions with 5% if they are really efficient. But the majority of 85% results from the combustion of the fuel itself. You can discriminate some between CO2 intensive fields, but it does not result in a big difference of the total emissions.''* Interview with Senior Investment Analyst Energy - P. 65 of the transcription report.

MSCI report

MSCI scores O&G companies on risk mitigation. Table 30 gives a representation of the scores of the indicators for the O&G industry in 2016 (MSCI, 2016):

Table 29: MSCI indicators for risk mitigation O&G companies. Source: MSCI (2016) Industry report O&G, p.33

Indicators Risk mitigation	**Percentage of integrated O&G companies mitigating**
1. energy efficiency:	
- Tracking of own emissions	85%
- Flaring & methane emission reduction targets	50%
2. carbon capture and sequestration capabilities	<20%
3. renewable energy in portfolio (solar, wind and/or 2nd generation biofuels)	33% with max $1 billion/ producer / year

Comparing the indicators mentioned by the respondents with the MSCI O&G report, energy efficiency includes the categories emission & leaks in the process and CO_2 intensity of the activities. Since these MSCI indicators in table 30 only include risk mitigation indicators for O&G companies, not all categories mentioned by the respondents can be linked to the three indicators in the table.

7.1.3 Methods for risk valuation

In general, the methods for risk valuation are not completely different for the O&G sector compared to the methods of other sectors. Pension providers use ESG scores, which have influence on the total score of the company. Based on this score, the company can be over- or underweight compared to the benchmark. Three pension providers explicitly mention the ESG score is integrated in the investment decision of the company. For the other six providers, it is presented as an advice to the portfolio manager.

Two providers under weighs the whole O&G sector in their investment decision. Four others don't apply it to the complete sector, but only to most CO_2 intensive companies, or based on different regions or comparison to their peers in the sector[48].

> *''We once did a project to test carbon foot printing as a method, but the results were too diverse. We had a portfolio which was analyzed by several external data providers. We asked them to make a Carbon footprint analysis of that portfolio. One said it was 30% more CO2 intensive compared to the benchmark, while the other said it was 30% less CO2 intensive compared to the benchmark.''* Interview with Global Head Sustainability - P. 73 of the transcription report.

One provider explicitly mentions under weighing a complete sector like O&G would result in unfair investment decisions. Another stated that carbon foot printing is not considered well-developed enough as a tool for risk management[49]. Apart from that the data is often provided by external parties, these providers also execute analysis and determine indicators for risk scores [50].

The problem with most methodologies is that they use data from the past, which do not consider future risks for these O&G companies. Botelho et al. (2014), found that although historical data analysis has proven to be an effective measure in estimating future performance and risks, the O&G industry requires more usage of forward looking data (Botelho et al. 2014). First, because the types of reserves (more unconventional) and the operations to exploit them, are rapidly changing. Second, because the valuation of O&G companies is mainly based on its proven reserves, while the capital is allocated to increasingly complex technologies (Tsoskounoglou et al., 2008). Third, management practices are hard to evaluate in an industry which harms the environment without proper regulation and a bias in the reporting of environmental risks (Botelho et al., 2014). Some respondents acknowledge this, while others stick to their traditional methods of risk analysis.

> *''There is the possibility that future problems are not taken into account in the historical data used for risk analysis. That is why we believe integration of ESG factors in the portfolio is important. These are the risks that will be traditionally neglected.''* Interview with Advisor responsible investment - P. 19 of the transcription report.

[48] Underweight O&G sector Page 16, 17, 46. Most CO2 intensive companies page 42, 46, 73. Peer comparison page 19, 85 of the Transcription report
[49] Unfair investment page 65. Carbon foot printing not developed enough page 72 of the Transcription report
[50] Page 22 of the Transcription report

Strategic Asset Allocation & Asset Liability Management

Strategic Asset Allocation tools like Asset Liability Management are not applied on the O&G sector level yet. Both are applied on a higher level, and mainly for the funds to see to what extent they can meet their future obligations to the client and adjust the investments accordingly. The consensus is that the costs of these methods are not (yet) outweighed by the potential benefits on O&G sector level. One provider indicated they once used ALM analysis to see what the impact of an energy transition would be on the portfolios of their clients. One other provider said it would be something they were looking at to do in the future[51]. Another provider stated these specific studies cost time and money, which is better allocated to other concerns. Also, in depth assessing the individual risks of a company is a different strategy than pursued by most pension providers.

> *''Other investors aim to investigate a company more intensive so they can better assess what the individual risks are for such a company, to make a better risk/return assessment than other investors. Like some hedge funds maybe, or to sell a carbon bubble burst strategy in the market. But that is really labor-intensive. I am not saying that is not possible, but that is not the path we chose.''* Interview with Head risk analysis - P. 49-50 of the transcription report.

Reflecting on this, it is concerning not all available tools are used to assess these risks due to labor intensity, considering the potential impact of a carbon bubble burst in multiple sectors in the portfolios. From the financial risk perspective, providers should do all to optimally asses the risks. Especially if these risks could be underexposed in current models.

[51] ALM used for climate risk impact page 37. ALM in the future for O&G page 33 of the Transcription report

7.2 Risk valuation of carbon bubble burst

The consensus among the respondents is that the carbon bubble risk is not substantial in their portfolios. Although the impact could be significant, they consider the probability low. Several reasons the respondents mentioned are elucidated here, followed by a critical reflection on their motivations. Besides the risks of investing in the O&G sector, the positive aspects are also discussed.

7.2.1 ''*Energy transition will happen gradual instead of abruptly*''

The shift towards a low carbon economy can happen in two ways. Either in a gradual shift, or via an abrupt transition. All respondents indicate the energy transition away from fossil fuels will happen gradual instead of an abrupt transition within four years[52]. If the transition will happen over five years or thirty years is uncertain, but none of them believe it will happen in a period shorter than five years. To materialize the risk of the carbon bubble, the pension providers believe a sudden transition is needed for instance via abrupt binding legislation, which puts a limit on the exploitable reserves, or due to disruption of emerging alternative energy technologies. Both scenarios are unlikely in the coming five years according to the respondents.

> *''There will be an energy transition, everybody knows where it ends, but nobody knows how fast it will go. If you choose not invest in a sector, you take a real big risk. If we exclude fossil fuels now but the transition takes 30 years, we miss out on 30 years of profit.''* Interview with Head risk Analysis - P.42 of the transcription report.

> *''The energy transition will go gradual and we will over time see how companies like Shell cope with it. I believe the characteristic of a bubble is that: all kinds of values are assumed in the market and suddenly it becomes clear there is no value.''* Interview with Global head responsible investment - P.71 of the transcription report.

Although all respondents believe the energy transition will happen gradually, the literature is divided on this. Loftus et al. (2015) examined the feasibility of 17 decarbonization scenarios, finding that those focusing on an abrupt transition use historically exceptional developments in the deployment of low carbon technologies, which significantly lowers the probability of such a fast energy transition. Kern et al., (2016) argue that history of transitions is just a partial approach to understands its patterns. Current global innovation dynamics, combined with higher level of governance can significantly accelerate future transitions. Although the conventional view on energy transitions considers them to take a decade up to a century (Fouquet et al, 2012), Sovacool (2016) finds empirical evidence on the dynamics of energy transitions, showing that the diffusion and adoption speed of the technologies required, can vary significantly. Either managed or not, the pace of energy transitions cannot be predicted.

Considering that transitions can occur abruptly, the Dutch pension market could make wrong assumptions regarding what they base their investment decisions upon. This implies the pension providers are not adequately managing these risks, by placing all their eggs in one basket.

[52] Page 3, 13, 23, 30, 38, 42, 62, 71 of the Transcription report

7.2.2 ''*Deflation is more probable than a bubble burst*''

The biggest risks are where they are not expected. The research on the carbon bubble grew in last years, and respondents believe it is already in the picture of investors. Some mentioned the recent scandal with fraud in emission software of Volkswagen, which was unexpected and therefore caused a bigger loss. However overall, respondents do not consider carbon bubble as a black swan type of risk[53].

> *''The problem with the carbon bubble theory is that it is too obvious, we know that the energy transition is coming (…) I would not say a bubble burst is probable, since it is already deflating.''* Interview with Strategy Consultant Sustainability - P.77 of the transcription report.

This assumes investors will move out of fossil fuels in time, but currently pension funds still invest substantially in these carbon-intensive companies[54]. Current rate of deflation will still result in a loss in the pension portfolios if a bubble will burst.

7.2.3 ''*Rise in energy demand is dominant*''

The future economic growth will go hand in hand with a growing demand for energy. Currently 80 % of the energy comes from fossil fuels and it will take time to switch to cleaner alternatives. Especially emerging economies in Africa and Asia will drive the demand for fossil fueled energy in the coming decade. Passenger cars can be electrified, but this is only a quarter of the total oil demand[55]. This implies O&G companies will remain important to supply the fossil fuels according to the respondents, which lowers their risk on the stranding of their assets.

> *''Emerging markets were the main driver for the total energy demand in the last 15 years, with more people entering the middle income class(…) On average more cars per person, more air traffic, all those things which people in the middle income class bracket do. I expect that trend will continue with more demand for energy. Part of that can be electrified, but not all. If that happens there will maybe be a small decline in oil demand, but not a total decay.''* Interview with Senior Investment Analyst Energy - P.62 of the transcription report.

Verifying the information of the respondents, transport accounts for 65% of global oil consumption, of which passenger vehicles account 50%. This implies global share of passenger cars on oil demand is 32% instead of a 25% (IEA, 2016). Passenger cars are likely to be electrified first, which will have a bigger impact than mentioned by the respondent. This is in line with the downplaying of the risks, since the impact of electrification of vehicles would be larger on the oil demand.

[53] Page 52, 65, 71 of the Transcription report
[54] Pages: 55, 23, 28, 36, 42, 62, 78 of the Transcription report.
[55] Page 62 of the Transcription report

7.2.4 ''*Transition to lower carbon economy is not a threat to the share price of O&G companies*''

Although for O&G companies a large part of the reserves is included in the valuation, this includes just a small part of the total O&G reserves. The expectation is that those listed O&G companies, with current production levels, will not run out of their proven reserves before the demand will be largely declined. This is different for the NOCs, which have reserve life ratios for over 70 years (CDP, 2016)

> *''We did stress tests on our portfolio, 1.5 years ago, to explore the impact of different climate scenarios. The results did not include that it is a large risk, but I cannot tell you the exact outcome of those tests.''* Interview with Senior Advisor Investments of a pension fund - P. 6 of the transcription report.

The pension providers believe that the proven reserves of the O&G majors (which account for 10-15 years) will be exploited. Providers also question to what extent this could materialize in a carbon bubble.

> *''The reserves are not on the financial balance sheet of those O&G companies. This is another reason why the carbon bubble risk is muted. Our main concern is that these companies invest scarce means in something where we don't see future value in. But that is something different than a carbon bubble scenario. Since, to materialize that risk, those reserves need to be on the balance, but they are not.''* Interview with Responsible Investment Manager - P. 31 of the transcription report.

Reflecting on this, the O&G companies would lose value if their proven oil and gas reserves become stranded. Since the value of an O&G company is based upon those reserves, which are an indication of future cashflow. The valuation of a company is not only based on its financial balance sheet. Hence, these companies can still be at risk to lose value if their reserves become stranded, although these are not on the financial balance sheet.

7.2.5 *''O&G investment benefits: return, diversification & inflation hedging''*

Return

One of the reasons pension providers still invest in fossil fuels are the profitable returns, which according to the pension providers outweigh the risks. Between 1995 and 2015, fossil fuel companies generated on average a higher long-term return compared to the companies in the MSCI All Countries World Index (ACWI). MSCI ACWI is an index, market capitalization weighted, which includes stocks from developed and emerging markets. It is constructed as a measure for the performance of the world equity-market (MSCI, 2017).

