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LOOKING BEYOND: DETERMINING THE ENVIRONMENTAL RISK OF OIL AND GAS RESERVES FROM AN INVESTOR'S PERSPECTIVE

Tatiana Botelho

Tese de Doutorado apresentada ao Programa de Planejamento Energético, COPPE, da Universidade Federal do Rio de Janeiro, como parte dos requisitos necessários à obtenção do título de Doutor em Planejamento Energético.

Orientadores: Alessandra Magrini
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TESE SUBMETIDA AO CORPO DOCENTE DO INSTITUTO ALBERTO LUIZ COIMBRA DE PÓS-GRADUAÇÃO E PESQUISA DE ENGENHARIA (COPPE) DA UNIVERSIDADE FEDERAL DO RIO DE JANEIRO COMO PARTE DOS REQUISITOS NECESSÁRIOS PARA A OBTENÇÃO DO GRAU DE DOUTOR EM CIÊNCIAS EM PLANEJAMENTO ENERGÉTICO.

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DETERMINANDO RISCO AMBIENTAL DAS RESERVAS DE PETRÓLEO E GÁS DO PONTO DE VISTA DO INVESTIDOR

Tatiana Botelho

Março/2015

Orientadores: Alessanfra Magrini e Roberto Schaeffer

Programa: Planejamento Energético

O Acidente da Deepwater Horizon pode ter abalado a credibilidade dos índices de sustentabilidade, mas também reforçou a importância de avaliação da sustentabilidade das empresas de petróleo e gás (P&G). O objetivo desse estudo é determinar se e como os riscos ambientais são relacionados com reservas e desenvolver indicadores que possam mensurar esse risco complementando dados históricos de desempenho para valoração dessas empresas. Dados das reservas de 2009 até 2012 de 24 empresas de P&G listadas na bolsa de Nova York foram usados para testar 5 hipóteses de como as reservas podem estar relacionadas com quatro riscos ambientais materiais: mudança do clima, acidentes, área sensível/acesso e água. A frequência com que as empresas reportam esses riscos foi avaliada usando analise de conteúdo. O teste t do Estudante foi aplicado em cada hipótese. Este estudo mostra que os riscos ambientais estão relacionados com as reservas da seguinte forma: (1) empresa com reservas de petróleo pesado reportam mais exposição a riscos de mudança do clima; (2) acidentes é uma questão mais preponderante em empresas que mencionam águas profundos na seção de risco dos Formulário10-K; e (3) água é uma questão mais presente em empresas com reservas maiores de gás natural e betumem. Assim, um novos indicadores quantitativos baseado em características de reservas foram elaborados e aplicados utilizando a base de dados do Cube Browser da Rystad Energy. Esses indicadores poderão auxiliar investidores, agencias de crédito e índices de sustentabilidade identificar com mais facilidade empresas expostas a cada um desses riscos.

Abstract of Thesis presented to COPPE/UFRJ as a partial fulfillment of the requirements for the degree of Doctor of Science (D.Sc.)

LOOKING BEYOND: DETERMINING THE ENVIRONMENTAL RISK OF OIL AND GAS RESERVES FROM AN INVESTOR'S PERSPECTIVE

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The Deepwater Horizon Accident may have shaken the sustainability ratings and indices credibility, but it also reinforced the importance of sustainability evaluation of oil and gas companies. The objective of this study is to determine if and how environmental risk relates to reserves and develop a new set of forward-looking indicators to complement past performance data in the valuation of O&G corporations. Data on reserves from 2009 to 2012 of 24 listed O&G companies were used to test five hypotheses, addressing how these profiles could relate to the four material environmental risks: climate change, accidents, sensitive area/access, water. The frequency with which companies reported these risks was evaluated using key word in context (KWIC) content analysis. Student's *t* tests were applied to each of the hypotheses. This study shows environmental risks are embedded with the oil and gas reserves. We found the following relationships: (1) companies with heavy oil reserves report more exposure to climate change risks, particularly emissions control; (2) accidents is more of an issue with companies that mention deepwater in the Risk Section of their Form 10-Ks; and (3) water is more of an issue with companies with higher bitumen and natural gas reserves. Thus, a new set of forward-looking quantitative indicators based on reserves characteristics was proposed and applied using Rystad Energy's Database Cube Browser to assist investors, credit agencies and sustainability raters and indexes to easily identify companies that are more exposed to each of these risks.

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1. Introduction

Sustainability is a growing concern in the investment community, as reflected by the proliferation of environmentally screened or socially responsible mutual funds and other portfolios (EUROSIF, 2014; US SIF, 2014; CDP, 2015; UN PRI, 2015). For instance, in the 12 years since its foundation, the United Nations-supported Principles for Responsible Investment (UN PRI) initiative has gained over 1,300 member institutions, representing more than US$45 trillion in assets (UN PRI, 2015). Further, the CDP, formerly known as the Carbon Disclosure Project, represents 722 institutional investors that hold assets of US$92 trillion, and addresses "key structural challenges presented by climate change and natural resource scarcity" (CDP, 2015).

Along with the growth of these funds, methodologies to evaluate corporate sustainability have also burgeoned. Sadowski *et al.* (2010a) and Singh *et al*. (2012) review more than 50 ratings and indices that seek to measure or compare corporate sustainability performance, and of these, more than one-third have emerged since 2005. However, in April 2010, when hydrocarbons spilled out of BP's Macondo Well into the Gulf of Mexico, causing the largest oil spill in United States (U.S.) history, socially responsible investment (SRI) funds held millions of dollars in BP shares (STEVERMAN, 2010). The good reputation that the British giant had enjoyed among the SRI community until the accident caused discomfort and discredited sustainability screening methodologies (FREELAND, 2010; MSCI, 2010; SIEGEL, 2010; SINGH, 2010; STEVERMAN, 2010; BOTELHO and MAGRINI, 2011; CERES and TELLUS, 2011; CHERRY AND SNEIRSON, 2011; INSTITUTE OF BUSINESS ETHICS, 2013; OWEN, 2013). The BP accident was even cited in a press release that created a new coalition, the Global Initiative for Sustainability Ratings, which went on to say that the "proliferation of scores of sustainability ratings providers has also spawned inconsistent and often opaque approaches and, in some instances, conflicts of interest among raters and rated companies" (CERES and TELLUS, 2011).

In addition to the discrediting of the sustainability rating methodologies, the BP accident served to reinforce the point that environmental risks could translate into huge financial losses (CERES and TELLUS, 2011; HEFLIN and WALLACE, 2011). Consequently, just as the financial rating agencies had to revise their methodologies significantly after the 2008 subprime mortgage crisis (PACKER and TARASHEV, 2011), the SRI community must also undertake a major review (BOTELHO and MAGRINI, 2011; CERES and TELLUS, 2011; WHITE, 2014).

In such a context, historical data analyses have proven generally effective in identifying trends and future performance (CHATTERJI *et al.,* 2009; DELMAS and BLASS, 2010). However, in this study, we contend that the oil and gas exploration and production (O&G E&P) industry in particular has three characteristics that require investors to consider forward-looking indicators as well as past results in order to determine future environmental risks and opportunities. The first characteristic is the rapid pace at which O&G reserves and the operations required to extract them are changing. According to the International Energy Agency (IEA, 2012), the surge in unconventional supplies, especially those from shale gas in the U.S., oil sands in Canada, and ultra-deepwater production in Brazil, will lead to net growth in global oil production driven entirely by unconventional oil.[1] Carbon Tracker Institute (CTI, 2014) emphasizes how each of these unconventional O&G sources

[1] According to the IEA: "Conventional oil is a category of oil that includes crude oil and natural gas liquids and condensate liquids, which are extracted from natural gas production. Unconventional oil consists of a wider variety of liquid sources including oil sands, extra heavy oil, gas to liquids and other liquids. In general, conventional oil is easier and cheaper to produce than unconventional oil. However, the categories 'conventional' and 'unconventional' do not remain fixed, and over time, as economic and technological conditions evolve, resources hitherto considered unconventional can migrate into the conventional category." (http://www.iea.org/aboutus/faqs/oil/) Further Discussion on what is defined by conventional oil in chapter 2.

presents differentiated production cost-curves that deeply affect investors' returns given the current decline in oil prices and the climate restriction scenario.

The second characteristic is that corporate valuation is based on proven reserves; that is, hydrocarbons that have not yet been produced and are economically viable to extract (HOWARD and HARP, 2009). In this regard, capital is allocated to E&P activities on the basis of the removal of risky assets, thereby applying ever more complex technologies in increasingly remote places (TSOSKOUNOGLOU *et al.,* 2008).

The third characteristic is the difficulty in evaluating management practices when there is considerable collaboration on environmental issues, a situation that leads some authors to support the institutional isomorphism theory in the O&G E&P sector.[2] Dahlsrud (2005) concludes that there is a high degree of collaboration and information sharing among four major O&G companies on explicit strategies and the tools that are chosen to deal with social, environmental, and economic issues. In addition, Pegg (2012) claims that Chinese companies are not “significantly different in their actions from the major western oil majors.” Global competition, interdependence, and collaboration over major accidents have sensitized companies to each other’s actions (LEVY and KOLK, 2002). In this context, Escobar and Vredenburg (2011) argue that a lack of clear regulations and enforcement mechanisms, aimed at steering companies with multiple operating sites toward sustainable development, can lead to mimetic isomorphism.

Howard and Harp (2009) highlight that E&P companies are “unique in that their primary asset base is depleting and therefore must be continually replaced.”

[2] DiMaggio and Powell (1983) develop a theory in which they argue that structural changes in organizations are driven to a lesser extent by competitive forces and are becoming more homogenous because of coercive, mimetic, or normative processes.

However, with regard to environmental indicators, most of the current reporting and performance standards seem to ignore this statement. SRI funds and indices usually apply a combination of past performance and current managerial actions as indicators of future environmental performance (CHATTERJI *et al*., 2009). Some of the information used comes from company reports, either mandatory or voluntary (FOWLER and HOPE, 2007; WOOD, 2010), but neither the main sustainability voluntary reporting schemes[3] nor the U.S. Securities Exchange Commission (SEC) require quantitative disclosure of location information about reserves; for example, whether the reserves are in conservation units or water-scarce regions (AUSTIN and SAUER, 2002; FREYMAN and SALMON, 2013). This, in turn, results in companies providing little data about their reserves' locations and characteristics.

The rapidly evolving exploration scenario, an exclusive feature of this industry, suggests that past environmental performance will most likely not resemble future risk. This present study contributes to such a suggestion by pointing out an issue that has been overlooked when evaluating O&G E&P activities: the relationship between reserve characteristics and environmental risk. In this regard, the purpose here is not to propose a new sustainability framework but to add to the discussion and hopefully to the improvement of corporate valuation.

The objective of this study, therefore, is to determine if and how environmental risk relates to reserves; a new set of forward-looking material[4] indicators can then be developed to complement past performance data in the valuation of O&G

[3] These include the CDP Oil & Gas Industry Sector (2014), the Global Reporting Initiative (GRI) O&G Sector Supplement (2012), the sector specific guidelines developed by the International Petroleum Industry Environmental Conservation Association (IPIECA), the International Association of Oil & Gas Producers (OGP), and the American Petroleum Institute (2011) as detailed in Chapter 2.

[4] A discussion of the definition of materiality is provided in Chapter 4. For the purposes of the analysis in this document, the U.S. Supreme Court definition of materiality will be used, which is information presenting "a substantial likelihood that the disclosure of the omitted fact would have been viewed by the reasonable investor as having significantly altered the 'total mix' of information made available." (TSC Indus. v. Northway, Inc., 426 U.S. 438 (1976)).

corporations. This information can help to guide investors, the developers of standards, and regulatory agencies in order to develop metrics that can assess a company's degree of exposure to environmental challenges.

In order to accomplish this objective, a methodology was developed as illustrated in Figure 1.1. First, a review of environmental impacts was conducted. This considered conventional as well as unconventional E&P processes. Concurrently, the socially responsible investors' universe was reviewed. This included a literature analysis on environment, social, and governance (ESG) ratings along with an examination of environmental reporting standards in order to understand what environmental indicators companies are reporting to the market. With possible environmental impacts on one hand and the needs of investors on the other, it was possible to select four material environmental risks that recurred in the literature analysis: climate change, accidents, sensitive areas/access, and water.

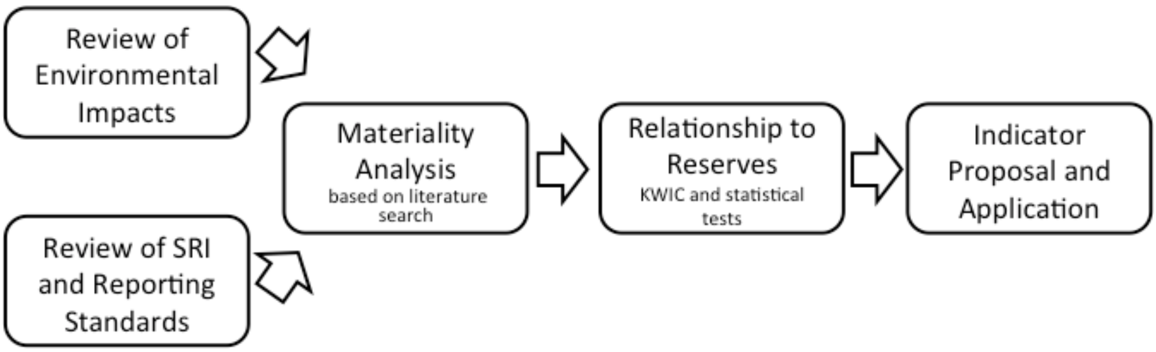


Figure 1.1 Methodological process

A test was then structured to check the hypothesis that the mix of reserve types can alter the exposure to environmental risk of the largest listed companies with E&P activities, as reported on Form 10-Ks (or the equivalents).[5] Data on reserves from 2009 to 2012 of 24 O&G companies were used to test five hypotheses, which

[5] The annual report required by the U.S. Securities and Exchange Commission on Form 10-K provides a comprehensive overview of a company's business and financial condition and includes audited financial statements. The annual report Form 40-F applies when the registrant is incorporated or organized under the laws of Canada or any Canadian province or territory, whereas Form 20-F must be submitted by all "foreign private issuers" that have listed equity shares on exchanges in the U. S. The reporting and eligibility requirements are stated in the Securities Exchange Act of 1934.

address how the reserves' profiles could relate to the four material environmental risks. The frequency with which companies reported these risks was evaluated using keyword-in-context (KWIC) content analysis[6] followed by Student's t-tests to check the relationship to the reserves' profiles.

The results of the statistical tests suggested indicators that should be developed to enable investors to identify clearly any exposure to the risks discussed. These indicators were applied to the 24 companies being studied using the reserve data from the global databases of Rystad Energy's Cube Browser (RYSTAD ENERGY AS, 2014). Thus, it was possible to identify companies that are more vulnerable to climate change, water, and accident risks.

On April 2, 2009, at a daylong meeting at Boston College, a group of 35 investment consultants, asset managers, and other stakeholders gathered to discuss the state of responsible investing (INSTITUTE FOR RESPONSIBLE INVESTMENT, 2009). The group concluded that "the challenge is not rating the ESG impact of investment products but enhancing information that would help investors to clarify their investment choices." The ultimate purpose of this present study is to show how information on reserves could empower market players to make better decisions.

Chapter 2 discusses the processes and environmental impact risks of the O&G industry, highlighting the changes brought by unconventional E&P. At the end of the chapter, there is also a discussion on how companies manage these impacts and risks. In Chapter 3, the state of socially responsible investing is reviewed, along with past studies that evaluate the connection of ESG and financial performance in the O&G sector. The chapter also presents some thoughts and literature on

[6] The method applied was a keyword-in-context (KWIC) content analysis that allows the researcher to include large amounts of textual information and systematically identify its properties by counting the frequencies of the most used keywords (Krippendorff, 2012). Please see the further discussion in Chapter 5.

methodologies that are used for sustainability ratings and closes with an analysis of the indicators present in the main reporting standards applied to the O&G industry. Chapter Four begins with a discussion on the definition of materiality among the different reporting instruments. The chapter follows this with a literature review and the selection of four main issues that are material to the E&P O&G sector, and considers why these are relevant. In Chapter 5, the relationship of the selected material issues to reserve characteristics is tested. Finally, in Chapter 6, an indicator proposal is illustrated followed by concluding thoughts and ideas for further research in Chapter 7.

2. Oil and gas: environmental risks and management

Oil and gas exploration and production (O&G E&P) companies explore for and extract fossil fuels such as crude oil and natural gas. These activities comprise the upstream operations of the oil and gas value chain. The value chain is also composed of the transportation, refining, and distribution of oil and gas derivatives such as gasoline, diesel, and naphtha. Each of these activities has different environmentally related risks and opportunities (UNEP, 1997). In this study, we focus on the upstream activities. The purpose of this chapter is to provide an overview of the main activities and the consequent environmental impacts.

2.1 Brief overview of the O&G E&P process

The definition of conventional hydrocarbons at any particular time depends on resource characteristics, available exploration and production technologies, and the economic conditions of production from the resource (BABUSIAUX and BAUQUIS, 2007; IEA, 2013). In the past, the definition of conventional oil and gas was related to hydrocarbons that could be produced given the technological and economic conditions existing at the time or in the foreseeable future. However, technological progress has considerably shifted perceptions, making the border between conventional and non-conventional fuzzy (BABUSIAUX and BAUQUIS, 2007).

Among experts and agencies, no consensus exists by which resources are considered conventional. Kjarstad and Johnsson (2009) present estimates from various organizations of proven reserves and remaining oil resources: BP and the *Oil and Gas Journal* include Canadian and Venezuelan oil in their conventional estimates; Cambridge Energy Research Associates (CERA)'s conventional resources include arctic and deepwater: while the International Energy Agency (IEA) and ExxonMobil considers all of these to be unconventional resources. For a further discussion on conventional vs. unconventional definitions, please see Malagueta (2009).