Figure 22 indicates the fluctuation of the return of the MSCI World energy index, compared to the return of the MSCI World and the MSCI ACWI in US Dollar. Between 2004 and 2014, there was an outperformance of the MSCI World Energy Index. After 2014 however, the difference becomes smaller and the energy index even performs worse than the MSCI World and MSCI ACWI. This implies the higher returns for fossil fuels do not apply at this moment.

Figure 22: Cumulative index performance of gross returns in USD between March 2002-March 2017, comparing MSCI World Energy, MSCI World & MSCI ACWI. Source: MSCI World Energy index (2017).

The MSCI World Energy index is constructed to capture the mid and large cap segments in 23 developed countries and mainly consists of different types of O&G companies. Coal companies are barely represented. Figure 23 gives an overview of the different sub-industry weights of the MSCI World Energy index. The Oil and Gas industry dominates this index, with more than 50% of the index of integrated O&G companies. This also explains the large exposure of pension markets to O&G companies.

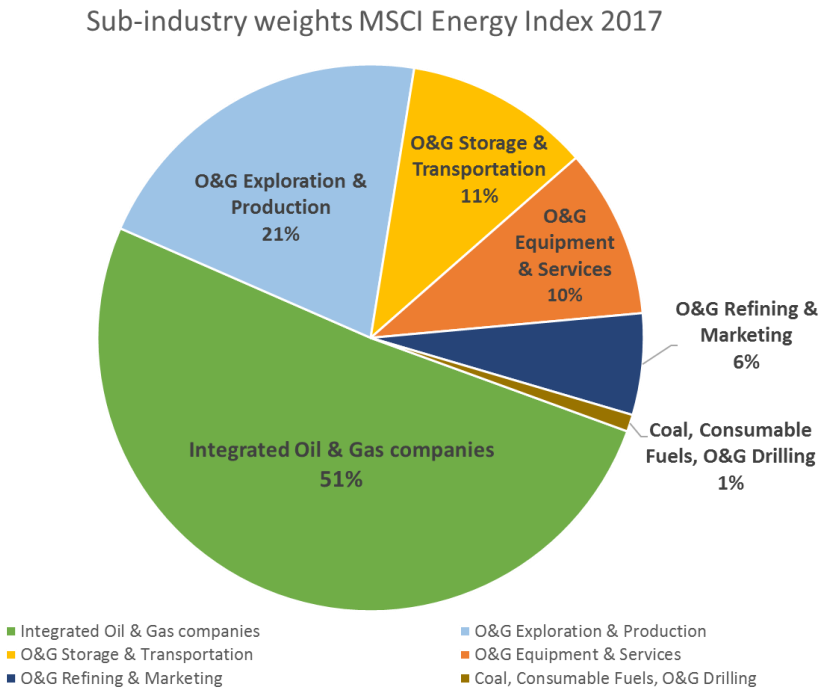

Figure 23: Sub-industry weights of MSCI World Energy index. Source: MSCI World Energy (2017).

However, excluding these O&G companies is not considered rational yet by the respondents, since it would limit the investment universe too much. Since O&G multinationals currently comprise such a large share of the MSCI Energy index, it is also more difficult to deviate from it.

> *''It is also difficult for us to exclude large parts. From an investment perspective, it is not good for your return. We also promised to invest more sustainable With return. Besides, we are that big that we need liquidity, so we need to maintain out investment universe as big as possible. ''* Interview with Senior Advisor Investment of a pension fund - P.8 of the transcription report.

> *''The main reason why the Dutch pension funds were most exposed to a carbon bubble burst according to the Dutch Central Bank in the report 'Time for Transition', was that they had the pressure to invest risk-averse. Since O&G is strongly represented in the index, they don't want to deviate too much from that index. This explains the relative large exposure.''* Interview with ESG analyst - P.14 of the transcription report.

Diversification

Companies in the energy sector provide diversification advantages (ABP, 2015). Since different sectors are never mutually correlating, the risk of a diversified portfolio is lower than the weighted average from the individual risk of the sector portfolios. Analysis of ABP (2015) indicated the yearly risk of the MSCI AC World Index is 15.5%, while the weighted average of the isolated sector risks is 18.3%. ABP states sector diversification based on non-complete correlation reduces the risk with 2.8%. Companies operating in the fossil fuel industry have a relative low correlation compared to other sectors, which makes them attractive from a diversification perspective[56]. However, ABP compares the fossil fuel companies as a separate sector here. The difference between all industries and all industries minus the fossil industry would be less, resulting in lower diversification advantages for fossil fuels.

> *''We expect that O&G will become less relevant in the long term, but in the coming 10-15 years we don't expect major changes in fossil fuel usage. Fossil fuels are still needed in the energy transition. Besides it is an attractive investment, for both return and diversification. ''* Interview with Advisor Responsible Investment - P.23 of the transcription report.

> *''It is also quite a one-dimensional bet, such a carbon bubble. It is not desired to take an extreme position on that, not rational. It is better to take different smaller positions and diversification. (…) For other scenarios than a carbon bubbl,. O&G companies might be a very positive investment.''* Interview with Senior Advisor Investment - P. 8 of the transcription report.

[56] Based on historical data from APG, assuming an equal level of pension payments. APG estimated that the added economic value of sector diversification equals outperformance of 0.6% per year. A decrease of 0.6% on the portfolio return, would imply a 20% increase of the pension premiums (ABP, 2015).

Hedging inflation

Another benefit of commodity related investments, like the energy sector, is that they can be used for hedging of inflation. Prices of commodities are strongly related to the consumer price index. Pension funds like ABP are exposed to commodity prices both indirect, via investments in energy companies, as direct, via commodity futures and non-listed commodity companies. Most investment in energy infrastructure can function as a hedge for inflation, since those tariffs are usually linked to the inflation (ABP, 2015).

7.2.6 Reflection on the arguments

Although return, diversification and hedging for inflation via O&G investments delivered benefits in the past, this is no guarantee that they still outweigh the risks. MSCI also offers an index which excludes fossil fuel companies since 2010. This index generated higher returns than the index with fossil fuels in last years (figure 24) (MSCI, 2016). A barrier for pension providers is that the tracking error[57] of this index is higher, which implies a higher risk of deviation.

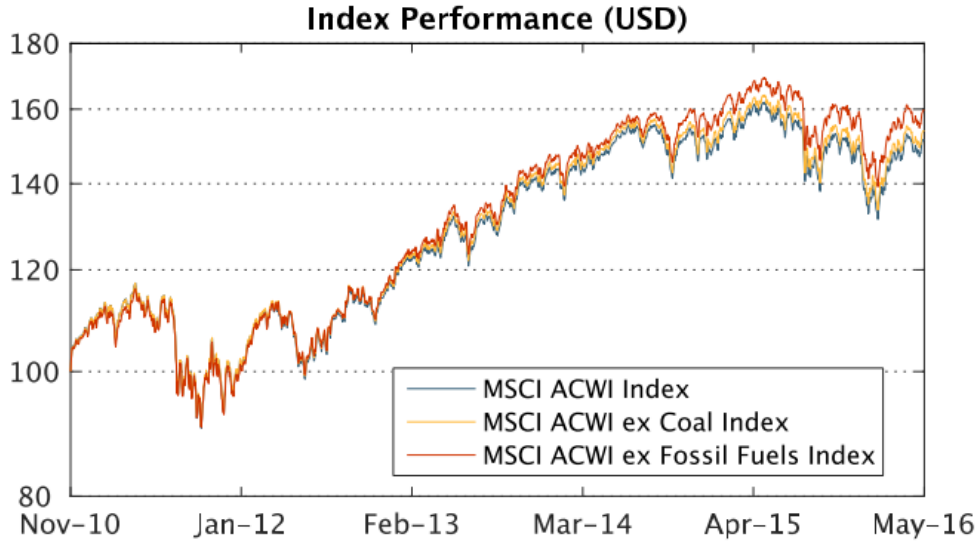

Figure 24: Historical Index performance US$ of MSCI ACWI Index, MSCI ACWI Ex Coal, & MSCI ACWI Ex fossil fuels Source: MSCI (2016) Fossil fuel divestment, a practical introduction. (p. 29).

This is evident, since the benchmark is the MSCI ACWI, so excluding companies gives higher risk of deviating from that performance. Pension providers which would have followed the MSCI ACWI index without fossil fuels, saw an average annualized gross return of 8.9% compared to a return of 7.5% of the normal MSCI ACWI index. Further financial specifications of these indices are provided in Appendix VIII. Taking these developments into account, the former relative benefits of O&G investments are decreasing.

However, pension providers might lack the incentive to hedge for systemic risks, like climate risks, which affect the complete market. The problem is they are compared to a benchmark, which will be affected equally by this. This is crucial and worrying at the same time, cause it would make it very difficult to shift away from an industry dominantly represented in the index with increasing risks, like the O&G sector.

[57] Tracking error is the divergence of the performance of a position compared to a benchmark.

> *''When you instruct the pension provider, you also give a benchmark for that specific equity portfolio. Those benchmarks are often market-weighted. This implies you are already in that part of the market where the capital is allocated to O&G companies. The risk that the complete sector is hit by a negative event, is not an incentive for the asset manager (pension provider) to hedge for such a risk. Since, if you mitigate for that risk it costs money. So you give in return. But if a negative event happens to the whole market, it is not a big problem, cause you lose for example 3%, and the market loses 3%. This gives no downside for you as a pension provider.''* Interview with Senior Policy Advisor of a pension fund - P.8 of the transcription report.

To further examine the probability of a carbon bubble and its effect on the financial sector, the next section elaborates on typical bubble characteristics from the literature, in line with current trends in the O&G industry.

7.3 Two Specific cases

Two trends in the O&G industry which are indicators for a bubble to be crisis prone are discussed here alongside with two cases (Schoenmaker et al. (2015). For both trends, evidence from the literature is used. The first trend is exploring resources in more unconventional fields like the Arctic, leading to higher capital intensive asset (Weijermars et al.,2014). Second, the lending of money and paying a constant dividend, while simultaneously the total debt in the industry rises (Domanski, 2015). In both cases, Shell was taken as an example during the interviews to acquire specific and comparable answers. Shell was chosen for the Dutch context, and regarding the recent developments in explorations in unconventional fields and high debt ratio.

7.3.1 Case: Arctic oil projects

Projects in deep sea, tar sands and Arctic areas are no longer exceptions for O&G companies. The market price needed to breakeven is much higher here, since both the exploration costs and the finding & development costs are a lot higher in these fields (figure 25) (Weijermars et al.,2014). Besides, the net energy benefits of these unconventional resources are much lower. Energy Return on Investment (EROI) is the energy which can be used from a source compared to what energy is needed to obtain the energy. The EROI of exploited oil and gas are declining in last two decades. Unconventional sources like oil sands (which require refinery upgrading) cost more energy have an EROI of 11:1 compared to an EROI of conventional oils of 20 to 40:1 (Hall et al., 2014).

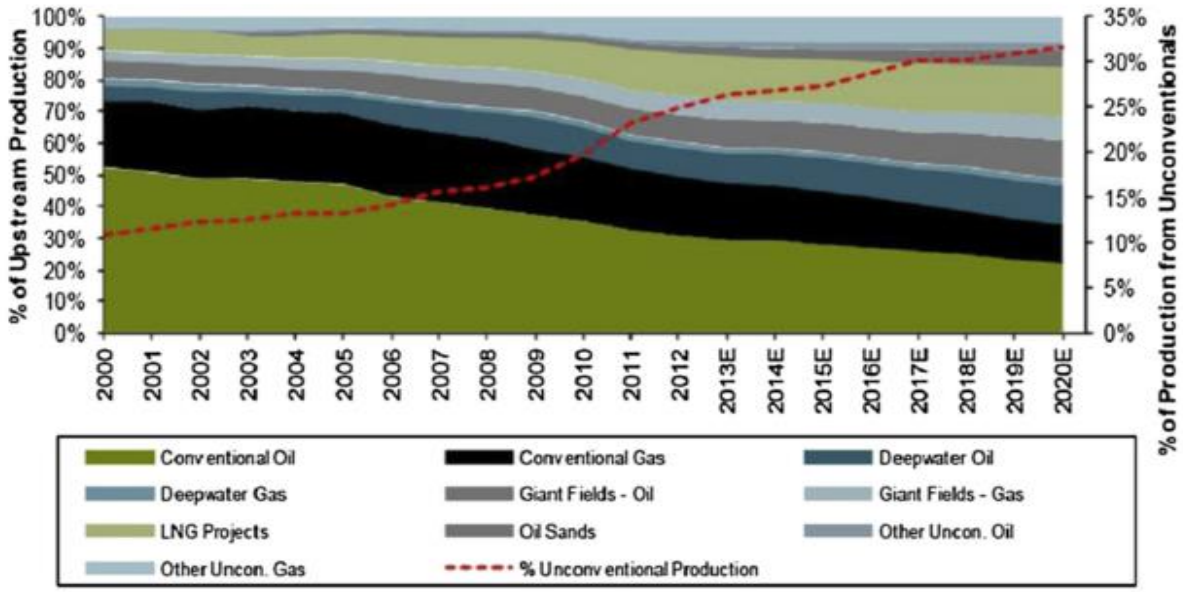

Figure 25: Production costs rise due to shifts towards more production of unconventional fields. Source: Weijermars et al. (2014) p. 76

The consensus in the Dutch pension market is that projects in the Arctic are disputable. Several of the respondents also pointed this out during shareholder meetings with Shell[58]. The risks on a disaster as happened with BP in Macondo[59] are much higher for projects in complex fields like Deepwater and the Arctic, due to the difficult circumstances[60] compared to conventional projects. Besides those

[58] Page 6, 11, 33, 46 of the Transcription report
[59] Macondo is the field in the Gulf of Mexico were the BP oil spill took place in April 2010.
[60] Page 15 of the Transcription report

environmental risks, pension providers point out the economic risk of a high breakeven price. Another respondent indicated that this economic risk of viability is something Shell should be concerned about[61]. The CEO of Shell Ben van Beurden stated 25% of the oil which will be newly discovered is in Arctic areas (Van Dijk, 2016). Whether such projects will continue[62] will depend on how urgent the demand for oil will be in the future according to respondents. If Shell would start exploration projects in Arctic, three of the providers stated they will divest if engagement has no effect on changing the plans of Shell[63].

Two providers mention they do not approve of Shell drilling in Arctic, but it will depend on the fund whether they would divest[64]. Two others say it depends too much on the developments of technology, which could reduce the risks of such activities. If demand for oil will continue to rise, it may be needed[65].The other provider refers to the final authority of the portfolio manager[66]. It was clear most respondents were reluctant towards making pledges on this topic.

> ''*We are against drilling in the Arctic for oil. So if Shell would do that, the client (the pension fund) could decide to stop investments in Shell. I do not think we would easily make that decision ourselves as a pension provider.*'' Interview with Advisor responsible investment - P. 26 of the transcription report.

7.3.2 Case: Funding dividend through debt

The total debt in the O&G industry has increased significantly in the last decade. Total debt in the O&G sector was estimated at $2.5 trillion in 2015, compared to $1 trillion in 2006 (Domanski et al, 2015). Nevertheless, several large O&G companies are refusing to lower dividend payments to their shareholders, while still lending extra capital to meet their financial obligations. In the case of Shell, current net debts are estimated at $75 billion, partly due to the acquisition of BG. The view of the Dutch pension providers on funding dividend trough lending money differs.

Most respondents point out this is not a strategy they support. Two mentioned dividend would be better allocated through long term value creation via new sustainable projects[67]. Three providers pointed out they don't see the need in paying a high dividend in financially difficult times. Cutting the dividend temporary is considered a better strategy[68]. Investing its profits in renewables is neither recommended, since Shell has not proven to be the suited company to create shareholder value via such projects, according to one respondent[69].

> ''*If lending money in difficult time ensures access to money on the long term, I can imagine this is a normal strategy. If it would be something foolish, it would definitely be penalized in the market.*'' Interview with Head Risk Analysis - P.46 of the transcription report.

[61] Page37 of the Transcription report
[62] Page 46 of the Transcription report
[63] Page 5, 11, 83 of the Transcription report
[64] Page 18, 33, 39 of the Transcription report
[65] Page 46, 73 of the Transcription report
[66] Page 64 of the Transcription report
[67] Page 13, 38 of the Transcription report
[68] Page 59 of the Transcription report
[69] Page 63 of the Transcription report

Two providers think this strategy is understandable, since stable dividends ensure long term commitment from the shareholders of a large O&G company. As large companies aim for profit maximization, efficient costs of capital are part of that strategy[70]. Furthermore, the credit ratings of these companies are still quite sufficient and numerous shareholders bought Shell because of the good dividend pay[71]. What the crucial threshold would be at which net debt would be too high for a company like Shell and divesting would be the response, was classified or unknown among the respondents.

> ''*I cannot disclose that kind of information, when we would divest due to too high debts. But I can tell you it is a serious topic of discussion*.'' Interview with Responsible investment manager - p. 33 of the transcription report.

7.3.3 Reflection on the cases

Partly because the high debt of Shell could be explained by the acquisition of BG, most respondents seemed unconcerned about these financial developments as a bubble characteristic. Regarding Arctic explorations of Shell, the pension funds were ought to take a stronger stand on this than most of the respondents, the pension providers. The low level of anticipation on these trends by the pension providers does not contribute to a thorough assessment of these risks. Although the pension providers have no normative mandate, they do have mandate to assess these risks, which currently seem to be downplayed. This is worrying.

To further examine if the carbon bubble risk of these O&G companies is undervalued, the next section discusses if a carbon bubble risk of O&G companies is priced into the market.

[70] Page 46 of the Transcription report
[71] Page 72 of the Transcription report

7.4 Is the carbon bubble risk priced in the market?

This is a crucial premise of the carbon bubble theory; that the stock market is over-valuing the O&G industry. This depends on whether the true costs of climate change are taken into account of the current market value. The consensus among respondents, is that the majority of the investors do not deny climate change, and are aware of what is happening. However, they were divided on whether carbon bubble risk is priced in the market.

> *''We expect that a large part of this carbon bubble risk is currently priced in the market. (…) We don't believe in perfect markets, but as investors we take into account several climate scenarios. And if we do that, others will as well. The major part of the investors are professionals.''* Interview with Senior Advisor Investments of pension fund - P. 6 of the transcription report.

> ''*Assuming perfect markets theorem, carbon risk should be priced in the market and is expected to be included in the valuation of the reserves.''* Interview with Investment strategy analyst- P. 40 of the transcription report.

> *''Yes I think it is currently priced correct. If you would say: it is not correctly priced in the market, it implies others in the market could make a profit out of that, if the price is incorrect. (…) That is also the charming aspect of financial markets; Everything is decided together. Together you say; This is what we believe is worth paying a certain price for.''* Head Risk Analysis - P. 48 of the transcription report.

> *''I think our company still has quite some faith that companies can make the energy transition, but I am not sure if that is justified. (…) Let me put it this way; If I would think the carbon bubble would be priced correctly in the market, I would not devote my time and energy in this.''* Interview with Responsible investment manager - P. 32 of the transcription report.

> *''No. I think we will only come to a correct pricing of such a risk, if we start with a proper shadow accounting of carbon, with a carbon price of at least 50 $.''* Interview with Sustainability strategy consultant - P. 84 of the transcription report.

The literature is also divided on this matter. Busch et al, (2006) Della Croce et al. (2011), Andersson et al. (2015) Van der Ploeg (2016), Weyzig et al., (2014) and Schoenmaket et al. (2015) believe the evidence is overwhelming that the carbon risk is currently underpriced, taking into account the negative externalities of emitting carbon in the atmosphere are postponed to the future. Supporters of the efficient market hypothesis think the markets are correct. Below the efficient market hypothesis is explained.

7.4.1 Efficient Market Hypothesis

Respondents mention the perfects markets theorem as argument that the carbon bubble risk is priced in the market. This Efficient Market Hypothesis (EMH) developed by economist Eugene Fama in 1970, states that stocks in the market are traded at their fair value, since they include and depict all relevant information. This implies that investors cannot outperform the market. Only doing riskier investments can lead to higher returns (Fama, 1970). Assuming perfect efficient markets, investors which have

confidence EMH tend towards a passive long term investment strategy, like index funds, since these generate the same returns as the market (Basu, 1977).

Opponents of this theory believe that it is possible to beat the market, or that some risks are not priced into markets. They argue all investors view this information differently, leading to different valuations of the stocks. Moreover, emotions and human mistakes can affect the valuations of stocks. Thirdly, stock values need time to respond to the information, and better informed investors can take advantage of this. Distinction is made between strong efficiency, semi-strong efficiency, and weak efficiency markets (Malkiel, 2003). Strong efficiency markets are perceived as not random and influenced by events in the past. The idea is that all information, both public and private is taken into account for the stock prices. Supporters advocate that even extra analysis or information does not lead to extra return. The semi-strong efficiency form states that the information which is publicly available is included in market prices. However, information which is private can lead to outperformance of the market and higher returns on investment. Weak form of efficiency markets claims that extra information of financial statements can lead to outperforming the market. Future prices are perceived as random, not influenced by events in the past. Hence, patterns in stock prices are not clear and technical analysis is useless (Malkiel, 2003). In the case of climate risks, it could be that these risks are underestimated regarding their long-term consequences.

7.4.2 View of the European Systemic Risk Board

The ESRB is an institution responsible for macroprudential oversight of the European financial system, focusing on systemic risks. It was established in 2010 after the financial crisis. The ESRB (2016) states: *''markets may not have fully priced in the risks from climate change''* p.15 They distinguishes between a gradual (soft) and an abrupt (hard) transition towards a low carbon economy. The latter can be characterized by large emissions cuts over a short time horizon, higher probability on physical risks of climate change and intensified via a lack of technical progress. Systemic risk is a type of risk at which an event could result in strong instability or the collapse of the entire sector or economy as a whole. This differs from a systematic risk[72]. A carbon bubble burst in an abrupt energy transition scenario is an example of a systemic risk. The ESRB (2016) identifies several channels through which such a systemic risk can be triggered by an abrupt energy transition.

First, reduction in energy supply and a potential rise in energy costs due to sudden pricing of external effects. Second, via an unexpected revaluation of carbon-intensive assets. This can be either real or financial assets, which have a strong dependence on carbon-intensive resources. Third, the impact and frequency of natural disasters can increase due to climate change. Those reasons can furthermore interact with other financial frictions and result in negative feedback loops (ESRB, 2016).

The implications for systemic risk include the exposure to the carbon-intensive assets and the level of debt financing in the industry. More data on these two subjects is required to give investors more insight. The problem is most risk evaluations are based on historical data, which may provide insufficient information for these risks (ESRB, 2016).

[72] Systematic risk, or a market risk, is a type of risk which affects the complete financial market. This type cannot be eliminated via diversification. Recessions, terrorist attacks and natural disasters are examples of a systematic risk.

7.5 How to deflate the potential carbon bubble in the pension market

With 1300 billion of euros in assets under management, the Dutch pension market could make a significant contribution towards acceleration of the energy transition. All respondents declare to have engaged actively with O&G companies[73]. Effectiveness of divestment is questioned and exclusion is considered as a radical option by the pension providers. Companies like PetroChina are currently excluded by some providers, but that is due to the violation of human rights and not due to a climate risk[74]. The main argument against divestment as a tool is the loss of influence as a shareholder and the risk that more environmental indifferent investors take over their investment positions in the company. Peer average comparison is used as a tool to have best of both worlds and facilitate a race towards lower carbon-intensive companies. However, more can be done to facilitate green growth (Della Croce et al., 2011).