According to the IEA (2013), the net increase in global oil production has been driven entirely by a surge in unconventional[7] supplies. These have come mainly from shale gas in the U.S., oil sands in Canada, and an increase in ultra-deepwater production in Brazil. Over the last decade, the development of unconventional resources such as tar sands, shale gas, and ultra-deepwater has expanded rapidly because these vast reserves are becoming economically and technically feasible to extract. Maugeri (2012) suggests that, contrary to common belief, oil production is growing rapidly and the decade of 2010-2020 could present the most significant oil supply increase in 30 years, bringing a "de-conventionalization" of oil supplies. These resources present a new set of environmental challenges that must be adequately evaluated when investing in a corporation.

There are four main stages that comprise O&G E&P activities in general: (1) survey; (2) exploratory drilling and appraisal; (3) development and production; and (4) decommissioning (UNEP, 1997; EPA, 2000; UNEPFI, 2006). These stages are applicable to conventional and to some unconventional resources with each of them generating a number of environmental risks, as summarized in Table 2.1. The magnitude and intensity of these risks vary depending on the technology that is applied, the resource extracted, and the location of the activities.

[7] According to the IEA: "Conventional oil is a category of oil that includes crude oil and natural gas liquids and condensate liquids, which are extracted from natural gas production. Unconventional oil consists of a wider variety of liquid sources including oil sands, extra heavy oil, gas to liquids and other liquids. In general conventional oil is easier and cheaper to produce than unconventional oil. However, the categories 'conventional' and 'unconventional' do not remain fixed, and over time, as economic and technological conditions evolve, resources hitherto considered unconventional can migrate into the conventional category." (http://www.iea.org/aboutus/faqs/oil/)

Table 2.1 - Main environmental risks of oil production stages

Stage of Oil Production	Environmental Risks	Main Activities
Survey	- Biodiversity/temporary habitat depletion, fragmentation, and degradation/ disturbance to marine organisms - Erosion - Noise - Access/opening up of previously inaccessible land to secondary development - Climate change - Local air pollution	- Land clearance/disturbance - Use of explosives - Air gun and other seismic study tools - Vehicular and plant exhaust emissions
Drilling & Appraisal	- -Biodiversity/habitat depletion, fragmentation, and degradation - Erosion and fissures - Noise - Access/opening up of previously inaccessible land to secondary development - Water contamination - Soil contamination - Local air pollution - Climate change - Energy demand	- Discharge of drill muds and cuttings - Well blowouts and other oil spills and leaks - Discharge of process wastewater and waste containing organic acids, diesel oil, and acidic stimulation fluids - Well cementing - Use and discharge of fracturing fluids - Land clearance/disturbance - Construction activities, noise, and vibration - Disturbance from transportation and traffic volumes - Vehicular and plant exhaust emissions - Flaring and fugitive emissions - - Methane venting
Production	- Biodiversity/permanent habitat depletion, fragmentation, and degradation - Erosion and ground subsidence - Access/opening up of previously inaccessible land to secondary development - Water scarcity - Water and soil contamination - Noise - Local air pollution - Climate change - Energy demand	- Land clearance/disturbance - Discharge of produced water possibly containing heavy metals, organic compounds, and high levels of salts; may also contain additives and other pollutants - Freshwater withdrawal - Construction activities, noise, and vibration - Well cementing - Discharge of completion fluid, wastewater containing well-cleaning solvents (detergents and degreasers), paint,

		stimulation agents - Application of fracturing fluids - Discharge of wastes - Introduction of barriers to wildlife movement - Increased disturbance from transportation and traffic volumes - Well blowouts and other oil spills and leaks - Pit/pond storage - Fugitive natural gas, other VOCs from natural gas conditioning - Vehicular and plant exhaust emissions - Flaring and fugitive emissions - Conditioning of tar sands - Methane venting
Decommissioning	- Erosion and ground subsidence - Soil and water contamination	- Site and pipe cleanliness - Well abandonment - Well blowout

Developed by the author, based on UNEP, 1997; EPA, 2000; UNEPFI, 2006; Reig *et al.*, 2014.
Note: "VOCs" are volatile organic compounds.

The next sections briefly summarize the conventional O&G E&P stages, based on the United Nations Environment Program (UNEP, 1997), the U.S. Environmental Protection Agency (EPA, 2000), ABB (DEVOLD, 2013) and books by Corrêa (2003), Thomas (2004) and Downey (2009). This is followed by a brief overview of unconventional resources and their particular processes and techniques. Note these are highly complex processes that are summarized below to serve as a basis for the environmental impacts discussion, which will then provide input for the materiality of the environmental risks and their relationship to reserves, discussed in chapters 4 and 5.

a) Survey

There are a number of methods to identify favorable areas of hydrocarbon accumulation that can be classified into geological or geophysical studies. Geological studies use geological maps and characteristics obtained from exploration wells in order to reconstitute the conditions for the formation and accumulation of hydrocarbons in a determined region. Geophysical studies use sensing instruments based on the interaction of energy and matter to gather physical data of an area that indicates the presence, position, and nature of subsurface resources. (THOMAS, 2004 and DOWNEY, 2009)

The most cost effective and most used geophysical technique is a seismic survey, which is based on the measurement of the time it takes for sound waves to travel through sedimentary layers. On land, large vibrator trucks are used to create the sound source, whereas air guns are used to release low frequency waves that penetrate the seabed to considerable depths. The returning signals are analyzed and processed to yield information on the sub-seabed structure. (THOMAS, 2004 and DOWNEY, 2009)

The 3-D and 4-D seismic survey requires large capacity supercomputers and can provide a good indication of where to drill, but a test well is necessary to determine if production is feasible. (DOWNEY, 2009)

b) Exploratory drilling

Once it is judged that there is a reasonable chance of discovering a sufficient amount of hydrocarbons at a site, an exploratory well is drilled. Most companies do not own rigs, but hire specialized contractors and their labor crew and pay either daily rates or footage contracts (DOWNEY, 2009).

For both onshore and offshore sites, the subterranean aspects of the drilling procedure are very similar. The drill bit is the component in direct contact with the rock at the bottom of the hole, and increases the depth of the hole by chipping off pieces of rock. The drilling fluid is also an important component in the drilling process and is required in the wellbore to: (1) cool and lubricate the drill bit; (2) remove the rock fragments, or drill cuttings, from the drilling area and transport them to the surface; (3) counterbalance formation pressure to prevent formation fluids (i.e., oil, gas, and water) from entering the well prematurely; and (4) prevent the open (uncased) wellbore from caving in (THOMAS, 2004 and DOWNEY, 2009). Although the drilling fluid may be a gas or foam, liquid-based fluids (called drilling muds) are used for approximately 93% of wells (API, 1997). There are three general categories of such drilling muds: water-based, oil-based, and synthetic-based (THOMAS, 2004).

Drilling speed is on average 30 meters per hour, but as the drill reaches different types of rocks it may curve and slow down (DOWNEY, 2009). Steel tubes, called casing, are periodically cemented to reinforce the sides of the wells. In addition to providing structural integrity, casing prevents contamination of water and water from entering the well. (THOMAS, 2004)

Several tests are performed during the drilling, which includes: (1) cutting analysis, to see what type of rock the drill bit is encountering; (2) well logging, to test the physical conditions of the well; (3) core sampling, to analyze a rock column; and (4) flow testing, to measure the capacity of oil and gas flow in the well. (DOWNEY, 2009)

A well can result in a dry hole, that is when no hydrocarbons are found, or if hydrocarbons are present, it can be an appraisal well, to determine potential production; step out well, to determine limits of an oil field; and development well, to begin production (DOWNEY, 2009). Completion takes place once the gas or oil well has been determined commercially viable. “This includes strengthening the well hole with casing, evaluating the pressure and temperature of the formation, and installing the proper equipment to ensure an efficient flow oil and gas from the well.” (DEVOLD, 2013)

c) Development and production

Production is the process of extracting the hydrocarbons; separating the mixture of liquid hydrocarbons, gas, water, and solids; removing the constituents that are non-saleable; and selling the liquid hydrocarbons and gas (UNEP,1997 and EPA, 2000). While there are oil- or gas-only installations, most frequently, a reservoir contains a number of hydrocarbons (methane, butane, propane, condensates and oil) as well as water, carbon dioxide, salts, sulfur, mud and sand (DEVOLD, 2013). In addition, water and gas may also be injected to maintain a certain pressure to push the hydrocarbon deposits into production wells (UNEP,1997; EPA, 2000; DEVOLD, 2013). These are separated by gas oil separation plant, which is expensive, and only makes sense in larger production sites (DOWNEY, 2009 and DEVOLD, 2013).

The production systems onshore and offshore are significantly different. A land based well can be commercial with only a few dozen barrels of oil a day and requires simple structure, such as a sucker rod pump (donkey pump) (DEVOLD, 2013). Offshore structures have evolved significantly and currently are highly complex, often a drilling rig and production platform can operate from the same structure (DOWNEY, 2009). Subsea production systems are wells located on the sea floor, as opposed to the surface. The petroleum is extracted at the seabed, and is then tied-back to a pre-existing production platform or even an onshore facility by flexible pipelines known as conductors or marine risers (DOWNEY, 2009 and DEVOLD, 2013). "This allows one strategically placed production platform to service many wells over a reasonably large area. Subsea systems are typically used at depths of 500 meters or more and do not have the ability to drill, only to extract and transport." (DEVOLD, 2013)

Another important component of the production process is the wellhead structure, often called a Christmas tree, which sits either subsea on top of the oil or gas well or on a platform out of the water. This structure allows for various technologies for maintaining the well and improving its production capacity. (DOWNEY, 2009 and DEVOLD, 2013)

It is worth noting that technological advances, such as directional drilling, enable in situ operations to drill multiple wells (sometimes more than 20) from a single location. This helps to reduce surface disturbance. (UNEP,1997 and EPA, 2000)

d) Decommissioning

Decommissioning involves plugging a well and restoring the site. This occurs when a recently drilled well lacks the potential to produce economic quantities of oil or gas, or when a production well is no longer economically viable. (UNEP,1997 and EPA, 2000)

2.2 Unconventional O&G

The IEA (2013) highlights three types of unconventional O&G as the main resources that are going to increase production until 2025: (1) shale gas, (2) oil sands, and (3) deepwater. It should be noted that this list is far from exhaustive. Unconventional resources can also include coal-bed methane, oil shale, methane hydrates, extra-heavy oils, and new frontiers such as Arctic oil. A brief discussion of the production methods that are applied in the extraction of these three main resources follows.

a) Shale Gas

Shale is a fine-grained, fissile, sedimentary rock made up primarily of clay and silt. The hydrocarbons contained in shale include shale gas, natural gas liquids (NGLs), and tight oil[8]. Because of its extremely low permeability, shale must be split apart to

[8] Tight oil can be found in other formations other than shale (Yergin, 2011).

allow the oil and gas to flow to the surface. This is done by hydraulic fracturing, which entails injecting fluid composed of water, chemicals, and a solid material (proppant) into the reservoir under very high pressure in order to create fractures to increase rock porosity and permeability. This is applied using horizontal drilling to expand the area of recovery. As the fluid flows back to the surface, a process commonly referred to as “flowback,” the sand and other proppants pumped into the formation are left behind to prop open the new and enlarged cracks. As flowback continues, the composition of the fluid carries higher and higher proportions of hydrocarbons. Within the first few weeks of flowback, some or most of the fracturing fluid returns to the surface as wastewater (GORDON, 2012; REIG *et al.*, 2014).

b) Oil sands

Oil sands are a combination of quartz sand, clay, water, trace minerals, and a small (10–18%) share of bitumen found primarily in the northern part of the Canadian province of Alberta. Their sulfur content can be in excess of 7% (OIL SANDS TODAY, 2015). Bitumen is a complex hydrocarbon mixture that generally does not flow, which makes it’s extraction processes more challenging, but can be synthetically processed into oil (YERGIN, 2011).

There are two ways to extract bitumen: mining and in situ production. Open pit mining is used when the reserves are less than 70 meters below the surface. Open-pit mining is similar to many coal-mining operations. Large shovels scoop the oil sands into trucks, which take them to crushers where the large clumps of clay are broken down. The oil sands are then mixed with water and transported by pipeline to a plant where the bitumen is separated from the other components. Tailings ponds are an operating facility common to all types of such surface mining (OIL SANDS TODAY, 2015).

For bitumen in deeper locations, an extraction process that is similar to conventional methods is employed. In situ drilling accounts for 80% of oil sands reserves (OIL SANDS TODAY, 2015). The majority of in situ operations use steam-assisted gravity drainage (SAGD). This method involves pumping steam underground through a horizontal well to liquefy the bitumen, which is then pumped to the surface through a second recovery well (YERGIN, 2011).

Oil sands cannot be transported to market by pipeline without adding diluting agents such as gas-processing condensates, including the diluent pentanes plus, in order to meet pipeline density and viscosity limitations. In Alberta, a large portion of bitumen production is currently upgraded to synthetic crude oil and other products before shipment to refineries (GORDON, 2012).

c) Deepwater

The process of deepwater and ultra-deepwater O&G extraction is not much different to the one described previously for conventional resources, except that the connection between the drilling vessel and the equipment on the sea floor is greatly lengthened, thereby increasing exposure to ocean currents and weather storms. Further, higher volumes of mud and drilling fluid are required and the maintenance of sea floor equipment (such as a blowout preventer) is more challenging due to low temperatures and high pressures at the ocean's bottom (NATIONAL COMMISSION ON THE BP DEEPWATER HORIZON OIL SPILL AND OFFSHORE DRILLING, 2011).

According to the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011), under such conditions, methane hydrates form into ice because of the low temperatures. In addition, the high pressure that can often be found at the sea floor can destabilize the drilling foundation and cause well-control problems. Further, beneath the salt, pressures in the pores of the sediment are exceedingly hard to predict. Reservoirs in the lower tertiary are also thicker and have higher viscosity than the fluids found in younger rock. Finally, ultra-deepwater developments are far removed from shore and are thus a considerable distance from the established infrastructure.

Such unconventional sources add considerable complexity and change the environmental risk profile of the industry. They contribute to the exacerbation of the existing material environmental challenges that the industry already faces such as climate change, accidents, access to sensitive regions, water consumption, and pollution.

2.3 Environmental risks and impacts

The broad environmental issues faced by the O&G E&P industry are manifested at local and global levels. In response, the O&G industry pioneered the organization of its environmental performance as a sector, forming the International Petroleum Industry Environmental Conservation Association (IPIECA) in 1974, a global oil and gas industry association for environmental and social issues, shortly after the first UN Environmental Convention (IPIECA, 2015).

In order to discuss the risks listed in Table 2.1, we have grouped them into seven issues, which are presented in Table 2.2. It is worth noting that there is a significant interrelationship among the issues. Accidents and leaks, for example, can affect sensitive areas (also known as biodiversity), water, and land contamination.

Table 2.2 Risks grouped into issues

Issues	**Risks**
Sensitive Areas/Access	- Biodiversity/habitat depletion, fragmentation, and degradation

	- Erosion - Noise - Access/opening up of previously inaccessible land to secondary development - Local air pollution - Water contamination - Soil contamination - Accidents and Leaks
Climate Change	- Climate change - Energy demand
Water	- Freshwater withdrawal - Water and soil contamination
Waste	- Water and soil contamination
Accidents and Leaks	- Water and soil contamination - Air pollution - Biodiversity/habitat depletion, fragmentation, and degradation
Air pollution	- Local air pollution - Accidents and Leaks
Noise	- Noise - Biodiversity and disturbance to organisms

Developed by the author.

2.3.1. Sensitive areas/Access

On and offshore exploration, drilling, and extraction activities are inherently invasive and affect ecosystems. Major impacts include deforestation, ecosystem destruction, the chemical contamination of land and water, and long-term harm to animal populations (particularly migratory birds and marine mammals) (O'ROURKE and CONNOLLY, 2003). As Epstein and Selber (2002) affirm, "Operational discharges of water, drill cuttings and mud have chronic effects on benthic (bottom-dwelling) marine communities, mammals, birds and humans."

In addition, unconventional processes require a significant amount of water, as will be discussed in section 2.3.3. The impacts on biodiversity have implications for entire ecosystems, since "overdrawn surface water sources can harm invertebrates and fish that feed migrating fowl" (EPSTEIN and SELBER, 2002).

In previously inaccessible areas, such as the Amazon or the Arctic, road building causes deforestation and secondary development, which in turn contributes to the loss of territory and displacement of native groups (UNEP, 1997; O`ROURKE and CONNOLLY, 2003; CASPER, 2009; SASB, 2014). The opening of access roads also allows settlers with competing interests such as logging and mining to enter communities, further contributing to the fragmentation of habitats (EPSTEIN and SELBER, 2002).

In ecologically sensitive areas, such as the Arctic and shorelines with mangroves and swamps, E&P activities can be even more damaging to biodiversity and ecosystems (CASPER, 2009; FREUDENBURG AND GRAMLING, 2010; SASB 2014). Further, as O&G companies attempt to access remote and ecologically sensitive locations, such as deepwater resources, and develop unconventional resources, such as oil sands that require larger land areas and generate more waste, the risk that E&P operations will affect biodiversity could be aggravated (EPSTEIN and SELBER, 2002).

Further, the decommissioning of onshore and offshore oil and gas wells can have negative environmental and social impacts if not properly managed. Such impacts include the change of land use, soil and groundwater contamination, and erosion (RODRIGUES, 2008).

2.3.2 Climate change

There are several sources of air emissions in the production process such as flaring, leaking and venting, combustion for power and heat generation, and the use of compressors, pumps, reciprocating engines, supply vessels, and helicopters.

Emissions from these sources include carbon dioxide, volatile organic compounds (VOCs), nitrogen oxides, sulfur oxides, ozone, carbon monoxide, particulates, methane, ethane, benzene, ethyl benzene, toluene, xylenes (BTEX), glycols, and polycyclic aromatic hydrocarbons (EPA, 2000; IFC, 2007a; IFC,2007b).