An impasse exists between the pension funds, which have the normative mandate over the money of the pension participants but lack the knowledge on risk, and the pension providers, which have the knowledge on risk, but lack the normative mandate. The pension providers do have the mandate to assess the risks, but as current risk assessments could underexpose climate risks like a carbon bubble due to a lack of data, the pension providers will not start to decarbonize their portfolios. This is depicted in figure 26.

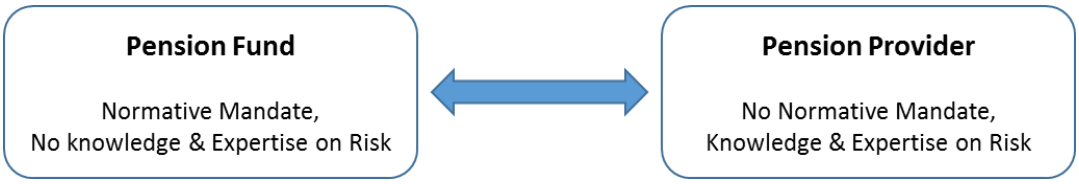

Figure 26: Impasse between pension funds and pension providers to shift towards a lower carbon-intensive portfolio.

During the interviews, respondents indicated that funds often lack the knowledge to ask the right questions at the pension providers on what the possibilities and methodologies are to start investing less carbon-intensive.

> *'The provider did not by itself start to invest less CO2 intensive.''* Interview with Senior advisor investments of a pension fund - P. 7 of the transcription report.

> *'We see it is stagnating at the pension boards. They need to have a vision where to go with their pension fund (…) Now they are starting to care, but still they lack the knowledge and the tools to ask the right questions. That is what they mention themselves as well''.* Interview with Sustainability strategy consultant -.P. 85 of the transcription report.

> *'We cannot make the decision to divest, it has to fit in the mandate of the client. That is why many asset managers are reluctant, they cannot decide to lower investments in O&G.''* Interview with ESG analyst - P. 12 of the transcription report.

[73] Pages: 6 10, 23, 27, 35, 47, 64, 70, 83 of the Transcription report
[74] Page: 53 of the Transcription report

> *''We are just a service provider, it is not up to us. I would definitely say we would support the 2 degrees target, but that does not matter that much. Actually, the boards of the pension funds should support it. They have not really expressed whether they support it or not.''* Interview with Senior Account Manager - p.36 of the transcription report.

> *''Yes, if the pension market wants to become more sustainable pension funds are important. Pension providers will start windowdressing to appear green, but they have no incentive whatsoever to deviate much from a benchmark and invest less in O&G ''* Interview with Senior policy advisor of a pension fund - P.8 of the transcription report.

Since only one pension fund was interviewed, not more data from the pension funds was available to investigate how this impasse can be eliminated. Reflecting on the interviews, it becomes clear that the pension funds play an important role to start the decarbonization of the portfolios of the pension providers to deflate a potential carbon bubble. The pension providers will not start automatically with this.

> *'I think the pension provider will always be eager to outcompete the market. And if there is a risk for the complete market, there is no incentive for the provider to avoid that risk. So if there are market risks, you will have to do something about that as a fund, by starting the conversation with the pension provider''.* Interview with Senior policy advisor of a Pension fund -.P. 7 of the transcription report.

> *'I hope I was able to explain to you that we are not in the business to outcompete the market, but mainly to avoid being overexposed. ''* Interview with Head risk analysis-.P. 49 of the transcription report.

Likewise, pension providers cannot just hide in their role of a service provider which only focusses on the financial risks, completely ignoring climate risks like a carbon bubble. This ostrich policy of the pension markets to these climate risks should be eliminated. Regulation focusing on availability of climate risk data, climate risk methodologies, the relation between funds and providers and transparency of O&G companies could alleviate this impasse. Detailed recommendations are provided in the Conclusion section 8.2.

7.6 Key Findings

The fourth sub-question was: *How do the Dutch pension funds and providers value the carbon bubble risk of O&G companies in their portfolio?*

Based on the interviews with actors from the Dutch pension market, the carbon bubble risk of O&G multinational is not perceived as a substantial risk in their portfolio. The impact of a carbon bubble burst on the portfolios is serious, with an impact up to 15% on the portfolios resulting in six points loss of the debt-coverage ratio and a reduction of the pension payments from 500 to 475 euros per month. The total impact would even be much higher, including more sectors than only O&G. However, the probability of a carbon bubble burst is considered low by respondents. All respondents think the energy transition will happen gradually. The growing global demand for energy is expected to be dominant over the environmental priorities. The benefits of investing in O&G companies outweigh the risks for investors, and the risk of environmental legislation on limiting fossil fuel exploration or a major transition to renewable alternatives, which are required for this risk to materialize, are not considered probable in the coming five years.

An important finding is, that it pension providers are reluctant to deviate from the benchmark to which they are compared. However, this benchmark often contains carbon intensive positions, which implies they are already in that part of the market where the capital is allocated to O&G companies. Besides, pension providers have little incentive to hedge for systemic risks like climate risks, cause these risks also affect the benchmark to which they are compared.

More unconventional fields are explored by O&G companies, and debt levels are increasing. To the pension providers, these developments are to an increasing extent large concerns, but it does not lead to divestment yet. First, because the developments are considered part of the market fluctuations and not perceived as a substantial risk. Second, because the pension providers are not able to make the normative decision to divest, this lies with the pension fund.

MSCI is the main data provider for ESG analyses. The indicators used by the pension providers can be divided into financial data, CO_2 emission intensity of the production process, specifications on fossil fuel reserves and governance of the company. Dominant methodology for carbon risk valuation is stress-testing of the portfolio. Carbon intensity of companies is often measured with carbon foot-printing. However, not all providers see the added value of carbon intensity as a sufficiently developed tool for portfolio management. ALM and SAA are not yet applied on carbon risk of the O&G industry level, and scarcely on climate risks, since the expected benefits does not outweigh the costs.

The respondents disagreed whether the carbon bubble risk or climate risks are currently correctly priced in the financial markets. Most responsible investment managers thought the carbon risk is currently underprized, other respondents believed in the efficiency of markets.

To deflate a potential carbon bubble, pension funds and providers need to overcome the impasse, where the fund has the normative mandate but no knowledge, and the provider has the knowledge on risks, but not the normative mandate.

Regulation could eliminate this impasse between pension funds and providers to deflate a potential carbon bubble and accelerate the energy transition. More data availability due to obligatory climate disclosure of investors, like in the French Energy Transition Law, could facilitate this.

PART IV

Evaluation

8. Conclusion

8.1 Main findings

This thesis analyzed the carbon bubble risk of O&G companies in the Dutch pension market through seventeen interviews, covering 990 billion euros in assets under management from the total of 1300 billion assets under management in the Dutch pension market. Based on these interviews it can be concluded that the Dutch pension market does not value the carbon bubble risk of O&G companies as a substantial risk in their portfolio. Although the impact of a carbon bubble burst could be significant, with an average of 7.54% and a maximum impact of 15% in the portfolios of the Dutch pension funds and a six point reduction in the debt-coverage ratio, the probability of such a carbon bubble burst is considered low. The main reasons are that the energy transition is expected to happen gradually instead of abruptly and that the increasing global demand for energy is expected to be dominant over the environmental priorities. Currently the benefits of investing in O&G companies still outweigh the risks for Dutch pension providers. Factors which could trigger a carbon bubble burst, like rapid technological developments in alternative energy sources or high level binding environmental regulations impeding fossil fuel exploitation, are by the Dutch pension market considered unlikely in the coming years.

To accurately value the carbon bubble risk of O&G companies in the portfolios of the Dutch pension market and determine how they *should* value the carbon bubble risk, more data is required on the actual investment positions of the Dutch pension funds and providers, since the carbon bubble risk can differ per company. It is probable that climate risks, like the carbon bubble, are underexposed in the current risk assessments of the pension providers due to a lack of data. This is enforced by the fact that most pension providers have many other risks to handle which limits their capacity. To accurately value the carbon bubble risk, more SAA tools like ALM could be used, and new methodologies should be developed and adopted.

O&G companies are currently valued by the Dutch pension providers based on discounted cash flow (DCF). Proven reserves of O&G companies, how these can be exploited and financial indicators are important determinants in these DCF models. To accurately value the carbon bubble risk of these companies, indicators like future value creation of O&G companies should become increasingly important. COP21 has not changed the way these O&G companies are valued. The climate agreement did provide pension funds and providers with more leverage to start the discussion at board level and require O&G companies to be more transparent regarding carbon data disclosure and their role in the energy transition.

Adaption of the European Directive IORP II requires that pension funds and providers assess the ESG risks of their investments following a specific set of criteria and that ESG risks acquire an equal level of attention compared to operational, liquidity or asset risks. Not all Dutch pension markets support this extra regulation or are on track in meeting these future requirements.

Strategic Asset Allocation and Asset liability management are not used on O&G sector level, and scarcely used to assess climate risks on a higher level at the pension funds. The Dutch pension providers value the risk O&G companies based on ESG criteria combined with financial data. Currently the Dutch pension providers do not exclude O&G companies based on climate risks.

The respondents are divided on whether the carbon bubble risk of O&G companies is currently included in the market price. To mitigate the impact of a potential carbon bubble burst, decarbonization of the pension portfolios is required. To realize this, the impasse between the pension

fund, which has the normative mandate but not the knowledge and the pension provider which has the knowledge but lacks the normative mandate, needs to be eliminated. Based upon these findings, the Dutch pension market should do more to examine the carbon bubble risk and devote more attention to assess whether the carbon bubble risk is priced into the market or not.

8.2 Implications & Recommendations

The exposure of 7.54% in the Dutch pension portfolios is higher compared to the research of the Dutch Central Bank (2016). More research is needed to conclude whether the exposure of the Dutch pension market to O&G companies has increased, or that other reasons are the cause of this deviation. Another important implication, is that pension providers are reluctant to deviate from the benchmark, which often already contains carbon intensive industries. This makes it difficult to realize decarbonization of the portfolios. Pension participants can use this research to gain more insight in the valuation methods of the carbon bubble risk and use the results of this thesis to start the dialogue with their own pension funds.

The results of the scenario analysis showed that ConocoPhillips, Exxon Mobil and Chevron are most at risk in a carbon bubble burst scenario and Occidental, Statoil and Eni in a business as usual scenario. These results can be used by other institutional investors as a first overview to base their investment decisions on and to minimize their investments in the O&G companies most at risk. The scenario analysis can also be used as a starting point for further analysis on which indicators are important in assessing the future credit worthiness of O&G companies in different scenarios.

The scientific relevance of this thesis is the verification of the usage of SAA tools like ALM at O&G sector level on carbon bubble risk with practitioners in the Dutch pension market. Although ALM and SAA are not applied on O&G sector level to assess carbon bubble risks, these tools should be more used to acquire insights in the ESG risks of the total portfolio, in line with the forthcoming implementation of IORP II in the European pension market. The limited use of SAA tools like ALM, implies pension providers are not (yet) convinced benefits of such studies would outweigh the associated time and costs. Researchers focused on SAA could use these implications (Ibbotson et al. 2000). Additional scientific relevance can be distinguished regarding the Value At Risk of financial assets due to climate change. The findings of the probability and impact of carbon bubble risk for the Dutch pension market can be used by Dietz et al. (2016), Bottelho et al. (2014) and Schoenmaker et al. (2015). The findings on important O&G valuation indicators from the pension providers can be used by Osmundsen et al (2006) and Busch et al(2006). Besides, this research can be used to set up similar studies in other countries, with the appropriate adjustments.

Dutch financial regulatory entities can use the result of this thesis that not all providers are in line with the new directive, to support the Dutch pension funds and providers in preparing their ESG risk management before IORP II comes into force on January 13th, 2019. Since the Paris agreement has not changed the way the Dutch pension market value O&G companies, global, European and national regulatory entities can use this result to accelerate implementation of binding national legislation in line with COP21. If this regulation is absent, investors will not change their (risk) valuations of companies which have a negative impact on the environment, like O&G companies. Similarly, the O&G companies have no incentive to change as long as their investors do not change their (risk) valuations. This will be an important step towards achieving a 1.5 ˚C or 2 ˚C target.