Associated gas brought to the surface with crude oil during oil production is sometimes disposed of at offshore facilities by venting or flaring into the atmosphere, if no pipeline is available to brig it to market (DOWNEY, 2009). This practice is now widely recognized as a waste of a valuable resource and a significant source of greenhouse gas (GHG) emissions. However, flaring or venting is also an important safety measure used on offshore oil and gas facilities to ensure that gas and other hydrocarbons are safely disposed of in the event of an emergency, power or equipment failure, or other plant upset. (DOWNEY, 2009).

Burnham *et al.* (2011) demonstrate that less than 20% of the emissions from gasoline produced from conventional sources are from the production cycle, which includes refining. However, the figure changes when oil sands are introduced, increasing from an average of 20 kg CO_2e/MJ for gasoline from crude oil to 45 kg CO_2e/MJ for gasoline from oil sands (BURNHAM *et al.,*2011). According to ETSAP (2010) emissions ranges for oil sands and heavy oil vary 28 to 46 gCO2/MJ and from 44 to 69 gCO2/MJ for oil shale, while traditional crude 22 to 25 gCO2/MJ. These data include emissions from production and combustion. Mui *et al.* (2010) compare the different estimates from both the technical and scientific literature that use different data sources, methods, lifecycle boundaries, and assumptions. They found that lifecycle GHG emissions for oil sands from mining are 8-37% greater than traditional crude oil, from in-situ mining this number increases from 23 to 73%.

Canadian and Venezuelan bitumen has higher CO_2 emissions per unit of energy produced than conventional oil and gas because it requires more energy in order to be extracted and upgraded (ETSAP, 2010). In a letter presenting its findings with regard to a permit application by the TransCanada Keystone Pipeline[9] project, the U.S. Environmental Protection Agency (EPA) stated that "the lifecycle GHG emissions from oil sands crude could be 81% greater than emissions from the average crude refined in the U.S. in 2005" (GILES, 2013). This pipeline project has suffered significant delay due to opposition from environmental groups, and was classified as an atrocity by former U.S. Vice-President Al Gore because of its climate change implications (GOLDENBERG, 2013a). Indications are that President Obama is likely to veto the project (SHEAR and DAVENPORT, 2015).

Further, Méjean and Hope (2013) estimate the social cost of all CO_2 emissions from the Canadian oil sands industry, including emissions from land-use change, and conclude that the social cost of CO_2 has a large impact on the total costs of synthetic crude oil. In particular, because of the carbon intensity of recovery techniques, the social cost of CO_2 will add more than half to the cost of producing synthetic crude oil from mined bitumen by 2050 (mean value), while the social cost of producing synthetic crude oil from in situ bitumen will more than double (MÉJEAN and HOPE, 2013).

When defending the exploitation of shale gas, a lower carbon emission is often an argument that is used. Mackay and Stone (2013) in a report to the UK government assert that "the carbon footprint (emissions intensity) of shale gas extraction and use is likely to be in the range 200 – 253 g CO2e per kWh of chemical energy, which makes shale gas's overall carbon footprint comparable to gas extracted from

[9] The US$7 billion, 1,700-mile proposed Keystone XL pipeline would carry crude oil from Alberta across the border with Canada to Montana and traverse five other states before reaching refineries on the Texas Gulf Coast.

conventional sources (199 – 207 g CO2e/kWh(th)), and lower than the carbon footprint of Liquefied Natural Gas (233 - 270g CO2e/kWh(th)).” However, Ingraffea (2012), points that the leakage of methane from shale gas could be least 30% more than, and perhaps more than twice as great as, those from conventional gas. Since methane has a global warming potential that is far greater than that of carbon dioxide, the footprint for shale gas is greater than that for conventional gas or oil and for coal used for electricity generation (INGRAFFEA, 2012). To the Canadian government, Ingraffea (2012) affirms, “the large GHG footprint of shale gas undercuts the logic of its use as a bridging fuel over coming decades, if the goal is to reduce global warming. This does not justify the continued use of either oil or coal, but rather demonstrates that substituting shale gas for these other fossil fuels may not have the desired effect of mitigating climate warming.”

2.3.3 Water

2.3.3.1 Water contamination

When crude oil is first brought to the surface, it can contain a mixture of natural gas, produced fluids such as salt water, and both dissolved and suspended solids. Water (which can be more than 90% of the fluid extracted in older wells) is then separated out. Such “produced water” is the main effluent of the E&P industry (EPA, 2000). It can be produced naturally, when present in the reservoir, or injected, either as a means to increase extraction capacity or as condensed water in the case of natural gas production.

Produced water occurs in conventional as well as unconventional fields, such as shale and bitumen (WANDERA *et al.,* 2011). According to Ingraffea (2012), shale gas wells are fractured with 50 to 100 times the volume of fluid used conventional gas production. After extraction and separation, the produced water is treated and discarded, in offshore production it goes most of the time to the sea (BAKKE *et al.,* 2013). In onshore production, more than 98% of this produced water is injected underground, with approximately 58% injected into producing formations to enhance production and about 40% into non-producing formations for disposal (CLARK and VEIL, 2009).

The total volume of produced water in 2007 in the United States was estimated to be 21 billion barrels, or 2.4 billion gallons per day (CLARK and VEIL, 2009). The ratio of produced water to hydrocarbons is estimated as 1.5-3:1; in addition, its volume increases with reservoir age (DOE, 2013). It is also the case that water-soluble components and impurities are difficult to remove from produced water and include harmful substances such as benzene, lead, arsenic, and uranium (UNEP, 19947; IFC, 2007a; DOE, 2013).

Oil sands extraction processes generate tailings as a waste by-product that is generally composed of water, sand, silt, clay, and residual bitumen. Only a small part of these effluents is reutilized by the industry; the majority goes into tailings ponds (BARTON, 2010). Tailings ponds are artificial effluent storage facilities common in mining operations; however, they are generally toxic and corrosive. There are numerous documented cases of toxic fluid leakage from tailings ponds into rivers such as the Athabasca or into groundwater. In addition, to date, no tailings ponds have been fully reclaimed (BARTON, 2010). There are also cases where migratory birds have mistakenly landed in tailings ponds and died (NATIONAL POST, 2008 *apud* MALAGUETA, 2009).

In the case of shale gas, despite the separation between reservoirs, which are several thousand feet below ground, and drinking water supplies, which are close to the surface, human error leaves open the possibility of contamination occurring.

Indeed, contamination has occurred primarily through methane migration, poor wastewater management, and chemical spills (WILLIAMS, 2012). Further, some fracturing occurs close to the surface and near aquifers, elevating the risks. However, the impact on groundwater quality is often hard to measure because of the lack of baseline data before the beginning of fracturing operations.

Other effluents present in the E&P of O&G listed by the International Finance Corporation (IFC, 2007a, b) are:

- Cooling water – may contain antifoulant chemicals to prevent marine fouling of offshore facilities.
- Desalinization effluents – high salt concentration.
- Domestic waste – high organic concentration.
- Drainage water – may contain oil and other chemicals.
- Hydrostatic test water – high pressure water used to verify the integrity of equipment and pipelines: may contain chemicals (corrosion inhibitors, oxygen scavengers, and dyes).
- On-site impoundments and tanks. Accidental spills and mismanagement can cause releases to the environment that can contaminate nearby waters and soils. Open impoundments, also called pits, are typically subject to requirements designed to minimize the risk of contamination.

2.3.3.2. Water consumption

Water is growing in importance as a criterion for assessing the physical, economic, and environmental feasibility of energy projects (FREYMAN and SALMON, 2013; REIG *et al.,* 2014). In this regard, it must also be borne in mind that increasing global temperatures and shifting precipitation patterns are causing regional and seasonal changes to the water cycle (NOAA, 2013).

In the conventional O&G E&P industry, the largest amount of water is used as a supplemental fluid in the enhanced recovery of petroleum resources (IFC, 2007a; DOE, 2013). Water is required to a lesser extent for other activities, including the drilling and completion of oil or gas wells, the workover of an oil or gas well, and the creation of underground hydrocarbon storage caverns through solution mining of salt formations. Water is also needed as gas plant cooling and boiler water; as hydrostatic test water for pipelines and tanks; as rig wash water; and as a coolant for internal combustion engines for rigs, compressors, and other equipment (DOE, 2013).

Water use in unconventional sources such as shale and oil sands is significantly higher than in traditional oil E&P methods. Hydraulic fracturing at a single oil or gas well involves the initial injection of "between 0.2 million and 2.5 million liters of water, and hydraulic fracturing a well [in its lifetime] can require between 7 million and 23 million liters of water" (REIG *et al.,* 2014). The wide range of amounts for consumptive water indicates the high levels of uncertainty about the possible impacts of hydraulic fracturing on freshwater availability. At present, 30-70% of the water remains within the natural fractures of the rock (DOE, 2009).

Despite current recycling efforts, oil sands extraction can consume up to three times as much freshwater as conventional oil production. The water intensity using the mining technique is 2.41 per bare los oil produced, whereas in *in-situ* production the freshwater consumption falls to 0.45 due to recycling. In 2011 in Canada, oil sands operators used approximately 170 million cubic meters (1.1 billion barrels) of water, equivalent to the residential water use of 1.7 million. (GRANT *et al.,* 2013)

2.3.4 Waste

The oil and gas industry in the United States alone creates more solid and liquid waste than all other categories of municipal, agricultural, mining, and industrial wastes combined. In particular, oil and gas drilling and pumping produce most of the sector's waste. Further, approximately 20% of non-hazardous waste produced in the United States every year comes from oil and gas exploration and production. (O'ROURKE and CONNOLLY, 2003)

Drilled cuttings removed from the wellbore and spent drilling fluids are typically the largest waste streams generated during oil and gas drilling activities (IFC, 2007a and b). In 1995, the U.S. E&P sector produced an estimated 149 million barrels of drilling waste and 20.6 million barrels of other associated wastes. (API, 2000). Although associated wastes constitute a relatively small proportion of total wastes, they are most likely to contain a range of chemicals and naturally occurring materials that are of concern to health and safety. As described previously in this chapter, during drilling various fluids and cements are used to cool the drill bit and stabilize the well. These fluids and additives accumulate in large quantities during the drilling process.

According to the International Association of Oil and Gas Producers (IOGP, 2013), other E&P wastes include: office material, discarded containers, used batteries, chemical residues, chemical product recipients, used oil filters, fluorescent tubes, and sanitary wastes.

2.3.5 Accidents and leaks

Spills are an important environmental performance indicator for the oil and gas industry because they can have a significant and visible impact on the environment (IOGP, 2013). Accidental releases at oil and gas production facilities can come in three forms: spills, leaks and blowouts. The degree of environmental impact is highly dependent on the nature of the release, where it occurs, and how it is subsequently managed. The IOGP (2013) define a spill as any loss of containment that reaches the environment (i.e., it is not retained within secondary or other containment), irrespective of the quantity recovered.

The majority of spills reported by the IOGP (2013) are oil spills, which include spills of crude, condensate, and processed oils. Such spills can have a number of causes such as equipment failure and leaking tanks. In addition, they can occur during transfers or from leaking flowlines, valves, and joints. Operating errors and unlawful third party damage such as sabotage and theft are also responsible for spills (EPA, 2000; IOGP, 2013).

Well blowouts are rare but can be quite serious, as seen in the Macondo incident in 2010. A Minerals Management Service study identifies cementing problems as one of the “most significant factors” that led to blowouts between 1992 and 2006 (NATIONAL COMMISSION ON THE BP DEEPWATER HORIZON OIL SPILL AND OFFSHORE DRILLING, 2011). When the drill encounters an unusually pressurized zone, or when equipment is being removed from the hole, the pressure exerted by the formation can become considerably higher than that exerted by the drilling or workover fluid. When this happens, the formation fluid and drilling or workover fluid can rise uncontrollably through the well to the surface. If there is a significant quantity of associated natural gas, the fluid can even ignite from an engine spark or other source of flame. Such blowouts have been known to completely destroy rigs and kill nearby workers, and although some can be controlled in a matter of days, others, particularly those offshore, can take months to cap and control. Drilled wells and many workover wells are equipped with a blowout preventer (DOWNEY, 2009).

When designed and used properly, drilling mud, cement, and casing work together to enable the drilling crew to control wellbore pressure. If any of these three elements fail, the crew can, in an emergency, close powerful blowout-preventer valves that should seal off the well at the wellhead. (FREUDENBURG and GRAMLING, 2010)

These blowout preventers (BOPs) are hydraulically operated and serve to close off the drill pipe. BOPs can be used manually or can be automatically triggered. Most rigs have regular blowout drills and training sessions so that workers can operate the BOPs and escape as safely as possible. With onshore spills, there is also a concern about surface runoff to streams and seepage into groundwater. (DOWNEY, 2009 and EPA, 2000)

Although the E&P of tar sands has not registered a meaningful explosions and spills, the National Resources Defense Council (SWIFT *et al*., 2011) claims that transportation of diluted bitumen (dilbit) is a significant threat given that the Alberta pipeline system has had approximately 16 times as many spills due to internal corrosion as the U.S. system. The environmental defense group claim the situation has occurred because oil sands crude pipeline companies are using conventional technology to transport dilbit. However, dilbit requires higher operating temperatures and pressures in order to move through pipeline systems and is also significantly more corrosive to such systems than conventional crude. (SWIFT *et al.,* 2011)

In regard to shale exploration and production, fracturing fluid spills and wastewater spills have occurred and pose a threat of contamination (HAMMER and VANBRIESEN, 2012).

2.3.6 Air pollution

As seen in Table 2.1, E&P operations also emit hazardous air pollutants (HAPs), criteria air pollutants (CAPs), and VOCs, all of which have localized human health and environmental impacts.

Sources of emissions from E&P operations include exhaust from diesel engines and turbines that power drilling equipment, the use of machinery, flaring (which emits nitrogen oxides, carbon monoxide, and particulate matter), and leaking tubing, valves, and open pits (VOCs) (EPA, 2000). In particular, midstream infrastructure bottlenecks, and the rapid increase in natural gas production in the past few years in the U.S., have resulted in significant flaring of excess gas. Prior EPA (2012) investigations have discovered flares that were operated so poorly that there was probably no combustion taking place at all. As a result, the flares were venting pollution directly to the atmosphere.

The National Emissions Inventory in the United States shows that in 2008, oil and gas production processes released over 1.5 million pounds of benzene, which is equivalent to 49% of all benzene emissions from industrial processes in that year (EPA, 2012). A 1997 EPA database also shows that oil and gas extraction accounted for the second-highest sulfur dioxide emissions of all the industries included in the database (29 in total), the fifth-highest VOC emissions, and the third-highest nitrogen dioxide emissions (EPA, 2012).

2.3.7 Noise

Oil and gas development activities that contribute to the noise levels in the oceans include seismic operations, drilling and production activities, offshore and near shore structural installation and construction activities, and marine traffic. There is evidence to show that low frequency noise has increased at a rate of approximately 3 dB per decade from 1950 to 1998 (WYATT, 2008). Such noise is thought to be primarily due to the increase in propeller-driven vessels because of the growing world economy. It has been suggested, however, that a significant proportion of this noise is due to the activities of the oil and gas industries, which account for nearly 50% of the gross tonnage of vessels although this is only 19% of the total number of vessels in the world's commercial fleet (WYATT, 2008). However, a particular concern is the impacts of seismic activities on marine mammals.

Gordon *et al*. (2003) and Wyatt (2008) conducted a literature review on the effects of seismic surveys on marine mammals and suggest that there is still a significant gap in our knowledge of the effects of seismic air gun noise. The potential effects of air gun noise in marine mammals include physical/physiological effects (such as hearing threshold shifts and auditory damage) and behavioral disruption, for instance, recent observations suggest that exposure to loud noise can result in decompression sickness. Where feeding, orientation, hazard avoidance, migration, or social behavior are altered, it is possible that populations could be adversely affected. There may also be serious long-term consequences due to chronic exposure, and sound could affect marine mammals indirectly by changing the accessibility of their prey species. Gordon *et al*. (2003) claim that "direct information on the extent to which seismic pulses could damage hearing are difficult to obtain; as a consequence, the impacts on hearing remain poorly known."

2.4 Corporate strategy and the management of environmental issues

The bulk of the corporate social responsibility (CSR) oil sector literature focuses on company's strategies and behavior using case studies. Scholars generally agree that O&G companies' CSR strategies have not been effective in developing nations (LE BILLION, 2001; APKAN, 2006; NWOKEJI, 2007; DIONGUE *et al.,* 2011;

RENOUARD and LADO, 2012). The case of Shell in Nigeria is considered emblematic because of the longevity of the operation, the level of corruption and poverty in this oil wealthy country, and, moreover, because Shell, the main operator, is considered a "world leader" in CSR (AKPAN, 2006; RENOUARD and LADO, 2012).

Skjærseth *et al*. (2004) examine the extent to which Exxon, BP, Shell, and Total accept the "Paradox of Plenty" in terms of policy and actions at macro/corporate and micro/facility levels. Although they find that "all companies claim that their operations benefit the countries in which they operate," none accept responsibility for the "Paradox of Plenty." At a corporate level, however, Shell and BP are found to be more transparent and engaged in CSR, and through specific case studies, the authors also find that these companies' actions are consistent with their words. The same four companies selected by Skjærseth *et al*. (2004); Exxon, BP, Shell, and Total; are studied in Dahlsrud (2005), who comes to a distinct conclusion. Dahlsrud (2005) focuses on the explicit strategies and tools that these O&G companies, the world's largest, choose in order to deal with the social, environmental, and economic issues that constitute CSR from their perspectives. The work finds a high degree of collaboration and information sharing among the companies, amounting to institutional isomorphism. The author points to the need for further research to clarify whether CSR is used for competitive purposes and how the implementation of similar strategies yields different performances.

Pegg (2011) examines the isomorphism theory further with regard to CSR, claiming that Chinese companies are not "significantly different in their actions from the Western oil majors." Unlike Skjærseth *et al*. (2004), who find a coherence between rhetoric and actions, Pegg (2011) claims that "Western oil company rhetoric on the significance of CSR commitments often greatly exceeds the empirical reality found on the ground" and that there are "distinct and narrow limits to the kinds of CSR actions these firms are willing to undertake." Two examples cited by the author are the industry's rejection of environmentally sensitive "no-go zones" proposed by the World Bank and the IOGP statement about "placing the onus of disclosure on host countries" rather than on companies as proposed by the Extractive Industry Transparency Initiative (EITI).

Slack (2011) highlights that although there is no standard definition of CSR in the sector, industry associations such as IPIECA have been active in defining elements and best practices. However, the author is quick to point out that these initiatives have had little impact on communities affected by O&G operations. In fact, Slack (2011) points to a general non-compliance with legal requirements in developing nations, which is independent of any CSR policy.

Within CSR in the petroleum sector, another line of work that has deservedly attracted scholarly attention is the corporate reaction to climate change (LEVY and KOLK, 2002; VAN DEN HOVE *et al*., 2002; MANSLEY, 2003; LOGAN and GROSSMAN, 2006; KOLK *et al*., 2008; BOASSON, 2009). Levy and Kolk (2002) study the roots of the differences in strategies toward climate change in American and European companies, namely Exxon, Shell, BP, and Texaco, the latter having merged with Chevron. They find that although the country of origin has an initial influence, the companies are slowly merging strategies. However, Mansley (2003), and later Logan and Grossman (2006), disagree. For these authors, the Exxon strategy is highly detrimental to climate change, places investors at reputational risk, and is very different from leaders such as BP and Shell. Like the other scholars, van den Hove *et al*. (2002) see three basic strategies: proactive, wait, and reactive, represented by BP, Total, and Exxon respectively. However, they make clear that climate change is a threat to the oil business and those companies that have a proactive attitude find themselves in an ethical dilemma.

If the institutional isomorphism theory holds true behavior of Oil and Gas companies in relation to environmental issues, than differentiating companies by their policies and management standards may be challenging. Therefore, finding the relationship between the environmental issues and reserves may be an interesting way to evaluate companies and predict future performance.

3. Sustainable Investing and Reporting

The roots of socially responsible investors (SRI), also called ethical or sustainable investing, are religious, dating back many centuries (STATMAN, 2010, RENNEBOOG *et al.,* 2008). This movement, however, gained momentum over the past decade as evidenced by membership of one thousand institutions, representing around US $ 45 trillion in assets, to the Principles Responsible Investment of the United Nations (UNPRI, 2015). The concept of socially responsible investment is growing in popularity, and, thus, gaining an increasing interest from academia in recent decades (VAN DEN BRINK and VAN DER WOERD, 2004; ZORRAQUIN and SCHMIDHEINY 1996, O´ROURKE, 2002; FOWLER and HOPE, 2007; ZIEGLER and SCHRÖDER, 2010).

A general definition for the SRI movement is "any type of investment process that combines investors' financial objectives with their concerns about Environmental, Social and Governance (ESG) issues" (EUROSIF, 2014). The different strategies available consist mainly of ethical exclusions[10], best-in-class[11], thematic funds[12], norm based screening[13], engagement and integration[14] and impact investing[15], often in combination with one another (EUROSIF, 2014).

Pension funds, universities, as well as a large number of individuals who invest on ethical financial market instruments, seek to identify the stocks they want to own or avoid through labels or ratings (CHATTERJI *et al*., 2009; CHATTERJI and LEVINE, 2007). Specialized agencies issue labels and indexes based on a "best in class"

[10] An approach that excludes specific investments or classes of investment from the investible universe such as companies, sectors or countries. (EUROSIF, 2014)
[11] Approach where leading or best-performing investments within a universe, category or class are selected or weighted based on ESG criteria. (EUROSIF, 2014)
[12] Investment in themes or assets linked to the development of sustainability. Thematic funds focus on specific or multiple issues related to ESG. (EUROSIF, 2014)
[13] Screening of investments according to their compliance with international standards and norms. (EUROSIF, 2014)
[14] Engagement activities and active ownership through voting of shares and engagement with matters companies on ESG matters. This is a long-term process, seeking to influence behaviour or increase disclosure. (EUROSIF, 2014)
[15] Eurosif (2014) defines impact investments as: investments made into companies, organizations and funds with the intention to generate social and environmental impact alongside a financial return.

approach, such as SAM, KLD, Oekom, Management & Excellence, Vigeo, Avenzi (BOTELHO and MAGRINI, 2011; VIGEO, 2011; OEKOM, 2011; MANAGEMENT & EXCELLENCE, 2011, MCSI, 2011). Best-in-class, considered a more advanced SRI strategy, applies a number of different criteria to select the best companies from each industrial sector based. Thus, the inclusion of a stock in such indexes is regarded as an indicator of excellent corporate sustainability performance (ZIEGLER and SCHRÖDER, 2010).

Hoepner (2007) presents a subjective categorization of the responsible investment (RI) literature in the following eight main groups. The first cluster, “Basic Literature”, includes introduction and definition of RI, and sixty-eight studies were found. The “Analysis of RI Over Time” composes of twenty-eight articles in three subcategories: history, trends and future outlook. Hoepner (2007) encountered thirty-three papers on “Ethical Reflections” and twenty-four on “Social and Environmental Performance of RI”. “Screening” comprised thirty-three articles reflecting on theory, practices, criteria and performance. Impact of RI had thirty-eight papers distributed among the following subcategories: theoretical modeling approaches [11], empirical (historical) analysis [7], and discussions of the impact of RI [20]. However, the largest amount of studies was found for “Financial Performance” with one-hundred and sixty-six papers (Hoepner, 2007).

Although there is a large amount of literature seeking to establish a link between social and environmental performance with financial returns, there is still uncertainty about the significance of this relationship (Margolis et al., 2007). Critics of the SRI movement suggest that SRI funds have been “very sloppy and often flat out wrong in identifying ‘doing good’” (JON ENTINE, 2006 apud CHATTERJI *et al*., 2009).

Next is a discussion on how investors evaluate the environmental sustainability of the O&G industry to determine if they are 'doing good' and the potential return implications, followed by the how corporations report sustainability information to the market.

3.1 Relevance of the Oil &Gas Sector to Investors

At the end of 2013, proven global oil reserves were 1,668.9 billion barrels, sufficient to meet 52.9 years of global production (BP, 2014)[16]. Members of the Organization of Petroleum Exporting Countries (OPEC) continue to dominate the industry, holding 72.6% of the global reserves (BP, 2014). Listed O&G companies are among those with the highest market value: nearly 1,500 listed oil and gas companies have an asset pool of US$4.6 trillion (Bullard, 2014). In 2013, global production of O&G was 90 million barrels per day (bbl/day) of crude oil (including conventional and unconventional oil) and 140 billion cubic meters of natural gas (EIA, 2014).

The largest companies are state-owned, such as Saudi Aramco and Petronas, and are not listed in the markets (Forbes, 2014). It is estimated that national oil companies (NOCs) control 73% of world oil reserves, 61% of world oil production, 68% of world gas reserves, and 52% of world gas production (Victor et al., 2011). However, even these companies rely on investors and markets because they have issued hundreds of billions of dollars of debt (BULLARD, 2014).

E&P is a capital-intensive industry, characterized by high-risk, high-return activities (CARNEY AND GEDAJLOVIC, 2001) with few exploration efforts leading to the discovery of commercially viable oil or gas fields. Between 2007 and 2011, capital expenditures for the 50 largest U.S. E&P companies (including integrated

[16] Proved reserves of oil as defined by BP (2014): Generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.

companies) were in the range of US$70 billion to US$150 billion (CTI, 2014). Expensed exploration and depreciation form a significant proportion of these total costs; in fact, depreciation can be as high as 50% of all costs (Carbon Tracker, 2014). In addition, enhanced recovery and unconventional resources require higher production costs per barrel; for instance, costs for horizontal drilling are about 24% higher than those for conventional drilling (SASB, 2013).

According to Bullard (2014), O&G companies are historically high-yield companies compared to other equities, with the top 100 companies in each sector delivering average dividend yields of more than 2%. They have been desired by pension funds and institutional investors who seek to benefit from the increase in share value (SHAPIRO AND PHAM, 2011). This reflects the fact that fossil fuel companies tend to distribute a high proportion of post-tax profits, and that their profitability is protected against competition by their ownership of mineral extraction rights. Thus, O&G stocks have outperformed other major sectors over the past five years (BULLARD, 2014). Further, institutional investors value the cash flow in the form of dividends, and the growth from increasing stock prices.

However, 2014 ended with plummeting oil prices along with a strengthened carbon divestment campaign by several investment groups (BULLARD, 2014; IMPAX, 2014; MCCRONE and BULLARD, 2014; THE ECONOMIST, 2014). Carbon Tracker and the Grantham Research Institute (2013) Institute claim that current valuations are based on the full exploitation of proven reserves not including longer-term climate policy, technology and impact risks. This study found that smaller companies with high exposure to oil sands are not resilient to the price stress in a carbons restricted scenario. In their analysis:

> *If listed fossil fuel companies have a pro-rata allocation of the global carbon budget, this would amount to around 125 - 275GtCO_2, or 20 - 40% of the*

*762GtCO_2 currently booked as reserves. The scale of this carbon budget deficit poses a major risk for investors. They need to understand that 60 - 80% of coal, oil and gas reserves of listed firms are unburnable. For these scenarios even with full investment in CCS, it extends the carbon budget for the 2^{o}C by only 12-14%. (*Carbon Tracker Initiative with the Grantham Research Institute, 2013)

Spedding et al. (2013) from HSBC, used a ceiling price on future projects to assess the potential value of O&G sector at risk, and found that the value of reserves at risk varies from 1% to 17%. "Although not directly related to unburnable carbon, a greater risk to the sector would be if lower demand led to lower oil and gas prices. In that case, the potential value at risk could rise to 40-60% of market cap*"* (SPEDDING *et al.*, 2013).

Carbon Tracker (2014) further analyzed the cost curves for exploration and production projects concluding that US$ 1.1 trillion in capex is being allocated at high cost projects; such as ultra-deepwater, Arctic and oil Sands; which need oil prices above US $95 a barrel. The study points out the listed companies have more exposure than National Oil Companies, and investors should understand these cost curves when selecting O&G stocks. Given the current drop in oil prices, many of these projects would not be feasible.

Impax (2014) performed analysis substituting fossil stocks with renewable and energy efficiency companies and concluded that investors should consider reorienting their portfolios towards low carbon energy, thereby retaining exposure to the energy sector while reducing the risks posed by the fossil fuel sector. Conversely, McCrone and Bullard (2014) advise that even if investor pull money out of these companies, there are few if any alternative sectors that offer the same combination of scale and yield. For instance, the total free float of the 106 companies that make up the WilderHill New Energy Global Innovation Index an entire order of magnitude too small to absorb money on the scale of the $4.9 trillion valuation of the quoted oil and gas sector (MCCRONE and BULLARD, 2014).

McCrone and Bullard (2014) argue that the rate stock substitution should be determined by the speed of the transition to a cleaner energy system. In the authors view, the bearish thesis the world can burn only a small part of the known deposits of fossil fuel will not hold true as abruptly as needed to avoid a temperature increase of more than two degrees centigrade, as recommended by the IPCC. The authors defend that gas will be a short-term winner and coal may be a looser, however, the fate of oil is still undetermined.

3.2 Sustainability and Financial Performance of the O&G Industry

The business case for sustainable investing relies on proving that good social-environmental performance can translate into financial results. Thus, it is no surprise that there is a significant volume of literature seeking to establish the effects of sustainability on returns for investors and the cost of capital (see WADDOCK, 2003 and HOEPNER, 2007 for a review). There are a few studies, nonetheless, that focus on finding this relationship within the O&G industry, with inconclusive findings as reported in this section.

For some critics, given that oil is not a sustainable energy source and the risks inherent in their exploration, production and consumption are high, these companies should not be part of social responsibility funds (SVERJENSKY, 2010). In fact, oil companies are consistently named among the least trusted corporations, and survey findings suggest that the oil industry ranks foremost in the public mind as needing more regulation (CORSO, 2009 *apud* SPANGLER AND POMPPER, 2011; HARRIS INTERACTIVE, 2013). Cai et al. (2011) asks, "Can a firm in controversial industries be socially responsible while producing products harmful to human being, society or environment?" Many in the sustainability field see SRI to have the potential to shift corporate behavior towards more sustainable patterns of production and consumption (O´ROURKE, 2003). According to the World Bank Extractive Industries Review, "extractive industries can contribute to sustainable development, when projects are implemented well and preserve the rights of affected people, and if the benefits they generate are well used."

The arguments presented by Spedding et al. (2013), Carbon Tracker (2014) and Bullard (2014) are all based on reserve profile and not on traditional environmental performance indicators. Schaeffer et al. (2012), Lee et al. (2011) and Cai (2011) test how sustainability performance; using as proxy the Dow Jones Sustainability Index (DJSI), Pacific Sustainability Index (PSI), and Kinder, Lydenberg and Domini (KLD) rating respectively; can have a positive impact on oil company's market value. Schaeffer et al. (2012) found that only two company's betas[17] decreased as a result of entering the DJSI, but these had no effect on market value. On the other hand, Lee et al (2011) concluded that PSI and research and development intensity are major determinants of business performance in the O&G industry across countries. Firm value proved to be positively associated to both CSR in Cai et al. (2011). Schaeffer et al. (2012), Lee et al. (2011) and Cai et al. (2011) used indexes/ratings that apply backward looking metrics to evaluate sustainable performance. The PSI developed by the Roberts Environmental Center of Claremont McKenna College is a combination of five methodologies, one of them being GRI 2000 guidelines (discussed in section 2.3), to create a scoring system, which yields a single score per

[17] Beta is an expression of how volatile an investment is compared to the overall market. (Russel, 2014)

company based on information available in corporate disclosures (MORHARDT, 2009). DJSI and KLD, on the other hand, use questionnaire in addition to the corporate reports and media investigation to rate the companies by applying a proprietary methodology (MCSI, 2015 and DJSI, 2015)[18]. Some of its indicators are aligned with CDP and GRI (Ecometrica, 2013). The predictability of these indexes and ratings has been examined by several authors, as discussed in the following section.

3.3 Sustainability Ratings

The ratings are currently one of the signs considered most relevant about the environmental performance of companies to the general public, which does not track all activities of companies and have no access or expertise to analyze the relevant data (LYON AND MAXWELL, 2006 and SADOWSKI et al., 2010). Investors, in turn, have a limited ability to analyze information about social and environmental performance of companies, therefore, demand tools adapted to their needs (AVETISYAN, 2010). Thus, the indexes are a crucial link in communication between companies and investors, especially those who have concerns about the social responsibility of companies in which they are investing (GES INVESTMENT SERVICES, 2007). Just as credit ratings "enhance transparency and efficiency in debt capital markets by reducing information asymmetry between borrowers and lenders", social ratings aim to provide social investors accurate information that makes transparent the extent to which firms' behaviors are socially responsible (MC DANIEL, 2007 apud CHATTERJI *et al.*, 2009).

Investors and other stakeholders who rely on sustainability ratings to identify target companies might be misallocating resources, if these have not been able to identify

[18] Since 2010, the questionnaires applied to the DJSI are not available online to the general public.

the best performance on sustainability. When metrics used are invalid, none of the hypothesized benefits of SRI can occur (CHATTERJI and LEVINE, 2007). To bring some light to the issue, five recent studies have attempted to scrutinize the rating process and some have attempted to evaluate their effectiveness, which will be described below in order of publication.

Fowler and Hope (2007) performed a critical review of sustainability ratings, focusing on the Dow Jones Sustainability Rating (DJSI). The authors found that DJSI favors large companies. 48.3% of companies in the DJSI had market cap over US$50 billion, whereas the Dow Jones Global Index (DJGI), the pool used to extract firms that make up DJSI, large-cap composes 29.6% of the index. The impact analysis of Calvert Social Index, Domini 400 Social Index, DJSI and FTSE4good was considered low in terms of the extent to which fund managers have opted to license the indices. Furthermore, the total amount invested adding all the indices together was found to be below $8 billion, in a market of over $20 trillion in assets. (FOWLER and HOPE, 2007)

In the second study, Chatterji and Levine (2007) explore the theoretical perspectives explaining the convergence and predictive validity of Calvert, KLD, FTSE4Good, DJSI and Innovest sustainability investment ratings. The fundamental question behind the paper is whether commonly used indicators of social responsibility are valid measures of corporate sustainability performance, and thus, corroborating the benefits of SRI.

The authors attempt to answer the question with statistical tests to verify the convergence of the ratings, in terms of criteria and membership, and the predictive validity, using KLD members' involvement in scandals. The SRI raters were found to have overall low convergent validity even after adjusting for explicit differences in methods and goals. However, there were raters with higher convergence among them, for example KLD and Calvert as well as Innovest and DJSI. The results led to the inference that the current diversity in social ratings reflects inconsistent definitions of social responsibility coupled with measurement error. Because the convergence did not improve even after accounting for explicit difference across raters, the authors conclude that most of the divergence in scores is not due to purposeful differences in targeting specific niches or marketing strategies. Furthermore, they conclude that the results mean that "most SRI ratings are not measuring "true" social responsibility." Since they make no claim on what "true" might be, it cannot be determined which rating applies the best metrics. However, the differences among them may be due to geographic proximity of the ratings and the pool from which the companies were extracted from. For example, both Calvert and KLD analyze US based companies, whereas the DJSI and Innovest start from global indexes. (CHATTERJI and LEVINE, 2007)

The ability of social metrics to predict major scandals in the near future was measured by the involvement of companies in major scandals, such as fraud against investors, killing of nearby residents and destruction of ecosystems, within a window after being listed in the rating. KLD's Domini 400 data was selected because it was the longest set available, since it was important to verify if the member was in a scandal within the next 3 years. The results showed the social ratings have a low predictive validity, with 35% of scandals firms and 36% of control firms are in the Domini 400. Nonetheless, Chatterji and Levine (2007) note the results do not support the Jon Entine's (2003) assertion that firms with high social scores are more likely to have scandals. When sub-scores were evaluated, a slight predictive ability flourished, but more tests need to be performed separating specific scandals and sub-scores, for instance, if environment sub-scores can foresee environmental accidents.