Several recommendations for governments, the Dutch pension market and the Dutch financial authorities are provided per actor. All of which should start rather today than tomorrow:

Public policy recommendations

I. To reduce the lack of data availability to effectively assess carbon bubble and climate risks, the Dutch Ministry of Finance, responsible for designing new legislation, should start with the construction of a Dutch Energy Transition Law. In line with the French version, this requires carbon accounting and ESG risk integration for investors and specific disclosures of their investment impact on the climate. This will alleviate the problem of imperfect information due to a lack of data, since investors and subsequently the companies in their portfolios will start with the accounting and reporting of ESG data. More transparency on the methodologies of ESG risk integration will also support more accurate risk assessments in financial markets and knowledge on the appropriate pricing of climate risks.

II. The European Commission should develop a proposal for a ''*Shadow Carbon Price''* Directive*,* which obliges carbon-intensive sectors, like the O&G sector, to account for a shadow price on carbon of their assets besides the financial value. This data should be taken into account at new investment decisions and reduces the risk of potential stranded assets due to sudden revaluations in a carbon-constrained world. The shadow accounting of carbon of these companies, should be fully accessible for investors so they can base their decisions on it. This also reduces the risk of asymmetric information and provides an extra incentive for carbon-intensive industries to reduce their exposure to climate risk. The level of the shadow carbon price can be determined in a later stage. To accelerate the process of adoption, the European Parliament should be involved via lobbying in the design of this Directive, already before the moment of approval.

III. To decrease uncertainty for pension funds, providers and other investors, a law should be implemented by the Dutch ministry of Finance which affirms the long-term goal of reaching a carbon-neutral economy. A legally binding form of this goal, could facilitate in defining the priorities and agenda setting needed for more long-term design of national climate regulation. The current Energy Agreement (Energieakkoord) does not provide sufficient detail or certainty for investors. More specific transition pathways, on national and sector level, towards a lower-carbon economy along a more detailed timeline are required.

Recommendations for the Dutch pension market

IV. Pension funds need to inform themselves more on carbon risks and form a vision on their possible contributions to hedge for carbon bubble risk and other climate risks. Discussion and agenda setting is required at board level. They should request their providers to come up with alternatives investments possibilities in lower carbon-intensive investments, since they are the client which should formulate these requests. The funds should also be aware that the pension providers will not develop new investment strategies to deflate a potential carbon bubble, if they don't instruct them.

V. Pension providers should start testing and developing methodologies to assess the carbon bubble and climate risks of investments and inform the pension funds on the possibilities. It is their task to adequately manage the risk. This includes adapting the current risk methodologies if new risks seem to be underexposed in the current assessments. Besides, they should present alternative

options on lower carbon investments and ways to reduce the carbon bubble risk in their portfolios. This alleviates the impasse due to the lack of such a request from the pension fund.

VI. Both pension funds and providers should not wait until data and methodology on carbon (bubble) risk are fully developed and available, since carbon bubble/climate risks can materialize in their portfolios before that time. Also, since developments in this field are evolving fast, they should not exclude climate risk tools if the carbon data or methodologies did not deliver sufficient results two or more years ago. This reduces the lack of adequate climate risk methodologies

Recommendations for the Dutch financial authorities

VII. The Ministry of Finance, DNB & AFM should create support for the Dutch Energy Transition Law in the Dutch financial sector, by facilitating working groups on the important aspects and regulatory details of this law with people from the ministry of finance, banks, investment funds, insurance companies, pension funds and providers and designers and regulators of the French Energy Transition Law. DNB already has expertise in this role with previous working groups on climate change in the financial sector. Since collaboration between the AFM and DNB is priority for both, they can lead by example in this project. Creating support in the financial system for the energy transition law was key according to the French designers of the law.

VIII. Besides this, the DNB should develop internal policy to develop new channels and methods to control the compliance of the new Dutch Energy Transition Law. No official monitoring channels are in place yet, and regarding the new methodologies and reporting procedures, it is probable the data will be difficult to compare at first. By consulting their colleagues of the Banque de France, first steps can be made.

IX. Next, DNB can fulfill its prudential supervisory task by monitoring if all the Dutch pension funds and providers are on track regarding the new IORP II Directive, which comes into force January 17th, 2019. To accelerate this process and support the laggards, information sessions can be organized with the different pension funds and providers to facilitate them with key constraints and characteristics of risk frameworks which align with IORP II. The transcription Report of the interviews of this thesis can be used to identify the main bottlenecks, like the lack of support for additional regulation, which need to be alleviated before the first steps can be taken.

X. Since the AFM supervises the transparency and trustworthiness of processes in the Dutch financial markets, they should develop internal policy which focusses on the potential impasse between Dutch pension funds and pension providers. The recommendations specified in point IV, V, and VI to alleviate this impasse should be addressed in surveys and interviews with the boards of Dutch pension funds and providers. In this way, the AFM can assess if the risk attitude at board level is in line with the code of conduct of the prudent principle of standard care. The AFM can use these assessments to intervene where needed. The ostrich policy of the boards of the pension funds and providers regarding climate risks can in this way be transformed to a more progressive attitude towards assessing these risks.

9. Discussion

9.1 Quality of the research

The reliability of this research is sufficient. By using both quantitative and qualitative data the findings to the research questions could be validated. The literature review resulted in many peer-reviewed and recently published academic articles in various prominent journals. Reproducing the literature research could generate different outcomes, since not all articles were obtained via the described search terms. Hence, different literature could be found via searching the reference lists of articles which were not selected in the first place. The desk research facilitated all other research methods with up to date information from the market from a variety of sources. Reproducing this research could also lead to the usage of other reports to acquire this information. The scenario analysis provides an indication of the implications for the eleven O&G companies. The indicators for the scenario analysis were chosen based up on the literature review, desk research and the interviews. The interviews are considered reliable. The audio recordings of the interviews are of good quality and the iterative process of the research contributed to accurate coding of the answers. The list of general questions used during the semi-structured interviews benefits the reproducibility of the research. However, each interview was unique, which implies that performing the same research again could generate a deviation in results. During the interviews was aimed for a critical but objective attitude and avoidance in stirring the respondents with the formulation of the questions. After two interviews, no concrete answers were obtained from the respondents on specific indicators which determined the value of the O&G companies. To acquire more data on the indicators, the view of the respondents on the indicators in the valuation model of Osmundsen et al. (2006) was included in the question list of the interviews. This model was presented after the respondent was asked to mention five indicators for O&G company valuation[75]. The first respondents which did not viewed the model of Osmundsen et al. (2006) during the interviews, were approached via email. Since the respondents valued the carbon bubble burst as unlikely , the respondents were asked to score to rank the five risk categories which resulted from the literature research on internal risks for O&G companies. The average ranking scores are presented in Appendix VII.

Internal validity of the interviews, to what extent the interview questions measured what they intended, was high. This was an advantage of conducting face to face interviews, since during the interviews some concepts could be explained if the respondent did not seem to understand a question or concept. To increase internal validity, the names of the respondents in the report were anonymized to avoid social desirable answers or impede respondents from disclosure of information. Before each interview was stated that the transcriptions and quotes used in the results of this thesis would be anonymous. The transcript of the one interview conducted over Skype, was send to the respondent to verify if the answers did not deviate from the original answers due to potential connectivity problems. The external validity of this research, to what extent the results can be generalized for the complete Dutch pension market is quite high, since 990 billion euro of the 1300 billion euros in total assets under management of the Dutch pension market are included in the sample. For other pension markets in other countries, it is possible that the influences of regulation are different and investment decisions are made based up on different criteria. The interviewed people were qualified and had knowledge in the fields of portfolio management, O&G investments and valuation, responsible investment and risk analysis. This also contributed to the validity of this research.

[75] Mentioning more indicators which determined the valuation of O&G companies was also allowed, but this was often hard for respondents, since they do not work with lists of indicators or did not had that much knowledge of the valuation of O&G companies. Five was used in the question to compare the answers with the model of Osmundsen et al., (2006) which also had five indicators for the value of O&G companies.

9.2 Limitations & future research

One of the limitations of the research is that only one pension fund was interviewed. To do a comprehensive analysis of the Dutch pension market, I aimed for more interviews with the pension funds. Unfortunately, most of them were not open for an interview. More pension funds would have contributed to better answering of the research question and increased the validity of this research. Future research could focus more interviews with pension funds, to acquire more insight in how the impasse between the pension funds and providers can be eliminated and how they see their role in deflating a potential carbon bubble burst and accelerating the energy transition, since they have the mandate over the money of the pension participants.

To make a better assessment on how the Dutch pension market should value the carbon bubble risk, actual investment data on the investment position of the pension providers would be of added value, since this would provide more information on the exact risk level per pension provider. Unfortunately, this information was classified. Disclosure by the pension providers on the details of the Discounted Cash Flow models of O&G companies, or details on methods and results of stress tests and risk assessments of the carbon bubble would also have contributed to better answering the research question, but this was also classified. Future research could be pointed at investigating how large exactly the role of proven reserves is in those discounted cashflow models, to acquire more insight in O&G company valuation. This can perhaps be done via more outdated, less competition sensitive data from other financial institution which invest in O&G companies.

A drawback of scenario analysis, is that it is subject to numerous assumptions, like the choice of the indicators and important factors per scenario. The choice of the indicators is partly subjective and has a large effect on the outcome. Due to the time constraints of this research, the scenario analysis also has the limitation of using only a limited number of indicators per scenario and focusses only on two scenarios. Elaborating on more scenarios with more indicators would have provided a better representation of different effects on the O&G companies in the energy transition. Although it now provides a good first overview, this is too simplified to base solid investment decisions upon, since the future of the energy system is highly complex and involves many different characteristics and interdependencies. To get a better picture of which O&G companies are most at risk with a potential carbon bubble burst, future studies could focus on which reserves of O&G companies are more likely to strand than others and under what different circumstances.

Another limitation was that during the interviews, not all respondents had the in-depth expertise of the different aspects of this research. This was solved by emailing the questions they could not answer during the interviews. Besides, interviewing different respondents from the same organizations would probably have yield different outcomes. The interpretation of the transcripts and the coding process were subject to a personal bias of the researcher. Nevertheless, this research can be a good starting point to set up similar studies in other countries in Europe, to analyze the carbon bubble risk of the pension markets in another country and explore how investment strategies can be designed to focus on low carbon investments without facing the risk of missing potential returns in the portfolio.

9.3 Reflection

Reflecting on the process of this thesis, I would have asked for interviews with (energy) portfolio managers and risk managers instead of responsible investment managers & ESG analysts. The first group had more specific knowledge on O&G valuation which was relevant for this research. I would also have started earlier with the scenario analysis. The plan was to obtain data during the interviews from the respondents on the investment positions in O&G companies. Since this did not work out, I could have used the interviews to validate the scenarios with the respondents. One of the things I learned was to be persistent in getting the information and approaching potential respondents. I liked the ethical, financial, regulatory & technical combination of this research topic.

After speaking with practitioners from the Dutch pension market, I believe the carbon bubble risk of the O&G industry is currently not correctly priced in the market. Taking into account the premises that fossil fuel combustion lead to more GHGs into the atmosphere, the 1.5 & 2 ˚C targets and associated concentrations of the parts per million are approaching. With that in mind, also the related detrimental consequences, while minimal costs have been allocated to the polluters so far. Hence, I don't think the Dutch pension market values the carbon bubble risk correct. The fact that many organizations of respondents fail to react thoroughly towards climate risks like the carbon bubble, but instead address the need for government policy, indicates in my opinion a passive attitude. The downplaying of these risks, combined with the fact that most providers are almost too busy to intensively manage the risks does not signals adequate risk management. Exemplifying was the info from MSCI from the O&G report (2016) used by respondents, containing mistakes on the emission reduction targets per country.