Chatterji et al. (2009) further analyze KLD ratings. They argue that investors seek ratings for a combination of past performance and potential future exposure. They obtained data on KLD´s 14 dichotomous environmental variables, which are equally divided into "strengths" and "concerns". In addition to the 14 scores, a total environmental strength, total environmental concern and net environmental score was also analyzed. The ratings were compared to data on companies' environmental performance from the period of 1990-2003 from Corporate Environmental Profiles Directory (CEPD), US EPA´s Toxic Release Inventory (TRI), the Emergency Response Notification System and permit denials from the Resource Conservation and Recovery Act (RCRA) or shut-ins from Minerals Management Service (MMS). Except for the first database, all others are from United States government agencies.

Chatterji *et al.* (2009)'s study revealed that KLD´s total environmental concern, as well as the variables that integrate it, reflect past outcomes adequately. The net environmental score and the total environmental concern also predicted future pollution level. However, the total environmental strengths did not reflect subsequent environmental performance. These results indicate that simple autocorrelation has a substantially higher predictive ability of over sophisticated judgment models. The authors recommend the validity of KLD´s ratings could be improved if more weight was given to historical performance data, and furthermore, they argue that sub-scores can be more accurate if used as a continuous indicator.

The performance evaluation of fifteen firms of the chemical sector vis-à-vis their rating at KLD is analyzed by Delmas and Blass (2010), the fourth work to be described in this section. Environmental performance is measured by US EPA TRI, regulatory compliance and a set of indicators for transparency and reporting defined by the authors. Several statistically significant correlations were found. Not surprisingly, firms with higher toxic release tended also to have lower compliance levels. Remarkably, however, companies with better reporting scores also correlated with lower levels of compliance. The results indicate clearly that companies can perform well in some criteria and poorly in others. When analyzing KLD scores, companies with highest number of environmental concerns also had high score for environmental strengths. Overall, better reporting and advanced management systems were correlated with high levels of toxic releases and less compliance. This result further corroborates Chatterji, Levie and Toffel (2009)'s conclusion that researchers and stakeholders alike still need to find better measures to qualify environmental management.

Using Deepwater Horizon accident as a backdrop, Botelho and Magrini (2011) studied the differences in methodologies of six sustainability indexes (Dow Jones Sustainability Index, GS Sustain, Oekom Industry Focus - Oil & Gas, Tomorrow's Value Rating, World's Most Sustainable Oil Companies and FTSE4Good ESG) and how that reflects in their raking of the O&G companies. The authors found that the French company Total is the only corporation included in all ratings followed by Shell, Repsol, Petrobras and ENI. It is noteworthy to mention that BP ranked above fifth place before the Gulf accident in all reviewed ratings; however, only one maintained the position after the Deepwater Horizon incident. Botelho and Magrini (2011) hypothesize that operational safety may be diluted among the other criteria resulting in a company that has a low safety score may still achieve high overall marks.

Botelho (2012) further scrutinized predictability the DJSI terms of oil spill. Two metrics that measure oil spills were selected, the number of spills and the volume spilled, and a z-test was applied to verify if members of DJSI spill less than non-members. The author found a weak negative correlation between DJSI members and non-members in terms of oil spill metrics. However, it was not possible to test if the DJSI criteria for "releases to the environment", which include oil spills, identifies correctly the companies most prone to oil spills. It probably does, as was found in Chatterji and Levine (2007) in the case of KLD, but other factors included in the overall points offset the poor scores in safety.

3.4 Environmental Reporting in the Oil&Gas Industry

PWC (2012) reports that investors are using ESG data, with financial firms opening ESG research department. An ACCA/Eurosif (2013) investor survey revealed that the most important sources of nonfinancial information for investors are sustainability reports (91% states 'high' or 'essential').

From CorporateRegister (2014) database, it is possible to verify that number of sustainability and similar reports issued yearly by corporations has grown from 26 in 1992 to 7,749 in 2013, including 222 Oil&Gas Producers who published reports in 2013. Similarly, a survey by KPMG (2013) found that "CR reporting is now undeniably a mainstream business practice worldwide," undertaken by 93 percent of world's largest 250 companies. For Lydenberg *et al*. (2010), this growth in voluntary sustainability reporting means that corporations and their stakeholders value this publication.

However, the quality and completeness of the reporting as well as their voluntary status places in question the reliability of the information published (LYDENBERG *et al*., 2010, GUNTHER *et al*., 2007). KPMG (2014) found that sectors with significant social and environmental impacts, such as the oil & gas sector, averaged the lowest scores in a quality evaluation (55 out of 100 for O&G). For 93 percent of the investors responding the ACCA/Eurosif (2013) survey, the provided information in sustainability reports is not sufficient to quantify the materiality of non-financial factors in financial terms. The same percentage also thinks that non-financial reporting is currently not sufficiently comparable across companies.

The most credible and important sustainability frameworks according to a GreenBiz (2013) survey are Global Reporting Initiative (GRI), CDP and DJSI. According to a Globescan SustaiAnbility Survey (2013), CDP and the Dow Jones Sustainability Index are among the top 5 sustainability ratings. However, DJSI questionnaire will not be analyzed here because it is not a reporting framework, but an index to evaluate sustainability, their survey is proprietary and not publically available.

GRI is the most commonly applied reporting standard (KPMG, 2014; LYDENBERG *et al.,* 2010, WBCSD, 2014, GUNTHER *et al.,* 2007). The GRI suggests to corporations reporting structure and indicators since 2000, when the first guidelines were launched. It was created in 1997 by the United Nations Environment Program (UNEP) together with Coalition for Environmentally Responsible Economics (CERES) to ‘‘enhance the quality, rigor and utility of sustainability reporting’’ (GRI, 2015). GRI uses a hierarchical framework in three focus areas, namely social, economic, and environmental (SINGH *et al.,* 2009). GRI released an O&G sector supplement in 2012.

Formerly the Carbon Disclosure Project, CDP is used by 82% of Global 500 Companies (WINSTON, 2010). CDP began in 2000 with the idea to ask companies to publicly share information about their carbon emissions and the actions they’re taking to manage them, at the request of an institutional investors network. The UK based nonprofit currently helps 767 institutional investors holding US$92 trillion in assets to reveal risk in their investment portfolios (CDP, 2015), both by implementing and disclosing a questionnaire and by creating an investment index.

CDP started focused on climate change and expanded to water and later to forests. The Oil and Gas module, based on reporting framework by Institutional Investors Group on Climate Change (IIGCC), Ceres, and the Investor Group on Climate Change Australia/New Zealand (IGCC), was launched in 2010 to complement the "core" climate change questionnaire for refiners, producers and integrated O&G companies. CDP has been successfully using the principle that shareholder actions is likely to prime firms to adopt practices consistent with the aims of a broader social movement (REID and TOFFEL, 2007 and KOLK *et al.,* 2008).

Another strong reference for reporting in the O&G sector is the API/OGP/IPIECA guidelines, a first version launched in 2005 with a revision in 2011. KPMG (2011) found an increasing tendency towards the use of sector specific guidelines such API/OGP/IPIECA guidelines for oil and gas sector. GRI and IPIECA have worked together to create a bridging document to align and facilitate the use of both standards simultaneously, which is presented in its entirety in Appendix A Table 1.

The IPIECA and API (2003) surveyed 32 companies from the oil and gas industry. From this sample 63% published a report on one or more sustainability issues. The companies most often include data on the subjects of oil spills (21 companies); environment, health and safety (EHS)-related fines paid (20); NOx and SOx emissions (19); greenhouse gases (17); total hazardous waste (17); and CO2, CH4 and VOC (16 each) emissions in their reports. Gunther et al. (2007) analyzed 19 companies from the oil and gas industry, and found the following eight indicators present in more than 50 percent of the reports: 'total water use', 'air emissions', 'non-compliance', 'direct energy use', 'spills', 'greenhouse gas emissions', 'total amount of waste' and 'initiatives for renewable energy'. Furthermore, six indicators are not reported by any of the companies: 'products reclaimable', 'energy consumption footprint', 'other indirect energy use', 'withdrawals of ground and surface water', 'amount of impermeable surface' and 'changes to natural habitats' (GUNTHER *et al*., 2007).

Although response rates in terms of numbers of disclosing firms are growing, Kolk et al. (2008) argue that "neither the level of carbon disclosure that CDP promotes nor the more detailed carbon accounting provide information that is particularly valuable for investors, NGOs, or policymakers at this stage."

As can be seen in Table 1 in Appendix A, 48 out of 53 environmental indicators presented are backward looking, i.e. based on past performance. Table 2.1 presents the current indicators from Appendix A and CDP that can be considered forward looking, and thus, provide direct insight into potential future performance.

Table 2.1 Forward Looking GRI Environmental Indicators

IPIECA CODE	GRI CODE	CDP CODE	INDICATOR
E5	EN-14	--	Strategies, current actions, and future plans for managing impacts on biodiversity.
E5	EN-11	--	Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.
E3	OG2	OG6	Total amount invested in renewable energy
HS4	DMA PR	OG6	Disclosure on Management Approach - Product responsibility - Fossil fuel substitutes
--	EC-2	OG1	Financial implications and other risks and

			opportunities for the organization's activities due to climate change.

Source: Developed by Author.

CDP has a more risk-based approach with several qualitative questions on risks, opportunities for the business including supply chain, as well as targets and strategy outlook (CDP, 2014a). Furthermore, in the O&G module, there is a section dedicated to development strategy (OG6) requesting information on capital-intensive development areas, financial disclosures, CAPEX and R&D and a section dedicated to production & reserves by hydrocarbon (OG1), including annual production values and reserves, breakeven cost of production and lower-demand scenario analysis (CDP, 2014b).

There is a mention of reserves in the GRI O&G sector supplement indicator OG1 - Volume and type of estimated proved reserves and production- which falls under the economic aspect (GRI/IPIECA, 2012). IPIECA considers reserve reporting as part of statutory annual reports for publicly owned companies and recommends it to be incorporated in sustainability reports if material, but is not explicitly included. (IPIECA/GRI, 2013). Neither GRI or IPIECA considers reserves characteristics as a possible environmental indicator. In the O&G Module, CDP included the following new question in 2014: OG1.6 Do you conduct any scenario analysis based on a low-carbon scenario consistent with reducing GHG emissions by 80% by 2050 to achieve the 2°C goal in your assessment of the economic viability of proved undeveloped and undeveloped reserves? (CDP, 2014b) However, this question is still qualitative and provides room for interpretation, rather than an easy metric for investor assessment.

In addition to the voluntary standards cited, the US Securities and Exchange Commission (SEC) in 2010 issued guidance to corporations listed in the United

States which requires them to report on climate change related information when deemed material to an assessment of the firm's future prospects. This guidance was based on existing legal requirements and reminds corporations that they already had an obligation to report on social and environmental factors that might materially affect the firms' performance (SEC, 2010). It was demanded by NGO and investor surveys of corporate filings showing that, in the absence of regulatory guidance, "environmental and social issues disclosure in SEC filings is sparse, inconsistent, and typically omits large issues facing the company" (CERES 2010 and LYDENBERG *et al*., 2010).

Having this context as a background, the next chapter will discuss the range of environmental risks challenging O&G corporations and how they affect the companies' bottom line.

4. Materiality evaluation of environmental aspects in the O&G E&P sector

4.1 Materiality

Not all environmental risk factors translate into significant financial threats or opportunities for a corporation. Thus, it is important to explain in more detail the concept of materiality and present those issues that are material to an organization's E&P activities.

Materiality has been defined in several different ways depending on the tool that is used (IASB, 2010; GRI, 2013; IIRC, 2013 SASB, 2013). However, the way in which the concept of materiality is applied in practice is seen by many as a major cause of the current disclosure problem in financial and sustainability reporting (ALLISON-HOPE and MORGAN, 2008; BARAKA, 2013; COHEN, 2014).

The framework of the International Accounting Standards Board (IASB) (IASB, 2010) states that:

> *Information is material if omitting it or misstating it could influence decisions that users make on the basis of financial information about a specific reporting entity. In other words, materiality is an entity-specific aspect of relevance based on the nature or magnitude, or both, of the items to which the information relates in the context of an individual entity's financial report. Consequently, the Board cannot specify a uniform quantitative threshold for materiality or predetermine what could be material in a particular situation.*

In addition, International Accounting Standard (IAS) 1 states that an entity:

> *(a) need not provide a specific disclosure required by a Standard if the*

information is not material; and

(b) should provide additional disclosures when compliance with the specific requirements in International Financial Reporting Standards (IFRS) is insufficient to enable users of financial statements to understand the impact of particular transactions, other events and conditions on the entity's financial position and financial performance.

The Global Reporting Initiative (GRI), on the other hand, defines material topics in its fourth generation Sustainability Reporting Guidelines (G4) as *"*those topics that have a direct or indirect impact on an organization's ability to create, preserve or erode economic, environmental and social value for itself, its stakeholders and society at large.*"* (GRI, 2013) Thus, the IASB definition focuses specifically on the financial consequences of information, while the GRI definition broadens materiality to include impacts on all stakeholders.

The International Integrated Reporting Council (IIRC), whose framework's ultimate goal is to create an interconnection among the financial information of the IASB standards and the sustainability indicators of the GRI, *"*considers that material matters are those that are of such relevance and importance that they could substantively influence the assessments of the intended report users. Where the various materiality definitions differ the most is in terms of the matters that are considered to be relevant." (IIRC, 2013) For the IIRC, relevant matters are those that affect or have the potential to affect an organization's ability to create value over time. For financial reporting purposes, the nature or extent of an omission or misstatement in an organization's financial statements determine relevance. In the context of sustainability reporting, an organization's economic, environmental, and social effects and the effect of the legal, commercial, social, environmental, and political context on that organization are considered in determining what is relevant.

Matters that are considered material for financial reporting purposes, sustainability reporting, or other forms of reporting can also be material for IIRC purposes if they are of such relevance and importance that they can change the assessments of financial capital providers with regard to an organization’s ability to create value.

While the materiality principle suffers from having several definitions, the most significant difference is between the approach taken by the IIRC and IASB, which ultimately looks at materiality through the lens of what is meaningful to investors, and the GRI's approach, which looks at materiality in terms of what is relevant for all stakeholders. In this study, we will use the IASB definition of materiality because our purpose is to focus on environmental issues that can affect a company's financial bottom line. Given the resource intensity of the E&P sector (as described in Chapter 2), and the potential wide-ranging environmental and social externalities, this sector has been the focus of regulation and public attention (SPANGLER and POMPPER, 2011). Therefore, management (or mismanagement) of material sustainability issues has the potential to affect company valuation through impacts on profits, assets, liabilities, and the cost of capital.

Instead of developing our own materiality analysis to determine which environmental issues are relevant to investors in the O&G E&P industry, a literature review was conducted that focused on understanding those issues that are reported as important by market agents such as banks (represented by the International Finance Corporation (IFC, 2007a, b)), investors (represented by Ceres (COBURN *et al.*, 2012)), auditing services (represented by EY (EY, 2013)), accounting (represented by BDO, an accountancy and consultancy company, (BDO, 2013 and 2014) and a reporting standard (represented by the Sustainability Accounting Standards Board (SASB) (SASB, 2014)). As discussed in chapter 3, SASB is the only reporting standard that performs a materiality analysis in order to develop the indicators, that is why it was chosen in this review over GRI (2012) and IPIECA/OGP/API (2010), which are more comprehensive in their indicator lists so that the companies may do their own materiality analysis to select what to report.

The issues presented in Table 2.1 were used as a starting point. Table 4.1 summarizes the main environmental issues identified by each one of the authors. It is clear that there are four predominant environmental issues that O&G corporations with upstream activities must address: climate change, accidents, sensitive areas/access to reserves, and water.

Table 4.1 - Material environmental risks of the upstream O&G sector

Perspectives:	**Banks**	**Investors**	**Auditing**	**Accounting**	**Accounting Standards**
Risks/Sources	**IFC (2007a, b)**	**Coburn *et al.* (2012) Ceres**	**EY (2013)**	**BDO (2013, 2014)**	**SASB (2014)**
Climate Change	X	X	X	X	X
Accidents and Leaks	X	X	X	X	X
Sensitive Areas/Access to Reserves	X		X		X
Water	X	X		X	X
Waste	X				X
Air Pollution	X				X
Noise	X				

Banks, investors' insurers, assurers, and other market players with a role in financing O&G exploration, development, and production assume the risk associated with a company's ability to find, extract, and deliver O&G resources successfully to the midstream market for a profit. Thus, it is important to understand their view on how environmental issues affect corporate value.

The following sections provide a description of how each of the four main environmental issues identified in Table 4.1 is likely to have material implications for companies in the O&G E&P industry. Each description also includes an explanation of how the issue can affect valuation and considers evidence of the actual financial impact. In addition, we explore the relationship between each environmental issue and reserves.

4.2 The materiality of climate change

As discussed in Chapter 3, mitigating climate change requires urgent and potentially significant policy changes. Indeed, climate change mitigation policies are already being implemented in the EU, China, Australia, and in several U.S. states even without a global consensus on binding national commitments for emissions reductions (GREGG, 2011: LEGGETT, 2011; EC, 2014). With regard to the O&G E&P industry, almost all the authors cited in Table 4.1 agree that climate change is a critical issue; it is also interesting to note that the industry is a factor that contributes to global warming as well as being affected by it.

4.2.1 The effect of E&P operations on climate change

The accountancy company BDO finds that among the top 20 most frequent risks cited in Form 10-Ks, four are environmental risks: natural disasters, extreme weather conditions, the impact of climate change, and greenhouse gas legislation (BDO, 2013 and 2014). In addition, in a recent O&G report, EY (2013) survey companies and experts, and find that among the top 10 risks are climate change concerns.

Spedding *et al*. (2013) assess risk for the O&G sector assuming a low carbon world. Using a ceiling price on future projects to assess the potential value at risk, they find that the value of reserves at risk varies from 1-17percent, which can rise to 40-60% of market cap if lower demand leads to reduced prices (SPEDDING *et al.,* 2013). The Carbon Tracker Institute (CTI, 2013) claims that 60-80 percent of coal, oil, and gas reserves of listed companies are unburnable, but that current valuations are based on the full exploitation of proven reserves and do not include long-term climate policy, technology, and impact risks. The study also finds that smaller companies with high exposure to oil sands are not resilient to price stress in a carbon-restricted scenario (CTI, 2013).

Although 90% of global O&G reserves is controlled by governments or national oil companies (70 percent in OPEC countries), privately owned companies have secured a significant share of current production. This is estimated at around 40-50 percent, indicating that such companies are likely to be affected significantly by a global cap on emissions (SPEDDING *et al.,* 2013). Further, Spedding *et al*. (2013), in their report for HSBC, say that O&G companies account for most of the “embedded carbon” of U.S. listed companies, calculated as the sum of all carbon emissions from the production of goods and services, and that the level of such embedded carbon has increased by 37 percent since 2011.

Unconventional processes, such as steam-assisted recovery, the processing of extra-heavy fuel, the extraction of tar sands or oil shale, and the conversion of gas or coal into liquid hydrocarbons, all require high-energy consumption and result in significant CO_2 emissions (BABUSIAUX and BAUQUIS, 2007). On the other hand, Spedding *et al*. (2013) suggest that companies with a gas bias face lower risks.

Coburn and Cook (2014) argues that regulatory limits on GHG emissions and the development of alternative energy could reduce global demand and prices for oil products or put them on a lower growth trajectory, thus lowering the quantity and net present value of oil reserves. Climate-related regulations in particular could result in a significant correction in the market value of companies' assets and have a material impact on future growth prospects and the cost of capital (COBURN and COOK, 2014).

In this context, the capture and geological storage of carbon dioxide (known as carbon capture and storage (CCS)) offers the petroleum sector an opportunity to mitigate emissions of stationary sources and thus reduce its risk exposure to climate change regulations (IPCC, 2010). However, the internalization of the corresponding costs or the use of CCS can modify the structure of direct costs, which may either enable or restrain the development of non-conventional oil and enhanced oil recovery processes. These costs will vary depending on site-specific factors such as onshore versus offshore, reservoir depth, and the geological characteristics of the storage formation (IPCC, 2010). Please see Vaz Leal da Costa (2014) for detailed discussion on the subject.

SASB (2014) states that falling demand or prices for O&G, or increased extraction costs, are likely to affect equity valuations through delayed capital expenditures, mothballed assets, reductions in asset values, or decommissioning and closure of O&G wells. Returns on invested capital are also likely to be affected because of lower prices, thereby putting pressure on margins. Companies at risk may also face ratings downgrades for their corporate debt, thus increasing their cost of capital and potentially restricting their access to refinancing (CTI, 2013).

Further, the price and cost impacts that result from climate regulations can affect the net present value of proven reserves, and therefore the valuation of E&P companies. These factors can also add uncertainty to the calculation of the reserves-to-production (RPR) ratio, a key indicator of future growth for the E&P industry. Therefore, the effect of climate change regulations and the development of alternative energy must be considered in the valuation of reserves and the determination of appropriate levels of capital expenditures to explore for and develop O&G reserves (SASB, 2014). It is worth noting that companies with tar sands reserves and gas reserves are more vulnerable to this issue.

4.2.2 The effect of climate change on E&P operations

Climate-related events frequency has increased in the last 30 years, with the total loss reaching US$155 billion in 2012 in the United States alone (NOAA, 2013a). The U.S. Department of Energy (DOE, 2014) report that these events affect E&P operations in terms of damaged infrastructure, changes to existing operations, the limited use of ice-based infrastructure, disruption to the drilling season of offshore and coastal facilities, and interference with operations and fuel supplies. For example, Burkett (2011) finds that Hurricanes Katrina and Rita damaged approximately 457 offshore O&G pipelines and significantly damaged onshore oil refining, gas processing, and pipeline facilities, all of which impacted O&G production for months.

According to the Carbon Disclosure Project (CDP, 2012), 75 percent of responding O&G companies have identified one or more significant physical climate change risks, with 96 percent of these risks seen to have an impact on the companies' own operations and the rest of the supply chain. Physical risks from cyclones, the rising sea level, and snow and ice were most commonly identified as high significance risks.

Natural disasters and extreme weather conditions were listed as a risk for 96% of O&G companies in 2013 (BDO, 2014). The substantial damage and financial loss that many companies experience as extreme weather conditions grow more frequent serve as a warning that companies must plan carefully for similar future events. Closely tied to such risks is a widely held concern about securing adequate insurance coverage. Because many insurance policies do not fully cover the impacts of natural disasters, the cost and reliability of insurance for the liabilities associated with operational risks was cited as a threat by 86% of companies in 2013 (BDO, 2014). Thus, weather disasters can incur increased costs for the entire E&P industry, although it is clear that offshore operations are more vulnerable (DOE, 2014).

4.3 The materiality of accidents

According to O'Rourke and Connolly (2003), exploration and drilling activities are the most dangerous sectors of the O&G industry, with risks of oil spills, leaks, blowouts, and injuries to workers and communities. Eckle *et al.* (2012) demonstrate the severity of E&P spills using a global energy-related severe accident database (ENSAD) and analyze more than 1,200 accidental oil spills that occurred between 1974 and 2010. While E&P was responsible for fewer spills in terms of numbers (24 out of 1,213) than other O&G activities, it caused 2.2 million tons of spilled oil out of a total of 9.8 million tons. In addition, the authors find no particular increases or decreases in the frequency of spills for E&P operations. They also suggest that a severe oil spill on a similar scale as the Deepwater Horizon incident in 2010 could occur every 23 years.

Motivated by the Deepwater Horizon Spill, Muehlenbachs *et al*. (2013) conduct an empirical analysis on incidents in the Gulf of Mexico and find that the dramatic increase in water depths for drilling correlates positively with the number of incidents such as blowouts, injuries, and oil spills. The authors claim that each 100 feet of added depth to a well increases incident probability by 8.5%. This study counters past research on this issue such as that of Shultz (1999) and Jablonowski (2007). This could be because the study by Muehlenbachs *et al*. (2013) is the only one that uses recent data (1996-2010), whereas the other authors use data up to 1998, when 400 feet was considered deepwater. As a point of comparison, the Petrobras pre-salt layer, which has been explored since 2010, lies in water that is around 9,000 feet deep and requires drilling for a further 13,000 feet in order to reach the oil (PETROBRAS, 2013).

Accidents can result in high death tolls and significant costs for companies. Excluding the Deepwater Horizon spill, the five deadliest offshore accidents in the world have resulted in a total of 546 deaths, and the five costliest offshore accidents have cost a total of US$2.9 billion as of 2002 (SASB, 2014).

With regard to the 2010 Deepwater Horizon spill, the state of Florida filed a lawsuit against both BP and Halliburton in April 2013 and demanded more than US$5 billion for “misconduct that led to this environmental and economic disaster” (BEATON, 2013). After the oil spill, BP’s share price dropped significantly given the uncertainty of potential liabilities, with estimates for these reaching billions of dollars, thereby raising fears of bankruptcy (HEFLIN and WALLACE, 2011). By the end of 2013, BP had paid $42.7 billion in compensation for the Deepwater Horizon spill, but the company it warned investors that this amount might not be sufficient to cover civil suites that have not been settled (BP, 2013).

However, Scholtens and Boersen (2011) find that between 1907 and 2007, the stocks of oil companies did not suffer significant impacts after accidents. The authors also find no evidence of capital restrictions due to the poor environmental image of oil companies and thereby conclude that financial market participants perceive energy accidents as "part of the game" and already discount for most of these in the valuation of the energy industry. On the contrary, Cohen (2010) demonstrates a negative stock price effect after oil or chemical spills. Further, Heflin and Wallace (2011) provide evidence that not only BP but also other companies operating offshore in the United States experienced significant negative returns following the Deepwater Horizon Spill in 2010. Indeed, the reputational impacts of the spill have been almost as significant as the direct financial costs. BP spent US$50 million on an apology commercial alone and millions of dollars more to repair its image (ATKINS *et al.*, 2011).

Although there is controversy about whether or not oil spills can decrease the market value of a company (SCHOLTENS and BOERSEN, 2011; FODOR and STOWE, 2010), it is clear from the Deepwater Horizon incident that an uncontained oil spill can be very costly and that the costs of compensation, cleanup, and remediation are increasing (GOLDENBERG, 2013b).

4.4 The materiality of sensitive areas/access to reserves

The E&P industry's activities can have significant impacts on biodiversity, as discussed in Chapter 3. Externalities from E&P operations in sensitive areas, such as the Arctic and certain shorelines with mangroves and swamps, can be extremely damaging to biodiversity and ecosystems (O'ROURKE and CONNOLLY, 2003). Thus, operations in these areas also entail more complex and expensive cleanup operations should there be hydrocarbon spills or leaks. As O&G companies attempt to access more remote, ecologically sensitive locations such as the Arctic and deepwater fields, and develop unconventional resources such as oil sands, which require large land areas and generate more waste, the risks that E&P operations will affect biodiversity, and therefore company value, can be exacerbated. According to EY (2013), the Gulf of Mexico spill has made regulators warier of E&P operations that use new technologies and operate in new areas.

The Arctic region is a significant oil frontier because of its vast O&G reserves, which the United States Geological Survey (USGS) has estimated at 90 billion barrels of oil, 1,669 trillion cubic feet of natural gas, and 44 billion barrels of natural gas liquids that is yet to be discovered (USGS, 2008). Although many of the reserves were discovered more than 30 years ago, the recent ice melt has facilitated the conditions for exploration activities. Thus, Harsem *et al*. (2011) expect expansion both in countries where there are considerable O&G operations: Canada, the U.S., Norway, and Russia; and in countries which will start E&P activities: Iceland and Greenland. Although conditions for drilling have improved, the scenarios in such regions are still harsh and risky. Weather conditions, infrastructure and transport networks, logistical chains, labor costs, social licensing, and commercial-legal requirements are some of the challenges that companies face when working in these regions. Such challenges translate into high costs and significant delays (GRONHOLT-PEDERSEN, 2010; CLINT, 2011; HARSEM *et al.* 2011). A spill in the Arctic poses a particularly significant threat, not only for the sensitivity of the region but also because of the complications related to containment and restoration (HARSEM *et al.,* 2011). Further, according to Kuzik (2011), a single drilling rig in the Arctic can cost up to US$200 million. Thus, the Shtokman field, which was discovered in 1988, has been delayed many times, and in 2013 it was announced that the anticipated start of investment would be further delayed until 2016 (GRONHOLT-PEDERSEN, 2010). Cost estimates for this project have risen from US$6bn in 1994 to US$20bn in 2007 to around US$40bn in 2011, according to Bernstein Research (CLINT, 2011).

E&P companies' decisions about acquiring reserves in ecologically sensitive areas, together with their performance on managing biodiversity impacts, can have material implications for the value of their reserves and therefore shareholder value. Austin and Sauer (2002) find that companies' shares of reserves in ecologically important areas have varied significantly. According to the authors' report, future policies related to companies' access to such reserves could lead to an average 2% loss in shareholder value across different scenarios. Non-integrated companies are likely to be the most affected.

Austin and Sauer (2002) estimate what such financial impacts could be applying a forward-looking valuation methodology based on scenarios given the constrained access to O&G reserves. The authors assess the financial impact in 16 major O&G companies, predicting that more exposed companies can lose up to 6% of shareholder value. The authors conclude that: "Companies heavily invested in sensitive areas are at higher risk from emerging opposition to industry presence."

In fact, increasing the size of protected areas is a target for the Convention of Biological Diversity and the global UN Millennium Development Goals. The number and size of protected conservation areas has increased exponentially around the world over several years, as seen in Figure 4.1. In 2012, the protected areas listed in the World Database on Protected Areas covered 14.6% of the Earth's land area and 9.7% of the Earth's coastal waters (0-12 nautical miles from the coast), but only 2.3% of the global ocean area (CDB, 2013). The target is that: "By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes."(CDB, 2013) The new protection status afforded to areas where reserves are located can lead to more stringent legislation and conditions for permits in order to protect ecosystems, which can cause delays or denial of permits. In addition, such protected area status can increase extraction costs because of increasing environmental awareness, the protection of ecosystems and endangered species, and local resistance, making it uneconomical to extract from these sites.

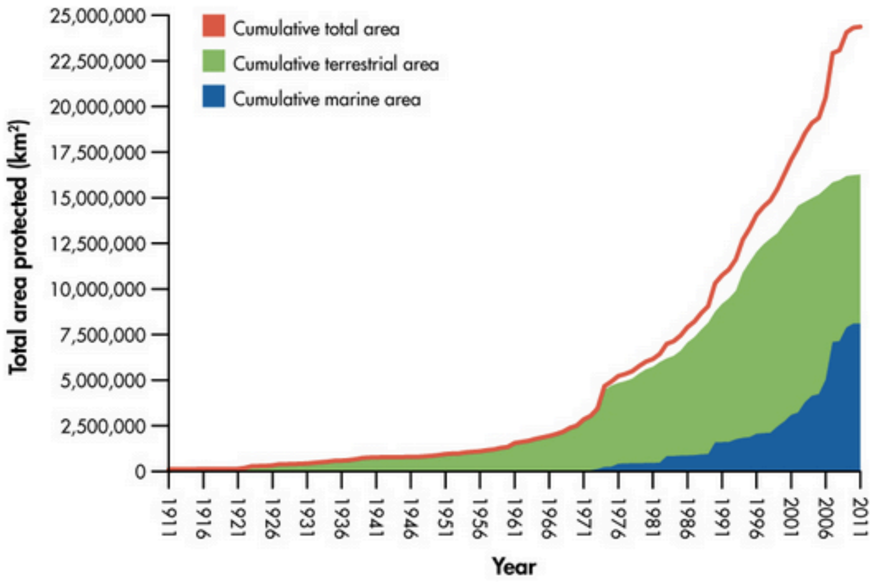


Figure 4.1 Growth in nationally designated protected areas (1911-2012). (Source: CDB, 2013)

Significant spills or explosions as a result of accidents can also affect access to reserves, and therefore company value. Such major risks, with a low probability of occurrence but high potential impact, are discussed in Section 4.3.

In sum, the probability and magnitude of the impact on financial results because of concerns about, and the protection of, ecologically sensitive areas and species, are likely to increase in the future, especially with the expansion of unconventional O&G production (SASB, 2014).

4.5 The materiality of water

O'Rourke and Connolly (2003) state that water bodies' contamination, especially from produced water, and significant quantities of water use are cited as having substantial impacts on E&P. Thus, there are two challenges with regard to water: (1) securing adequate supplies for use in operations, and (2) preventing contamination of water resources.

4.5.1 Water consumption

Depending on the extraction technologies, E&P operations need relatively large quantities of water. Further, the IEA (2013) estimates that water use could become increasingly challenging for unconventional gas development in parts of China and the U.S., and for Canadian oil sands production. Indeed, BDO (2014) finds that companies are expressing increasing concern about their ability to secure sufficient water to facilitate E&P, whether as a result of increasing competition, government-imposed restrictions, or a shortage driven by drought conditions. In 2014, the number of companies citing water shortages as a risk grew to 42% from 32% in 2013 and 11% in 2012 (BDO, 2013 and BDO, 2014).

The location of E&P facilities can also determine risk exposure of reduced water availability and related cost increases. The World Resources Institute in a recent report (Reig *et al.*, 2014) says that 38% of global shale gas reserves are located in water stressed regions. In the U.S., Freyman and Salmon (2013) reports that of 24,450 O&G wells, nearly half are located in areas with "high and extremely high water stress." JP Morgan (2008) states that tar sands developments, which use 4-5 liters of water to separate out each liter of oil, are particularly vulnerable to this risk. The substantial use of water resources, combined with water's growing scarcity due to human consumption and climate change, can pose operational risks to companies because of a lack of water availability or higher costs. Consequently, tens of millions of dollars in regional savings can occur if a corporation engages in proactive water planning (FREYMAN and SALMON, 2013).

As with operations in ecologically sensitive areas, operations in water stressed areas can also lead to protests and lawsuits, which in turn cause lost revenue and higher costs from delayed production, create legal liabilities, lead to permit denial, and ultimately increase companies' risk profiles and the cost of capital. For example, Shell's shale gas project in the semi-desert Karoo region in South Africa faced protests over water availability, which resulted in delays and a temporary government ban on hydraulic fracturing (REIG *at al.,* 2014). Further, JPMorgan (2008) reports that "increased publicity surrounding supply shortfalls can lead to increased government intervention, such as the recent restrictions on water use in the Atlanta area and in Australia, altering companies' cost structures."

In addition, JP Morgan (2008) warns that water risks are difficult for investors to assess, "due both to poor information about the underlying supply conditions and to fragmentary or inadequate reporting by individual companies. As a result, market prices of securities are unlikely to accurately reflect the potential costs of water-related problems."

4.5.2 Water pollution

Water contamination is a significant regulatory and reputational risk for the E&P industry, particularly where operations intersect with drinking water supplies. Contamination can result from produced water, fracking fluids, or methane leakage. The characteristics and potential environmental consequences of effluent discharge are discussed in Chapter 2.

The rapid expansion of shale gas extraction through fracking has raised concerns about groundwater pollution (WILLIAMS, 2012). A U.S. congressional study shows that fracking products contain 29 chemicals that are known to be possible human carcinogens (U.S.HOR, 2011). Thus, both shale gas and oil sands have the potential to face restrictions because of water issues, whether consumption or pollution (WILLIAMS, 2012; FREYMAN and SALMON, 2013; IEA, 2013). The contamination of aquifers and water bodies from produced water, fracking fluids, methane leaks, and oil or chemical spills can also create tensions with local communities if, for example, such communities are deprived of drinking water.

Moreover, produced water discharges and injections incur significant costs for E&P companies. Produced water handling and treatment is estimated to represent US$18 billion in costs for the O&G industry in the U.S. alone, with per-gallon costs of cleaning produced water as much as 300 times greater than the costs for municipal water and 3,000 times greater than for agricultural irrigation water (ENDRESS+HAUSER, Inc., 2014). Khatib and Verbeek (2003) estimate that Shell Oil's worldwide produced water management costs are more than $400 million per year.