Besides the call for governmental action, I also noticed conflicts of interest at the pension funds and providers. Not all people at those funds and providers are on the same page regarding the optimal approach towards these risks. Some feel the need to change, while others deny it. The seemingly long term implications of climate risks appear to strengthen the second effects.

I believe more efforts can and should be made to deflate a potential carbon bubble to mitigate the impact of a burst. Since the negative externalities of carbon emissions are currently not sufficiently included in the business models of O&G companies, governments should take a leading role in carbon pricing to ensure the costs of climate change are no longer mainly passed on to the future generations. The fact that respondents also address this supports the need for more policy. Nevertheless, the Dutch pension market should start well in advance.

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Appendix I Interview questions

This is the list of questions during the semi-structured interviews with pension funds & providers.

1. Wat zijn de belangrijkste indicatoren voor de waardering van O&G bedrijven?

- Wat zijn de 5 belangrijkste financiele& upstream indicatoren om naar te kijken bij O&G valuatie?

- Osmundsen et al.(2006) hebben een model voor waardering van O&G industrie. $EV/DACF = A + aP + \sum\beta KPI_{it} + \Upsilon R_{it} + u_{t.}$ Is dit compleet? Zou hier een risicofactor bij moeten?

- Hoe wordt SAA & Asset Liability Management gebruikt voor O&G industrie en klimaat risico?

- Op jullie website zag ik de duurzame doelstelling: .....
  In jaar rapport ..... Hoeveel investeren jullie nu in O&G industrie?

2. Heeft Parijs COP21 de manier van O&G bedrijven gewaardeerd worden veranderd? Hoe?

- Wat is er precies veranderd?

- 24 november jongstleden, heeft het Europees parlement een wet aangenomen dat alle Europese pensioen organisaties, ‘’*environmental, social and governance risks*" van hun investeringen moeten waarnemen volgens voorgeschreven criteria. Climate risk same level of attention as liquidity, operational or asset risks als omschreven in het IORPs (Institutions for Occupational Retirement Provision) II Directive. Hoe zal dit effect hebben op O&G bedrijfswaardering?

- Op jullie website las ik dat jullie achter de 2 graden doelstelling van Parijs staan?

- Hoe matchen jullie dat door nog steeds in O&G te investeren? Door aan de vraag te blijven voldoen zullen we over de 2 graden gaan, wat conflicteert met jullie 2 graden support?

3. Stel dat er een carbon bubble burst zou plaatsvinden, waar O&G bedrijven 40% van hun waarde verliezen, wat zou het effect daarvan zijn voor jullie als uitvoerder?

- Stel: Olie prijs blijft komende jaren op 50$ per vat, onconventionele dure velden zijn niet breakeven, 40% van de O&G reservers blijven in de grond, en de O&G bedrijven verliezen 40 % van hun waarde. Hoe zou dit jullie portfolio/dekkingsgraad beinvloeden? Hoeveel zou dit kunnen schelen?

- Wat zou jullie respons zijn? Terugtrekken? binnen welk termijn? Hoe snel kan je divesten?

- CASE: Ben van Beurden zei in een interview met FD 26 november dat hij uitkeren van dividend een van zijn belangrijkste prioriteiten is. Mede daarom leent Shell al een tijd bij om een constant dividend uit te betalen, met net debt van > 70 miljard. Op de lange termijn lijkt dit niet een gezonde strategie, wanneer is dit een breekpunt?
- CASE: In datzelfde interview zei hij : ''*Ik denk dat we als samenleving niet zullen ontkomen aan Arctische Olie. Ongeveer 25% van alle olie en gas die nog gevonden moet worden, zal naar verwachting in het Noordpoolgebied gevonden moeten worden.''*
  Als engagement niet werkt, zouden jullie dan uitstappen?

4. Dit in ogenschouw nemend, hoe zouden de uitvoerders het risico van O&G bedrijven moeten waarderen?

- Hoe waarderen jullie het carbon bubble risico van O&G bedrijven in jullie portfolio?

- Wat zijn de methodes die gebruikt worden om de risico's van O&G bedrijven te bepalen?

- Welke indicatoren?

- Hoe worden die gescoord? (Vooral op positieve ESG integratie & transparantie? Of ook op een stresstest met welke reserves van bedrijven daadwerkelijk het meeste risico lopen?)

- Wordt het carbon bubble risico op dit moment correct ingeprijst volgens jullie, In ogenschouw nemend dat de energie transitie abrupt kan plaatsvinden?

- Hoe zou dit nog verbeterd kunnen worden? Fonds(geenverstand) <-> uitvoerder(geen beheerder)

Appendix II Codes of interviews

table 30: Coding Scheme of the interviews with the Dutch pension market

Code	Meaning
Indicator O&G valuation 1:A	Indicators used for O&G valuation
ALM/SAA 1:B	To what extent Asset Liability Management and Strategic Asset Allocation is used
Investment view 1:C	What the general view is on investments
Exposure O&G 1:D	How much the fund/provider is exposed to O&G
Active/passive management 1:E	Whether the portfolio is active or passive managed
COP21 valuation change 2:A	How Paris changed O&G valuation
Impact of COP21 2:B	The impact of Paris
Regulation effect 2:C	To what extent other regulation is implemented and followed
2 ˚C scenario 2:D	View on 2 ˚C scenario
Effect Carbon Bubble Burst 3:A	How much would be lost if a carbon bubble would burst
Response Carbon Bubble Burst 3:B	Would they sell or hold their positions after a Carbon bubble burst
Dividend and Debt 3:C	View on increasing debt & constant dividend to shareholders in O&G industry
Arctic projects 3:D	View on Arctic projects.
Value Carbonbubble Risk 4:A	How the carbon bubble risk is valued
Risk Methods 4:B	What methods are used to assess this risk
Risk Indicators 4:C	What indicators are used to measure this risk
Risk weight 4:D	How these indicators are weighed to measure this risk
Priced carbon bubble risk 4:E	View on whether the Carbon bubble risk is currently correctly priced in the market
Improvements 4:F	Suggestions for improvement
Data 5:A	What data sources are used
Transition 5:B	View on energy transition, gradual or abruptly
Fund vs Provider 5:C	View on relation/impasse of fund & provider
Divestment time 5:D	What time is needed for divestment of O&G positions
Model valuation 5:E	How the O&G valuation model of Osmundsen et al is seen

Appendix III Types of climate risks and related financial impacts

table 31: Overview of different types of climate risks & financial impacts. Source: Conference Financial Stability Board, Taskforce on climate-related financial disclosures, at KPMG Amsterdam on 13-10-2016 & page 11 of the FSB report Recommendations of the Task Force on Climate-related Financial Disclosures(2016).

Risk type	Descriptions	Financial impact
Physical risks		
Acute	Physical impact of more catastrophic weather events like cyclones & floods	– Reduction or disruption in production capacity (e.g., shutdowns, transport difficulties, supply chain interruptions)
Chronic	Physical impact of more frequent weather events: – Changes in precipitation patterns and extreme variability in weather patterns – Rising mean temperatures – Rising sea levels	– Impacts to workforce management and planning (e.g., health, safety, absenteeism) – Write-offs and early retirement of existing assets (e.g., damage to property and assets in "high-risk" locations) – Increased operating costs (e.g., inadequate water supply for hydroelectric plants or to cool nuclear and fossil fuel plants) – Increased capital costs (e.g., damage to facilities) – Reduced revenues from lower sales/output – Increased insurance premiums and potential for reduced availability of insurance on assets in "high-risk" locations
Non-Physical, Transition Risks		
Policy/Legal/Litigation	– Increased pricing of GHG emissions – Enhanced emissions-reporting obligations – Mandates on and regulation of existing products and services – Exposure to litigation	– Increased operating costs (e.g., compliance costs) – Write-offs and early retirement of existing assets due to policy change – Impaired assets – Increased insurance premiums – Fines and judgments
Technology	– Substitution of existing products and services with lower emissions options – Unsuccessful investment in new technologies – Upfront costs to transition to lower emissions technology Markets	– Write-offs and early retirement of existing assets – Reduced demand for products and services – Upfront research and development (R&D) expenditures in new and alternative technologies – Upfront capital investments in technology development – Upfront costs to adopt/deploy new practices and processes

Market/Economic	– Changes in supply, demand, and competition –re-pricing of carbon-intensive assets – Changing customer behavior – Uncertainty in market signals – Increased cost of raw materials	Asset impairment; viability of certain business models; company or securities valuation – Reduced demand for goods and services due to shift in consumer preferences – Increased production costs due to changing input prices (e.g., energy, water) and output requirements (e.g., waste treatment) – Abrupt and unexpected shifts in energy costs – Changing revenue mix and sources Re-pricing of assets and speed of re-pricing (e.g., fossil fuel reserves, land valuations, securities valuations)
Reputation	– Shift in consumer preferences – Stigmatization of sector – Increased stakeholder concern or negative stakeholder feedback	– Reduced demand for goods/services – Reduction or disruption in production capacity (e.g., shutdowns, delayed planning approvals, interruptions to supply chain) – Impacts on workforce management and planning (e.g., employee attraction and retention) – Reduction in capital availability

Appendix IV French Energy Transition Law – Article 173

The law came to force on the first of January 2016 and is designed to facilitate in the mitigation of climate change and diversification of the energy mix. It is one of the first laws in the world regarding its strict requirements on carbon reporting for institutional investors. On the 30th of June 2017 the latest, information on the impact of investments on climate change must be included in the annual reports. This info is specified per type of investor (UNPRI, 2016):

I. Listed companies with more than 500 million on their balance sheet should include:
   a. The financial risks related to the effects of climate change.
   b. The measures the company adopted to reduce these risks.
   c. The consequence of climate change on the activities of the company and its goods and services.

II. Banks and credit providers will need to include in their annual reports the risk of disproportionate leverage (not for carbon specifically) and the risks exposed via standard stress tests.

III. Institutional investors need to disclose in their annual reports:
   a. How ESF factors are considered in their investments.
   b. In what way their policies are in line with the national strategy of an energy/ecology transition.

The law provides further specification on ESG integration, integration on climate change-related risks and alignment of national and international decarbonisation targets. Regarding ESG integration reporting:

a. Disclose general approach regarding investment policy and risk management
b. Asset managers show the percentage share and list of funds which include ESG criteria
c. What methods are used for the analysis of the criteria and justification of the approach
d. Info on the outcome of the analysis and the actions engaged

Regarding climate change-related risks:

a. Report on transitions risks due to a shift to a low-carbon economy, and direct physical risks, due to physical impact of climate change
b. Assessing the contribution towards meeting international targets of limiting global warming. Risks include: extreme weather consequences, price & accessibility of resources, policy risks focused on climate targets, funds investing in assets which contribute to green growth and the measuring of past, current & future GHG emissions in the portfolio.

Regarding voluntary decarbonisation targets:

a. Targets investors set for themselves to assess how they contribute to national & global targets and how to align these
b. Actions needed to realize those targets. This can include policies of the investment, engagement and divestment.

The decree on the implementation did not provided in-depth information on the monitoring and compliance of the new law. It is possible the financial regulator (AMF) will take this role. The decree will be reviewed by the government in December 2018.

Recommendations for other countries aiming for implementation of similar regulation, include early discussions in the industry to obtain early feedback, extra support on voluntary disclosure of carbon in the portfolios and engagement with civil society groups to determine their role in the process (UNPRI, 2016).