Further, wastewater from operations can also lead to regulatory penalties. For example, SASB (2014) reports that XTO Energy was required to pay a penalty of US$100,000 and spend a federal government-estimated US$20 million on a comprehensive plan to improve wastewater management practices in order to recycle, properly dispose of, and prevent spills of wastewater generated from its E&P activities. Cabot Oil and Gas Corporation also had to paid a fine to the state of Pennsylvania because of drinking water contamination due to gas escaping from a incompletely cased well (RIDLEY, 2011).

Regulators have sought to address these concerns through several actions and proposed rules, with the potential for significant costs and business risks to E&P companies. The EPA, for example, issued an advance notice of proposed rulemaking in 2014 to consult stakeholders whether reporting chemicals used in hydraulic fracturing should continue voluntary or if it should be mandatory (OTUM, 2014). In addition, Pennsylvania has banned Cabot Oil & Gas from drilling in part of the state since April 2010 (WILLIAMS, 2012). In the U.K., there will be baseline monitoring to check methane levels in drinking water before drilling starts. The U.K. Environment Agency has also imposed ongoing environmental monitoring requirements (EVANS, 2014).

The high risk of regulations around water contamination from hydraulic fracturing can create difficult conditions for companies, including restrictions on access to capital. In such a context, ExxonMobil included a clause in the US$41 billion offer it made in December 2009 to buy natural gas producer XTO Energy that would allow ExxonMobil to back out if regulations made fracking illegal or "commercially impracticable" (MICHEALS and SOULDER, 2010). Although the deal ultimately went through, this highlights the potential impacts that emerging fracking regulations can have on E&P company value.

Thus, managing water consumption and wastewater can influence the operational risks faced by companies, with potentially acute impacts on value from disruptions to production. Water use and contamination can also affect ongoing operating costs and cash flows through one-off capital expenditures or regulatory penalties.

The difficulties that investors face in order to assess these risks are not restricted to water issues, as pointed out by JP Morgan (2008), but apply to all the issues discussed. However, the indicators recommended by IPIECA (2010) and GRI (2012) are restricted to performance metrics, such as the volume of consumed water, GHG emissions, and qualitative metrics for biodiversity conservation efforts. These indicators have little meaning without context, are difficult to compare because of operational differences, and, most importantly, provide little predictability regarding future performance. If we can link these issues to reserve characteristics, as we will attempt in the next chapter, we can significantly improve information; thus, investors will have a better understanding of the risks to which companies are exposed.

5. The relationship between reserves and environmental risk factors

The aim of this chapter is to contribute to the improvement of corporate sustainability valuations by investigating whether reserves' profiles can affect the environmental risk exposure of an O&G E&P corporation.

5.1 Methodology

We hypothesize that the mix of conventional oil, natural gas, and oil sands reserves can alter the exposure to environmental risk of the largest listed companies with E&P activities, as reported on Form 10-Ks[19] (or the equivalents). Data on reserves from 2009 to 2012 of 24 O&G companies were used to test five hypotheses, which address how reserves' profiles could relate to the four material environmental risks: climate change, accidents, sensitive area/access, and water. The frequency with which companies reported these risks was evaluated using keyword-in-context (KWIC) content analysis. Analysis of variance (ANOVA) and Student's t tests were applied to each of the hypotheses.

5.1.1 Data collection

Sections 5.1.1 through 5.1.3 describe how the material risk factors were derived and how the data on reserve profiles were collected, and present the reported risk factors.

[19] The annual report required by the U.S. Securities and Exchange Commission on Form 10-K provides a comprehensive overview of a company's business and financial condition and includes audited financial statements. The annual report, Form 40-F, applies when the registrant is incorporated or organized under the laws of Canada or any Canadian province or territory, and Form 20-F must be submitted by all "foreign private issuers" that have listed equity shares on exchanges in the U. S. The reporting and eligibility requirements are stated in the Securities Exchange Act of 1934.

5.1.1.1 Reserves' profile data

Although listed corporations in the O&G industry control only one-third of hydrocarbon reserves, they were chosen as a study group because of the consistency with which they are required to report information about their reserves (KRETZSCHMAR and SHARIFZYANOVA, 2010). The NASDAQ Company List was used to select our study sample because it enabled us to find stocks that were listed on the three main stock exchanges: the NASDAQ Stock Market, the New York Stock Exchange (NYSE), and the American Stock Exchange (AMEX) (NASDAQ, 2013). The search was filtered for the energy sector and included two industries: integrated oil companies and O&G production. Companies that did not engage in E&P activities were excluded. Only companies with a market cap above US$20 billion were considered. The 24 companies selected and their reserve profiles are presented in Table 5.1.

Reserve data were collected from Form 10-Ks and equivalent reports for the fiscal years 2009-2012. The final rules of the U.S. Securities and Exchange Commission (SEC) on the modernization of O&G reporting[20] became effective for accounting periods ending on or after December 31, 2009; thus, for the purpose of comparability, prior years were not included. Proven developed and undeveloped reserves were gathered and added together.[21] It should be noted that proven developed reserves generate current cash flow, and are therefore the least-risky reserve class (HOWARD and HARP, 2009).

Table 5.1 Origin, market cap, and reserve profiles for 2009-2012 (in percentages)

[20] Available at: http://www.sec.gov/rules/final/2008/33-8995.pdf.

[21] SEC's *Modernization of Oil and Gas Reporting*: When producing an estimate of the amount of oil and gas that is recoverable from a particular reservoir, a company can make three types of estimates: 1. an estimate that is reasonably certain; 2. an estimate that is as likely as not to be achieved; and 3. an estimate that might be achieved, but only under more favorable circumstances than are likely. These three types of estimate are known in the industry as (1) proved, (2) proved plus probable, and (3) proved plus probable plus possible reserve estimates.

Companies	Origin	Market Cap(billion USD, April 15th)	2012			2011			2010			2009		
			Heavy[a]	Liquids[b]	Gas[C]	Heavy[a]	Liquids[b]	Gas[C]	Heavy[a]	Liquids[b]	Gas[C]	Heavy[a]	Liquids[b]	Gas[C]
Exxon	North America	403	17%	34%	49%	15%	34%	51%	11%	36%	53%	12%	39%	49%
PetroChina Company Limited	Emerging Market	237	0%	60%	40%	0%	50%	50%	0%	66%	34%	0%	52%	48%
Chevron Corp.	North America	229	7%	51%	43%	7%	51%	43%	7%	55%	38%	6%	55%	38%
Shell	Europe	207	14%	33%	54%	12%	31%	57%	12%	32%	56%	12%	29%	59%
BP	Europe	133	1%	59%	40%	1%	59%	40%	1%	59%	40%	0%	58%	42%
Total	Europe	109	10%	43%	48%	9%	44%	47%	8%	51%	42%	4%	53%	44%
Petrobras	Emerging Market	106	0%	85%	15%	1%	81%	19%	0%	84%	16%	0%	85%	15%
China Petroleum e chemical Corp.	Emerging Market	100	0%	72%	28%	0%	72%	28%	0%	73%	27%	0%	72%	28%
CNOOC Limited	Emerging Market	84	5%	64%	31%	3%	64%	32%	0%	64%	36%	0%	63%	37%
ENI	Europe	82	0%	49%	51%	0%	50%	50%	0%	57%	43%	0%	54%	46%
Statoil	Europe	77	0%	46%	54%	0%	44%	56%	0%	41%	59%	0%	42%	58%
Conoco Phillips	North America	72	22%	40%	38%	17%	41%	42%	16%	41%	44%	11%	49%	40%
Occidental Petroleum Corp.	North America	65	0%	72%	28%	0%	72%	28%	0%	73%	27%	0%	73%	27%
Suncor	North America	45	88%	9%	3%	85%	10%	6%	85%	9%	6%	84%	8%	8%
Anadarko	North America	43	0%	46%	54%	0%	45%	55%	0%	44%	56%	0%	44%	56%
EOG	North America	34	0%	56%	44%	0%	36%	64%	0%	28%	72%	0%	17%	83%
Imperial	North America	34	96%	1%	2%	96%	2%	2%	94%	2%	4%	94%	3%	4%
Canadian Natural Resources	North America	34	66%	20%	14%	62%	21%	16%	65%	20%	15%	66%	19%	15%
Apache	North America	29	0%	51%	49%	0%	46%	54%	0%	44%	56%	0%	45%	55%
Hess	North America	25	0%	75%	25%	0%	74%	26%	0%	72%	28%	0%	67%	33%
Marathon	North America	23	35%	41%	25%	35%	41%	25%	35%	38%	27%	36%	37%	27%
Cenovus	North America	23	79%	14%	7%	71%	156%	13%	69%	17%	14%	60%	19%	21%
Devon	North America	22	18%	29%	53%	15%	26%	58%	15%	25%	60%	15%	26%	59%
Noble	North America	21	0%	30%	70%	0%	31%	70%	0%	33%	67%	0%	41%	59%
AVERAGE			**19%**	**45%**	**36%**	**18%**	**43%**	**39%**	**17%**	**44%**	**38%**	**17%**	**44%**	**40%**

Notes:
a. Bitumen and synthetic oil.
b. Crude oil, condensate, and natural gas liquids.
c. Skew Z-score: 1.98; kurtosis Z-score: 0.26.

Most companies report crude oil, condensate, and natural gas liquids together, as presented in Table 5.1 under Liquids. Bitumen and synthetic oil reserves are listed under Heavy Oil because of their different extraction procedure. The Gas column includes conventional natural gas and shale gas. The reserves are presented as a percentage of the total because this study is interested in determining the degree of each company's exposure to different types of hydrocarbon. In this regard, because of the difference in company size (e.g., Exxon is over 10 times larger than 50% of the other companies), the absolute numbers can be misleading when determining the degree of exposure.

5.1.1.2 Risk factors' data

For the purpose of comparability, this study used the annual filings submitted to the SEC for the fiscal years 2009-2012. The details are on Form 10-Ks or the equivalent Form 40-Fs for Canadian securities in the U.S. and Form 20Fs for foreign-domiciled corporations. These reports make valuable study material because corporations must list their current and future risks to investors in a format that is both legal and marketing-free. According to Gray *et al*. (1995) and Frost (2007), material information is more readily available and reliable in regulatory filings than in sustainability reports because the voluntary nature of the latter allows companies to focus only on positive stories with emotive content.

Based on the material issues identified in Table 4.1, a preliminary list and categorization of risk factors were adopted, as in Gray *et al.* (1995) and Hackston and Milne (1996). This list was complemented by an analysis of the subtitles that referred to environmental issues in the Risk Factors section of the reports. Although Form 10-K is a regulated corporate communication, companies are free to report risk factors in the order and depth that they see fit.

By reviewing the Risk Factors subtitles, it was clear that there were three predominant themes present: environmental regulatory restrictions, climate change, and accidents. It should be noted that regulatory restrictions encompassed the other themes. For example, accidents were related to fines and penalties, and climate change was linked to carbon restrictions and taxes. Further, companies often referred to environmental regulatory risks in general terms; hence, to avoid redundancy, no search was made for terminology related to regulations (e.g., fines, laws, permits, and taxes).

Content analysis was then used to detect the frequency and depth with which these issues were reported in the Risk Factors sections of the reports. The method applied was keyword-in-context (KWIC), which allowed the researcher to include large amounts of textual information and systematically identify its properties by counting the frequencies of the most used keywords (Krippendorff, 1989). KWIC is better than a simple word-frequency count because each word is viewed in the sentence in which it appears; therefore, the researcher is able to exclude words with different meanings (STEMLER, 2001). A point of concern is the reproducibility of the coding schemes; that is, whether the coding rules used will lead to the same text being coded in the same categories by different people (WEBER, 1990 apud STEMLER, 2001). However, the KWIC approach has proved to be effective in prior corporate communications studies (GRAY *et al.*, 1995; LAJILI and ZÉGHAL, 2005; LINSLEY and SHRIVES, 2006; CHO *et al.*, 2010; ESCOBAR and VREDENBURG, 2011).

The emergent coding was used, several reports were read, and keywords were extracted to compose the search that complemented the preliminary list, resulting in Table 5.2. So as not to restrict the research, high-level term generalization was allowed; that is, we preferred to use a root word, such as “safe” instead of “safely” or “safety.” This is because when we looked for the root word all terms were found, and those that did not match the intended meaning were excluded. Each word was verified in context to ensure that the meaning was adequate. Owing to some ambiguity of word meanings and use, the researchers recorded all exclusions to ensure reproducibility. Content coding is a brute-force, iterative, and labor-intensive activity; thus, a computer-aided tool was applied to assist in the process, in this case, HyperResearch™ .[22]

Table 5.2 Codes used

CODES		
Risks	**Category**	**Words**
Accident	Accident Types	blow
		loss of well control
		explosi[a]
		equipment failure
		fire
	Accident	accident
		incident
	Health	casualt[a]
		fatal

[22] http://www.researchware.com/products/hyperresearch.html

		death
		loss of life
		injur[a]
		health
	Safety	safe
		hazard
	Spill	spill
		leak
		discharge
		release
	Remediation	remediation
		clean up / clean-up
Climate Change	Emissions Control	emission
		CO2
		GHG
		house
	Renewable Energy	renewable
		green economy
		low carbon
		clean energy
	Physical change	weather
		storm
		cyclone
		hurricane
		tornado
		flood
	Climate change	climate change
Sensitive Areas/Access	Sensitive	biodivers[a]
		sensitive
		pristine
		ecolog[a]
		habitat
		nature
		species
		flora
		fauna
		threatened
		endangered
		wild
	Ecosystem	jungle
		forest
		marine
		arctic
		ecosystem
	Access	access
		inhospitable
		remote
		challenging environmental
		harsh
		hostile
Water	Pollution	water
		effluent
		liquid waste
	Scarcity	water

		drought

Notes:
a. Root of the word.

5.1.2 Hypothesis development

A total of five hypotheses were developed for the four environmental material risks presented in Chapter 4. The first two hypotheses, presented in Section 5.1.2.1, relate climate change words to heavy hydrocarbon reserves. In Section 5.1.2.2, the types of reserve characteristic that could yield a higher accident risk are discussed, and the third hypothesis is presented. In Section 5.1.2.3, the argument that those companies with the largest reserves are more exposed to sensitive areas/access risks is presented, which is the fourth hypothesis. The fifth hypothesis is in Section 5.1.2.4 and proposes that increased water risks are associated with companies that have heavier oil or gas reserves.

5.1.2.1 Climate change

Oil sands have higher GHG emissions during the production of fuel (MÉJEAN and HOPE, 2008; BURNHAM *et al.*, 2011; GILES, 2013). Further, according to a well-to-wheel analysis conducted by Englander *et al*. (2013), carbon emissions are 12-25% higher with oil sands than with conventional oil production despite recent technological and efficiency improvements. In addition, in a review of production emissions, Charpentier *et al*. (2009) consider 13 studies of GHG emissions from oil sands production based on different reservoir characteristics, technologies, and emission levels. The emissions associated with the production of synthetic crude from oil sands are between 10.2 and 26.9 g CO_2/MJ (62 and 164 kg CO_2/bbl) for surface mining and upgrading, and between 16.2 and 28.9 g CO_2/MJ (99 and 176 kg CO_2/bbl) for in-situ techniques and upgrading. For comparison, the emissions from conventional oil production are between 4.4 and 4.7 g CO_2/MJ (27 and 58 kg

CO_2/bbl). The discussion of the Keystone pipeline in Chapter 2 illustrates how the extraction of this type of reserve receives significantly more pressure from climate change activists than that of other reserves (BRODER, 2013).

Further, other unconventional oils such as extra-heavy and tight oil have also shown greater GHG emissions compared with conventional oil. For instance, shale gas lifecycle analysis highlights a controversy because upstream methane emissions counteract reduced combustion GHG emissions (WEBER and CLAVIN, 2012). Indeed, Engelder (2011) states that in "a 20-year time period, the greenhouse gas footprint of shale gas is worse than that for coal or oil." Brandt (2009) estimates that well-to-wheels emissions for tight oil (shale oil) result in 23-73% greater emissions compared with the U.S. 2005 average diesel baseline. The Association for the Study of Peak Oil (ASPO, 2009) presents significantly higher emission estimates for production from shale oil, providing a range of CO_2 emissions between 232% and 892% higher when compared with the production of conventional crude, which results in a lifecycle emission increase between 128% and 232%.

The technology brief of the Energy Technology Systems Analysis Program (ETSAP, 2010) gathers results from a number of studies and reveals that the emissions range for oil sands is equivalent to that of extra-heavy oil because of the large amounts of natural gas burned for the steam injection process, and the conversion of extra-heavy oil to conventional oil.

Thus, it is expected that companies with more unconventional oil reserves are more likely to suffer from climate change restrictions and thus report relatively more climate change risks (CTI, 2013). This alternative hypothesis will be tested against the null hypothesis of no difference in company reports. However, it is not possible to differentiate tight oil and extra-heavy oil from conventional oil in the current reporting guidelines; thus, in accordance with Table 5.1, the hypothesis considers heavy oil as only bitumen and synthetic reserves.

The second hypothesis examines the opposite effect. Socolow and Pacala (2006) envision natural gas substitution for coal as an essential step in order to solve the climate change problem. Further, in a study analyzing the effects of carbon constraints on O&G stocks, Spedding *et al.* (2013) anticipate that natural gas "would be less affected in a low-carbon world." Thus, we predict that companies with more natural gas will report less climate change risks.

Given the reserve profile presented in Table 5.1, the null and alternate hypotheses were formulated as follows.

Hypothesis 1

H1a: Companies with ≥ 15% proven heavy oil reserve profiles report more climate change risks.

H1b: Companies with ≥ 15% proven heavy oil reserve profiles do not report more climate change risks.

Hypothesis 2

H2a: Companies with ≥ 55% proven gas and no heavy oil reserves report fewer climate change risks.

H2b: Companies with ≥ 55% proven gas and no heavy oil reserves do not report fewer climate change risks.