Appendix V: Main world energy drivers in 2050

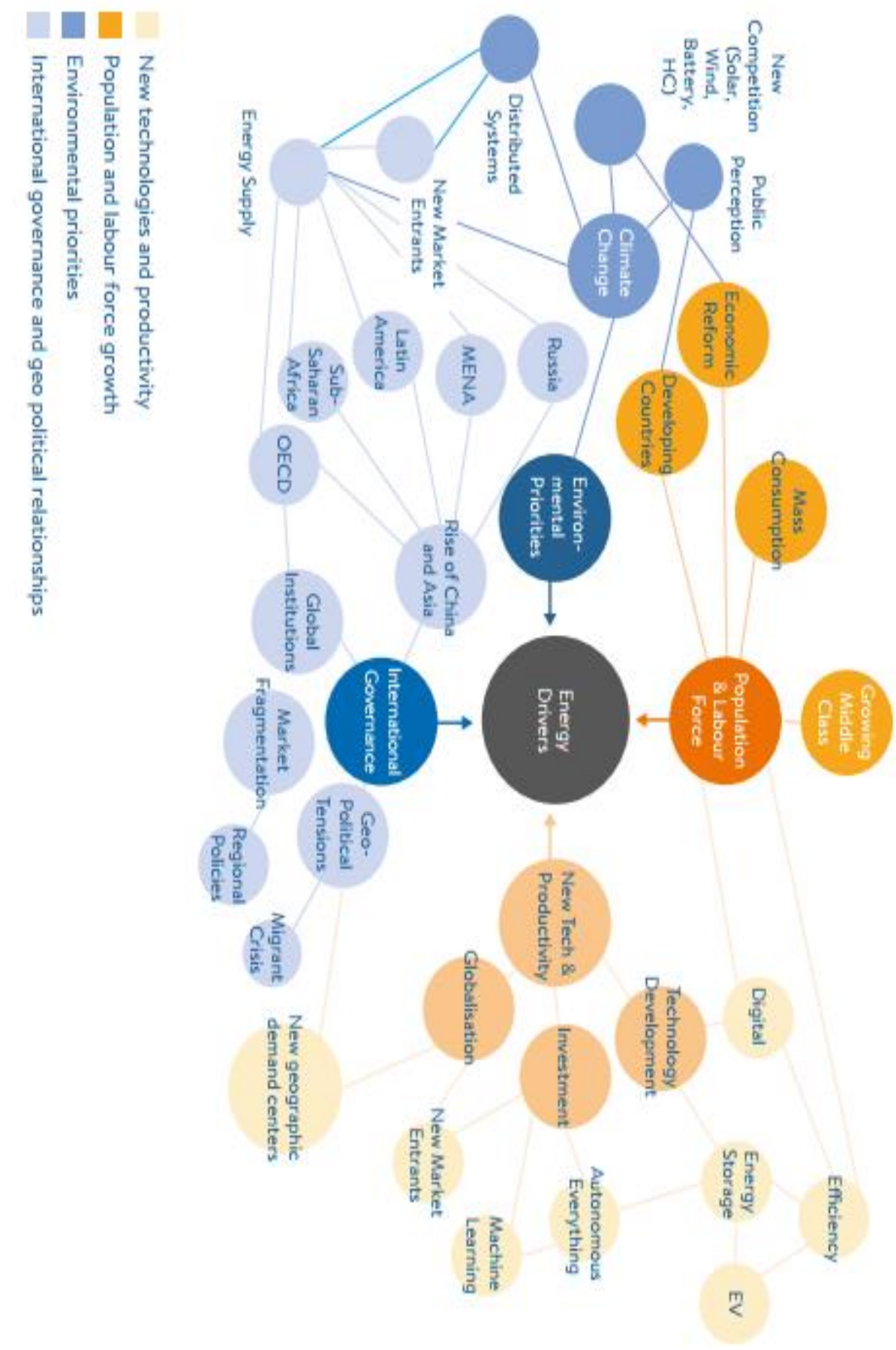
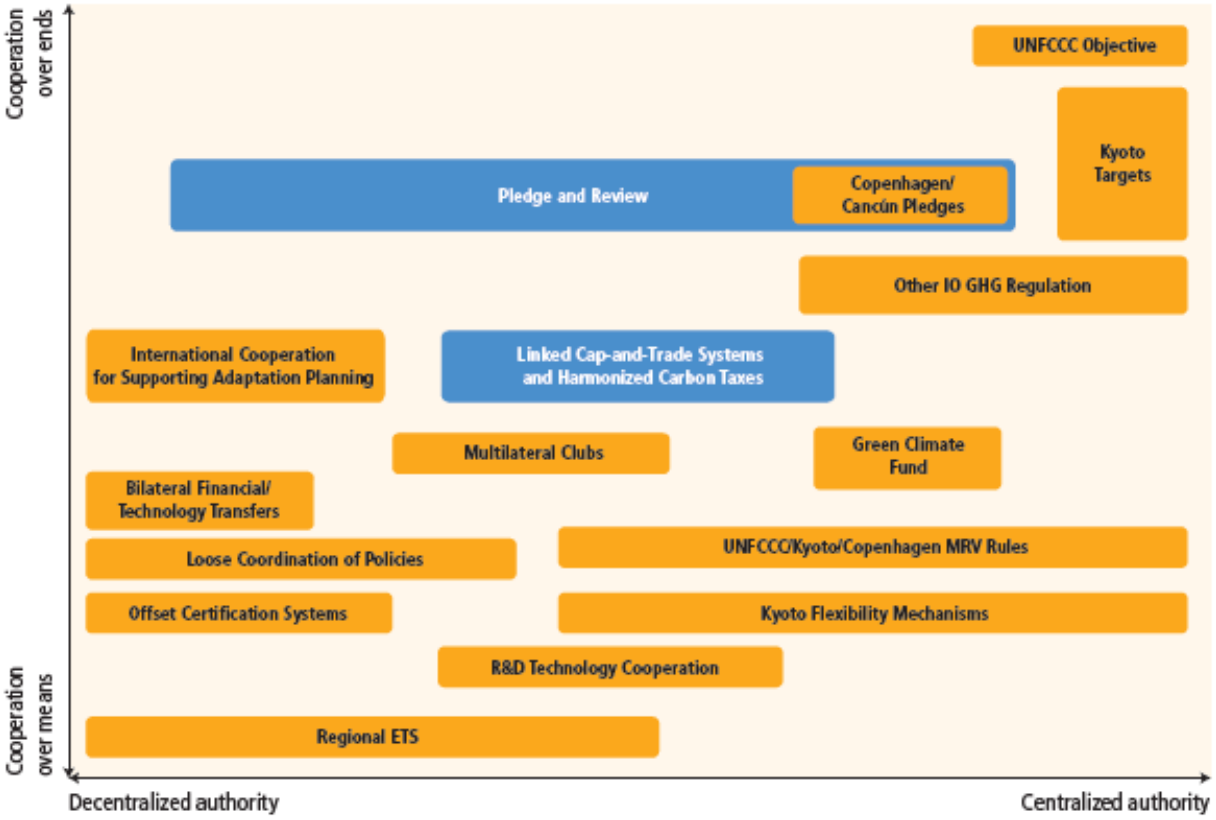


Figure 27: Factors shaping world energy. Source: World energy Council (2016) p 15.

Appendix VI: Overview of international cooperation on climate change

This picture shows different existing(orange) and possible(blue) forms of international cooperation. Although not exhaustive and the Paris agreement not included yet, this gives an indication of the possibilities. The width of individual boxes indicates the range of possible degrees of centralization for a specific agreement. The degree of centralization specifies the authority an agreement confers on an international institution, not the process of negotiating the agreement. Source: IPCC (2014) *Climate Change* p.105



Loose coordination of policies: examples include transnational city networks and Nationally Appropriate Mitigation Actions (NAMAs); R&D technology cooperation: examples include the Major Economies Forum on Energy and Climate (MEF), Global Methane Initiative (GMI), or Renewable Energy and Energy Efficiency Partnership (REEEP); Other International organization (IO) GHG regulation: examples include the Montreal Protocol, International Civil Aviation Organization (ICAO), International Maritime Organization (IMO);

Appendix VII Importance of risk factors for O&G companies

During the interviews, respondents were asked to rank these risk factors for O&G companies. The table 33 gives an indication based upon the average scores of the respondents. The second column depicts the rank, ranging from 1 (most important) to 5(least important). The third column presents the average weight(%) of what is most important. Since none of the respondents perceived a carbon bubble burst plausible, this approach provided an indication of the most important risk factors for O&G companies from the perspective of the Dutch pension market. Specification of the variables and metrics which was presented with this table can be found in table 28.

Table 32: Overview of average risk factors scores for O&G companies internal, according to seven respondents

Risk factors of O&G companies	**Importance Rank (1 most important- 5 least important)**	**Weight in % (sum=100%)**
Water resilience	4.71	6.43
Capital flexibility	2.14	29.29
Climate governance & strategy	1.71	25.71
Emmissions & resource management	3.57	17.86
Fossil fuel asset mix	2.86	20.71

Although this is a simplified representation of the internal risks of O&G industry, it provides an indication what the Dutch pension market values as most important risk factors for O&G companies. Climate governance & strategy is ranked highest by respondents, capital flexibility received the highest weight. A potential explanation could be that shareholders have high interest in the financial position of O&G companies to ensure the payment of dividend. Water resilience is ranked lowest, which is only critical in exploration areas with water scarcity. O&G companies can use the scores on the importance of future risk factors to include in their strategies and to ensure long term investments from the Dutch pension market.

Metrics Risk factors O&G companies

table 33: Overview internal risk factors and metrics for O&G industry. Metrics adopted from CDP (2016) In the pipeline.

Risk Factors	**Description**	**Metrics**
Water resilience	Both on and offshore testing of where water scarcity poses risk on production or leads to high cost	i) Water stress exposure ii) Water withdrawal intensity iii) Water disclosure
Fossil fuel asset mix	The types of hydrocarbons in the proven reserves of the O&G company. Gas is seen as transition fuel.	i) Production mix between oil and gas ii) Proved reserves mix by oil and gas
Capital flexibility	E&P costs and F&D costs. Financial stability and flexibility is increasingly important with volatile oil prices. Allocation of capital and efficiency of investments.	i) Reserve life (R/P) and development status ii) Production costs and capex intensity iii) Finding and development costs iv) Financial gearing
Climate governance and strategy	Remuneration structures, Investments in alternative energy sources, stress-testing of own portfolios.	i) Carbon regulation supportiveness ii) Climate governance iii) Low-carbon and alternative energy spend
Emissions and resource management Water	Intensity of own emissions, targets to reduce them. Leaking of methane is very damaging to the environment and management of flaring levels desired.	i) Upstream emissions intensity ii) Emissions reduction target iii) Methane emissions intensity and disclosure iv) Flaring intensity v) Lost gas production

Appendix VIII Specifications MSCI Index Ex Fossil Fuels

The table 35 gives an overview of the specifications of the historical Index performance in US$ of MSCI ACWI Index, MSCI ACWI Ex Coal, & MSCI ACWI Ex fossil fuels. Source: MSCI (2016) *Fossil fuel divestment, a practical introduction*. (p. 29).

table 34: Specifications of Key metrics of low carbon Indices from MSCI (2016)

KEY Metrics	MSCI ACWI index	MSCI ACWI ex Coal Index	MSCI ACWI ex Fossil Fuels Index
Total return* (%)	7.8	8.1	8.9
Total Risk (%)	13.4	13.3	13.0
Return/Risk	0.58	0.61	0.68
Sharpe ratio	0.57	0.60	0.67
Active return (%)	0.0	0.3	1.0
Tracking Error(%)	0.0	0.3	1.0
Information Ratio	NaN	1.19	1.00
Historical Beta	1.00	0.99	0.97
Turnover(%)	2.8	3.1	3.3
Price to Book* **	1.9	1.9	2.0
Price to Earnings	15.8	15.9	16.4
Dividend Yield (%)* **	2.8	2.6	2.5

Period: 30 Nov 2010-31 May 2016

***Gross returns annualized in USD**
****Annualized one-way index turnover over index reviews**
***** Monthly averages The**

Appendix IX Carbon Budget elucidation

The levels of carbon emissions associated with the < 1.5 ˚C, < 2 ˚C and < 3 ˚C temperature targets are calculated by the IPCC (2014) using multiple simulation models. The global temperature change relative to pre-industrial levels, compared to the cumulative Gt CO_2 emissions, are presented in figure 28. The colored circles indicate the different ranges of CO_2 concentration in parts per million associated with the scenarios of the IPCC (2014).

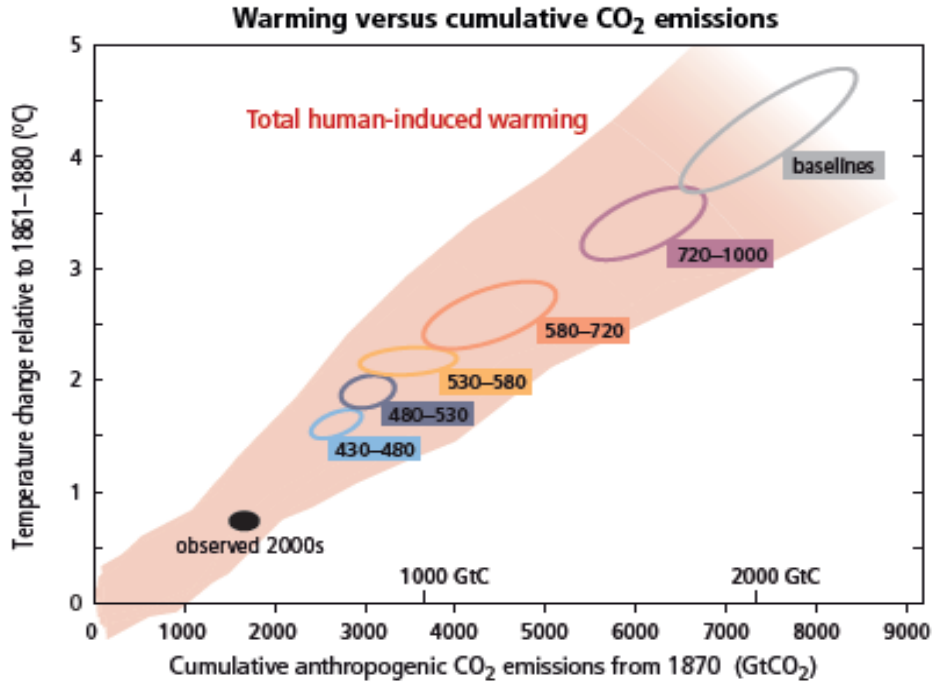


Figure 28:Global warming versus the cumulative CO2 emissions in the atmosphere. RCP 2.6 is unlikely to exceed 2 ˚C increase with 430-480ppm. Source: IPCC (2014) Climate change report p.9.

Cumulative CO_2 emissions from 1870 in $GtCO_2$									
Net anthropogenic warming [a]	<1.5˚C			<2˚C			<3˚C		
Fraction of simulations meeting goal [b]	66%	50%	33%	66%	50%	33%	66%	50%	33%
Complex models, RCP scenarios only [c]	2250	2250	2550	2900	3000	3300	4200	4500	4850
Simple model, WGIII scenarios [d]	No data	2300 to 2350	2400 to 2950	2550 to 3150	2900 to 3200	2950 to 3800	n.a. [e]	4150 to 5750	5250 to 6000
Cumulative CO_2 emissions from 2011 in $GtCO_2$									
Complex models, RCP scenarios only [c]	400	550	850	1000	1300	1500	2400	2800	3250
Simple model, WGIII scenarios [d]	No data	550 to 600	600 to 1150	750 to 1400	1150 to 1400	1150 to 2050	n.a. [e]	2350 to 4000	3500 to 4250
Total fossil carbon available in 2011 [f]: 3670 to 7100 $GtCO_2$ (reserves) and 31300 to 50050 $GtCO_2$ (resources)									

Table 35: Cumulative CO2 emission consistent with limiting warming to less than the temperature limits, at different probability levels, and different evidence. Blue circles highlight the selected values for further calculation. Source: Climate change report p.64, IPCC (2014).

The carbon budgets left to be burned for 66% are selected in table 36, since these reflect the highest number of simulations staying within the temperature threshold, including all GHGs. The values obtained via the complex models focusing on the Representative Concentration Pathways (RCP) developed by the IPCC, are selected for the sake of data availability, instead of the values from the simple models[76].

The cumulative emissions from 2011 in Gt CO_2 represent what is left to be emitted, while still staying within the threshold. Aiming to stay within 2 ˚C increase since 1870, the carbon budget was 2900 Gt CO_2 emissions. Since 2011 already 1900 Gt CO_2 emissions was emitted, which leaves 1000 Gt CO_2 to be emitted after 2011. Since these values reflect the CO_2 emission budget for staying within the specific temperature threshold after 2011, the CO_2 emissions from 2012-2016 need to be subtracted from this.

Global CO_2 emissions ranged between 31 and 33 Gt between 2012 and 2016 and have been stable in the last two years[77] (IEA, 2017). In total, 161 GT CO_2 emissions was subtracted to obtain the carbon budget from 2017 onwards. The distribution of fossil fuels which need to remain in the ground, was analyzed for the 2 ˚C target by Mc Glade & Ekins (2015) with a carbon budget of 870-1240 Gt CO_2 between 2011-2050[78]. These values are presented in table 37.

table 36: Carbon budget after 2016 and importance of factors

Temperature threshold	**Gt CO_2 Left to be burned after 2016** [79]	**Effect of Unburnable carbon & Adaptability on O&G companies**	**Distribution of unburnable fossil fuel reserves**
Carbon bubble burst < 1.5 ˚C	239	Highest	-
Carbon bubble burst < 2 ˚C	839	High	Oil: 35% Gas: 52% Coal: 88%
Carbon bubble burst < 3 ˚C	2239	Medium	-
Business as Usual	∞	Low	∞

[76] Complex models use a ''threshold exceedance budget'' approach, where simulations are done assuming emission continue at the RCP 8.5 pathway (baseline emissions). Once the temperature crosses a threshold, the associated cumulative CO2 emissions are calculated. Simple models use a ''threshold avoidance budget'' approach, where only the simulated scenarios which not exceed a temperature are used to deduct the carbon budget from.

[77] Global Emission CO2 in Gt per year (IEA, 2017):

2012	2013	2014	2015	2016
31.60	32.14	32.40	32.20	32.20

[78] There is assumed the distribution of unburnable fossil fuel reserves remained the same for staying within the 2 ˚C limit, although the carbon budget was reduced after 2011. The original value of 1000 Gt CO2 lies within the range of 870-1240 used by Mcglade & Ekins (2015).

[79] The Gt CO_2 emissions of the carbon budget after 2011 from the IPCC (2014) are reduced by 161 Gt CO2, the total CO2 emissions from 2012-2016, (IEA, 2017). See also Appendix IX

Appendix X

Calculations on Stranded assets of O&G companies in < 2 ˚C

Based on data of the oil and gas reserves of the 11 companies, the effect on the MCap in a 2 ˚C scenario were calculated, using results of McGlade and Ekins (2015) published in the renowned journal Nature in 2015 as a starting point. They found 35% of the oil and 52% of the gas reserves and 88% of the coal reserves must stay in the ground before 2050, to stay below the parts per million carbon dioxide concentration associated with the 2 ˚C target. These results are based upon multiple model simulations, delivering geographically disaggregated estimates of the unburnable reserves, assuming no CCS[80]. Table 38 uses the data from CDP (2016) Oil sands and crude oil were both accounted as oil.

Table 37 Overview fossil fuel type proven reserves of O&G companies from CDP (2016).

O&G company	**Proven reserves (Bilion boe)**	**Oil Sands (%)**	**Crude oil (%)**	**Gas (%)**
Statoil	5.1	2	42	56
Eni	6.9	0	49	51
Total	11.6	1	46	53
Shell + BG	15.3	4	43	53
BP	10.4	1	44	55
Occidental	2.2	0	74	26
Petrobras	10.5	1	83	16
ConocoPhillips	8.2	8	54	38
Chevron	11.2	4	52	44
Exxon Mobil	24.8	7	47	46
Suncor	4.7	78	21.8	0.2
TOTAL of 11 companies (bil boe)	**110.9**	**10.69**	**56.03**	**44.18**

To give an indication of the average loss on MCap for O&G companies, the sum of the current MCap of the O&G companies was set equal to their current proven oil and gas reserves. The sum of the shares of the eleven O&G companies reserves of oil and gas were reduced by 35 and 52 percent respectively. Then, the exploitable reserves in a 2 ˚C scenario, were compared to the previous exploitable reserves in oil and gas. The percentage difference in MCap of the 11 O&G companies was calculated by subtracting the new value of MCap by the old MCap, and dividing it by the old MCap, times a hundred percent. This calculation assumed that the effect of unburnable reserves on the MCap of an O&G company is 1:1 and assumed an equal effect of unexploitable oil and gas reserves on the MCap of O&G companies. Although this calculation is a simplified representation of the reality, it gives an indication of the average loss for the eleven O&G companies and the complete O&G industry in a 2 ˚C scenario.

[80] The linear optimization, integrated assessment model TIAM-UCL was used, taking into account multiple IPCC emission scenarios. The different temperature trajectories were calculated with the MAGIC model, using probability distributions on temperatures and emissions.

Table 38: Effects of reserve limitation on MCap of the 11 O&G companies assuming 35% of oil and 52 % of gas reserves need to remain in situ. This leads to 42% loss in MCap, not considering a discount factor

Total proven reserves in billion boe 11 O&G companies	**Oil reserves (billion boe)**	**Gas reserves (billion boe)**	**MCap billion (US$)**	**Share of MCap from oil reserves (US$)**	**Share of MCap from gas reserves (US$)**		
110.9	66.72	44.18	1250	750	500		
	*35%	*52%					
	Unburnable:	**Unburnable:**					
	23.35	22.97		262.50	287.17		
				billion $	billion $		
			New MCap	487.5 $	240 $	Total=	727.5 $
						%loss MCap	**-42%**

These calculations assume, an equal effect between the limitation of oil exploration and the limitation of gas exploration on the MCap of the firms. This means the 42% of stranded reserves of the 11 O&G companies would also result in 42% MCap loss. To discount for the MCap loss, a discount factor should be applied. Since money in the present, is worth more than the same amount in the future. So, the future loss of the reserves, will result in a lower effect on the MCap. A discount factor of 8% is used for these calculation, based on literature of reserve valuations (Arnot, 2004).

From the literature, the following formula is adopted for the Present Value at time t. Here:

FV= the Future Value loss, due to stranded assets on the sample. (42%*1250)=525 billion USD
i= discount factor of 8% is assumed (Arnot, 2008)
n= the expected years before of producing with reserves
PV= the present value of the MCap loss.

$$PV_t = \left(\frac{FV}{(1+i)^n}\right)$$

To calculate n, the total Proven reserves of the sample are used, of which the yearly production of the sample is subtracted each year, assuming ceteris paribus. This gives a value of 12 years for n. Probably, some of the 2P reserves of O&G companies are also used before reaching the 2 ˚C target, but these were not included due to a lack of data and since it is unknown how much these 2P reserves contribute to the value of the O&G companies.

table 39: Years of production left of Proven reserves of 11 O&G companies. yearly production of 8.70 is subtracted each year.

year	Proven reserves sample minus yearly production sample (8.71 bilion boe/year)
0	111
1	102
2	93
3	85
4	76
5	67
6	59
7	50
8	41
9	33
10	24
11	15
12	6
13	-2

$$PV_t = \left(\frac{525}{(1.08)^{12}} \right)$$

= 208.48 billion USD loss of MCap.

Comparing this to the current Mcap of the sample, 1250 billion, the new MCap would be 1041.52 billion USD. This would only indicate a loss of 17%.

However, this is subject to many other effects than are not taken into account here, like debt service, change of production ratios, depletion, longer period of production, differences in risk valuations, cost not related to property, price & demand changes and other risk factors. Hence, it is difficult to determine these companies will lose exactly due to stranded assets.