No guidance or prior similar studies were found that could help to determine an ideal percentage to use as a threshold. Hence, common sense together with the current data presented in Table 5.1 were used to establish such a percentage. In the case of gas reserves, 55% was chosen because it indicates a clear majority of gas reserves, given that a few companies, such as ENI and PetroChina, exhibit borderline 50%. This same percentage was later applied to test Hypothesis 5, presented in Section 5.1.2.4. The same rationale could have been applied to heavy hydrocarbon reserves; however, only four companies would then have been considered. Thus, since the expansion of bitumen and synthetics has taken place relatively recently, we chose to apply the same percentage that the SEC requires for the disclosure of geographic location, which is 15% or more of the company's reserves (SEC, 2009).

5.1.2.2 Accidents

Accidents were also identified as a relevant environmental issue for the O&G E&P industry (see Table 4.1). Scholtens and Boersen (2011), however, find that stocks of oil companies did not suffer significant impacts after accidents between 1907 and 2007. The authors discover no evidence of capital restriction due to the poor environmental image of oil companies and conclude that financial market participants perceive energy accidents as being "part of the game" and discount for most energy accidents in the valuation of the energy industry. However, Heflin and Wallace (2011) provide evidence that not only BP, but also companies operating offshore in the U.S., experienced significant negative returns following the Deepwater Horizon spill in 2010.

Consequently, although there is controversy about whether an oil spill can decrease a company's market value (FODOR and STOWE, 2010; SCHOLTENS and BOERSEN, 2011), it is clear from the Deepwater Horizon accident that an uncontained oil spill can be very costly and that the costs of compensation, cleanup, and remediation are increasing (HEFLIN and WALLACE, 2011; GOLDENBERG, 2013b).

Traditionally, safety indicators have focused on the number of historical accidents or near misses and are known as lagging indicators (SKOGDALEN and VINNEM, 2011). These indicators may not be useful as early warnings (BAKER *et al*., 2009), and there are now an increasing number of studies on leading indicators and analysis involving the identification of root causes. For example, recent research on offshore oil E&P has established a relationship among major hazard precursors to safety culture, noise, and water depths (VINNEM, 2010; MUEHLENBACHS *et al.,* 2013). Of these three factors, only water depth is related to reserves.

As aforementioned, Muehlenbachs *et al.* (2013) demonstrate that deeper oil E&P increases the likelihood of accidents. Therefore, our hypothesis is that companies with deeper reserves are expected to be exposed to greater accident risk, and thus report relatively more risk.

However, Form 10-K and equivalent reports do not require the disclosure of reserve depth. Thus, we have assumed that companies that mention deepwater and ultra-deepwater in the Risk Section of their Form 10-Ks and the equivalents are likely to be ones with more E&P activities in these areas, thereby making the null and alternate hypotheses as follows.

Hypothesis 3

H3a: Companies that mention deepwater in the Risk Section of their Form 10-Ks and the equivalents report more accident risks.

H3b: Companies that mention deepwater in the Risk Section of their Form 10-Ks and the equivalents do not report more accident risks.

5.1.2.3 Sensitive areas/access

The third relevant environmental issue that the industry must tackle is access to reserves located in sensitive areas. Past troubles such as those encountered by Texaco (now Chevron) in Ecuador and by Shell in Nigeria may be a precursor to future systematic difficulties (AUSTIN and SAUER, 2002; AKPAN, 2006). In Chapter 4, the case of the Arctic is discussed, with examples of projects delayed for 30 years and budgets six times greater than the initial estimates (GRONHOLT-PEDERSEN, 2010; CLINT, 2011; HARSEM *et al*., 2011).

When Austin and Sauer (2002) assess the impacts of access risks, they estimate that approximately 40-45% of reserves are located in protected areas. In a scenario representing global support for conservation and the protection of biodiversity, this means that up to 5% of reserves would be considered off limits (AUSTIN and SAUER, 2002). However, with proprietary field information, a further up-to-date analysis could be conducted to determine the percentage of reserve acreage located in sensitive areas.

The acreage of reserves in environmentally sensitive areas is also not reported in Form 10-Ks and the equivalents. Nonetheless, we have assumed, based on data from Clint (2011) and Harsem *et al*. (2011), that development costs for E&P sensitive areas, such as the Arctic, would be on the high side; hence, such areas are likely to attract larger companies with greater investment capacity, leading to our fourth hypothesis.

Hypothesis 4

H4a: The top 50% of companies, measured by reserve size, report more sensitive area/access risks.

H4b: The top 50% of companies, measured by reserve size, do not report more sensitive area/access risks.

5.1.2.4 Water

The last environmental risk selected in this study is water, which has been growing in importance in recent years owing to the boom in shale gas and oil sands (FREYMAN and SALMON, 2013). The IEA estimates that water use could become increasingly challenging for unconventional gas development in parts of China, the U.S., and Canada (IEA, 2012). Moreover, the rapid expansion of shale gas extraction through fracking has raised concerns about groundwater pollution (WILLIAMS, 2012). A U.S. congressional study shows that fracking products contain 29 chemicals that are known to be possible human carcinogens (U.S.HOR, 2011). Thus, both shale gas and oil sands have the potential to face restrictions from water issues, be it from the perspective of consumption or pollution (IEA, 2012; WILLIAMS, 2012; FREYMAN and SALMON, 2013); therefore, we expect that companies with more shale and bitumen reserves will report more water risks.

Unfortunately, it is not possible to differentiate shale gas from conventional gas reserves consistently in all the reports. The two companies with the most gas exposure, EOG and Noble, with gas reserves that make up almost 70% of reserves, report intense shale gas activity. Thus, we will assume that companies with a clear majority of gas reserves include at least some shale gas reserves.

Hypothesis 5

H5a: Companies with ≥ 55% proven gas or ≥ 15% proven heavy oil reserves will report more water risks.

H5b: Companies with ≥ 55% proven gas or ≥ 15% proven heavy oil reserves will not report more water risks.

5.1.3 Data treatment, analysis, and limitations

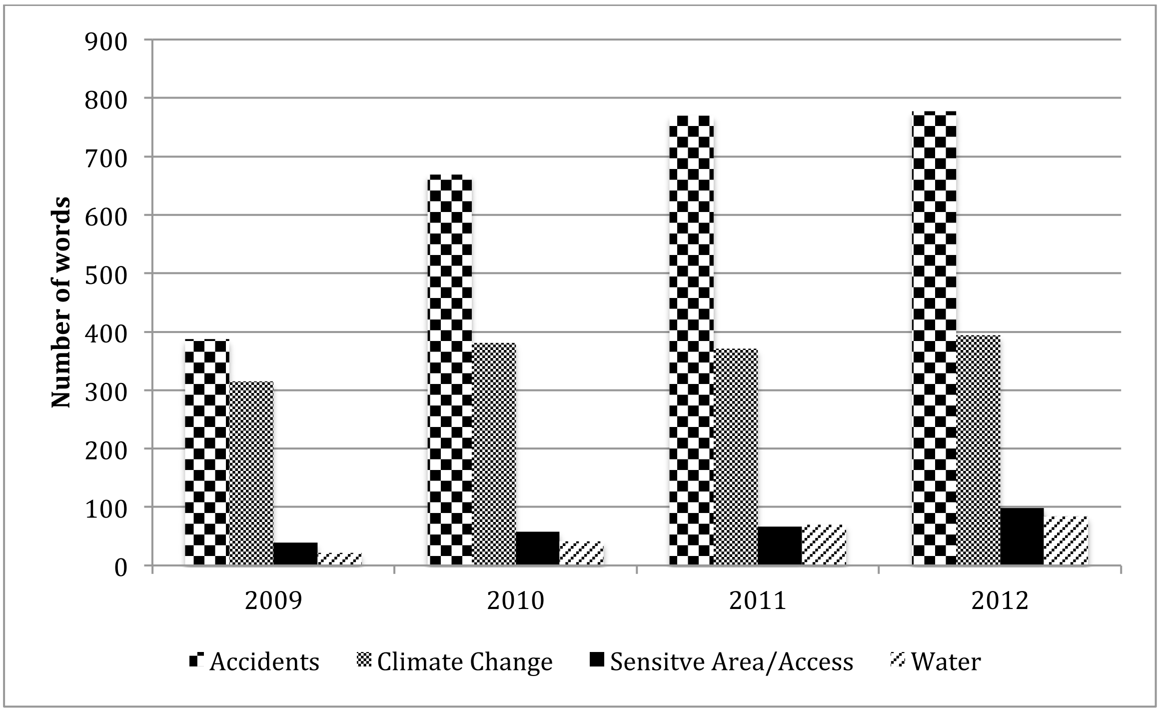
The Risk Factor sections in Form 10-Ks and the equivalents describe all types of risk to which a company is exposed: financial derivatives, accidents, fluctuation of the oil price, political risk, etc. The number of words in these sections of the reports analyzed over four years varies from under 1,000 to more than 17,000. This finding may be due to one company having more risks than another, but most likely reflects cultural behaviors that result in one company being more prolix than another. To decide which indicator to use to test our hypotheses, we performed a correlation analysis between the total environmental keyword count and the total words in the Risk Factor sections. We found a weak correlation in 2009 and 2010 (with Pearson's r ranging from 0.65 to 0.75) and a strong correlation in 2011 and 2012 (with Pearson's r ranging from 0.88 to 0.93). A high correlation means that, in general, the sum of the keywords of the four main environmental risks (see Table 5.2) has the same relative weight in all sampled companies. Since this was not applicable in all years, we opted to perform the tests with the absolute numbers and the percentage of words per category; that is, we divided the words in each category by the total number of environmental words, as presented in Tables A1 through A8 in Appendix A.

To test Hypotheses 1–5, a Student`s t test was used. A Microsoft® Excel spreadsheet with Statplus® support was employed for statistical analyses, applying a one-tail and two-sample unequal variance test using 5% significance. The tests were performed twice per hypothesis, using the absolute and relative risk factor word count. Appendix B, Tables B1-B6 show the companies in each of the performed tests.

In this study, we assumed that O&G companies know and adequately report their environmental risks. This is exploratory research in that few prior studies have attempted to relate reserves to environmental risk; therefore, our assumption is likely to be an oversimplification of reality, but is considered sufficient for this simple analogy.

5.2 Results and discussion

It should be noted that the reports were reviewed for the fiscal year prior to the Deepwater Horizon oil spill, which occurred in April 2010, and for the three years after the accident. The category with the largest number of words in the Form 10-Ks and the equivalents for all four years is Accident, followed by Climate Change, which agrees with what was reported by BDO (2013) and EY (2013) (Figure 5.1). The 73% observed increase in the number of words related to accidents from 2009 to 2010 is a clear result of the impact of the Gulf of Mexico oil spill.



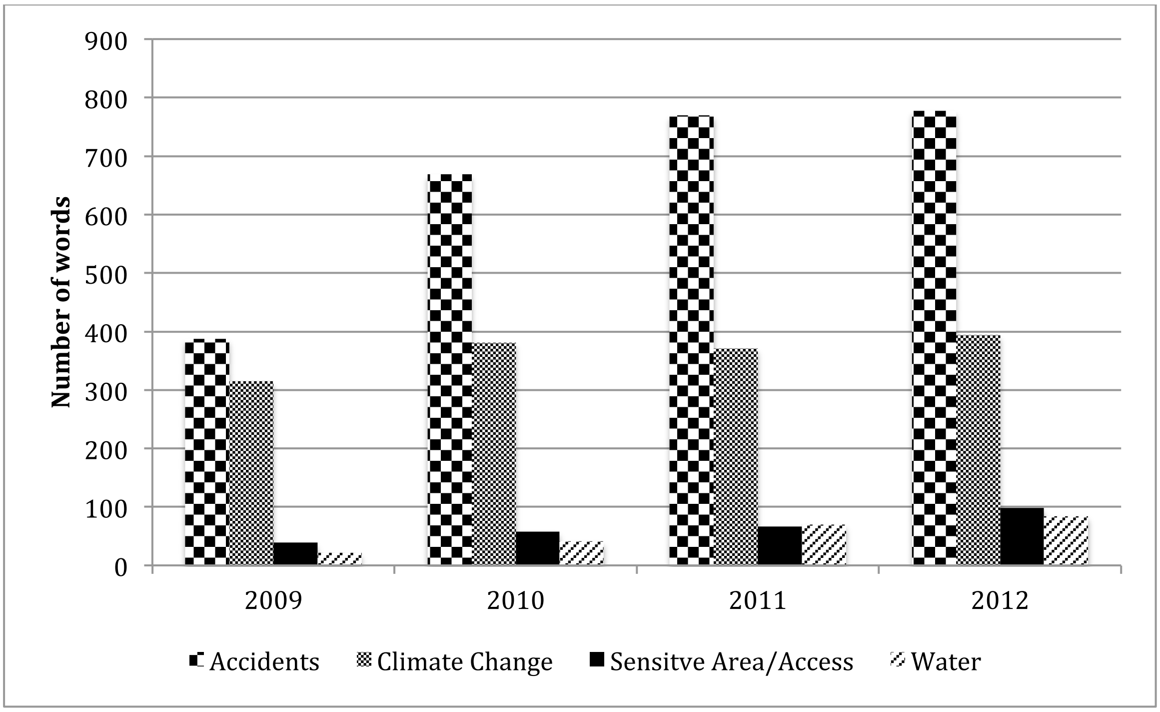


Figure 5.1 Total number of words per environmental risk

Climate change increased by 25% during the four-year period. Water, as a material risk, is an incoming issue because it is mainly associated with the recent production of shale gas and oil sands, so it would be expected to be lower than the others; nonetheless, it is increasing at an average rate of 59% per year. The surprise is the low frequency of words related to the sensitive area/access issue because this topic has been followed by the industry since the beginning of the environment movement and has been the subject of a number of IPIECA and OGP guidance documents. The Risk Factor sections of the reports have also expanded because companies are either more exposed to risks or more prolix. During the period analyzed, these sections grew by 45%, mainly because of ENI and Noble. Thus, the importance of considering the absolute and relative numbers of the counted keywords is confirmed.

The summary statistics for the tests with reserves (the tests for Hypotheses 1 through 5) are shown in Tables 5.3 and 5.4. In order to be conservative, the null hypothesis was only rejected if it failed the tests with percentages and absolute values in the four years studied.

Table 5.3 P-values of the Student t-tests for the relative keywords

Years	Hypothesis I		Hypothesis II		Hypothesis III		Hypothesis IV	Hypothesis V
	Climate Change Sum	Emissions Control	Climate Change Sum	Emissions Control	Accidents Sum	Spills	Sensitive	Water
2009	0.077	0.037	0.326	0.166	0.125	0.214	0.060	0.078
2010	0.161	0.042	0.363	0.041	0.42	0.070	0.006	0.202
2011	0.014	0.012	0.467	0.063	0.030	0.122	0.007	0.019
2012	0.014	0.009	0.447	0.454	0.030	0.103	0.100	0.059

Table 5.4 P-values of the Student t-tests for the absolute keywords

Years	Hypothesis I		Hypothesis II		Hypothesis III		Hypothesis IV	Hypothesis V
	Climate Change Sum	Emissions Control	Climate Change Sum	Emissions Control	Accidents Sum	Spills	Sensitive	Water
2009	0.084	0.044	0.011	0.395	0.065	0.058	0.137	0.015
2010	0.041	0.023	0.041	0.378	0.006	0.023	0.034	0.063
2011	0.138	0.036	0.0003	0.302	0.008	0.026	0.031	0.040
2012	0.155	0.031	0.139	0.253	0.008	0.020	0.278	0.060

5.2.1 Climate change

All sampled companies reported climate change risk from 2010 onward. This was a significant evolution, considering that, in an earlier review, Austin and Sauer (2002) find that only BP and ConocoPhillips made any reference to climate change in their Form 10-Ks or the equivalents.

The sum of the results for the four categories under climate change (Table 5.3) was used to test Hypotheses 1 and 2. In both cases, the null hypothesis is accepted for total proven reserves. For Hypothesis 1, the p-values vary from 0.155 to 0.014 among the years studied within the absolute number of words and the percentage; for Hypothesis 2, the p-values have a wider variation among the absolute and relative values, as observed in Tables 5.3 and 5.4.

However, when the focus was placed on one category of climate change, that is, emissions control, the results are different for Hypothesis I. We can affirm with 95% certainty that companies owning 15% or more bitumen and synthetic reserves report relatively and absolutely more emission control risks than companies with little or no heavy oil reserves. The p-values vary from 0.009 to 0.044 in all years, which means that we can accept the alternative hypothesis with 95% certainty in all cases. The majority of the companies with heavy oil reserves greater than 15% are highly specialized with high exposure to oil sands. The fact that they report more emission control risks confirms the findings of the CTI (2013), and leads to the conclusion that these organizations are less resilient to a carbon-restricted scenario. Despite this risk, heavy oil reserves increased their participation in the profiles of the sampled companies' reserves from 17% in 2009 to 19% in 2012, as shown in Table 5.1.

Unlike the expectation of the Spedding *et al.* (2013) analysis, companies with the majority of gas reserves (Hypothesis 2) do not report relatively fewer climate change issues. For this test, the results are contradictory using absolute and relative risk factors. The mixed results may be due to our sample companies in this test. Only one company holds more than 60% gas reserves (Noble), whereas for Hypothesis I, more than half of the sample is composed of companies holding over 15% in heavy oil reserves.

Another interesting aspect is the high number of keywords regularly obtained in the subcategory Physical Effects, which seeks to measure the impact of the changing weather on E&P activities (see Tables A1-A8 in Appendix A). Further research is needed in order to understand which reserve types are more exposed to these effects of climate change. Intuitively, it should be expected that offshore activities are more often subject to weather-related risks. Another category under climate change, Renewable Energy, has frequent low word counts as can be seen in Tables A1-A8 in Appendix A, revealing that O&G companies clearly do not see alternative energy sources as a threat to their businesses.

5.2.2 Accidents

Four tests were also performed for Hypothesis 3, which investigated whether companies that mentioned deepwater and ultra-deepwater reserves in their Form 10-Ks and the equivalents report relatively more accident risks. The tests involved absolute and relative risk factor keywords for the sum of all accident code categories and the subcategory of spill. For absolute value, both in terms of accident sum and spills, we can reject the null hypothesis with 90% certainty, indicating that companies with deepwater and ultra-deepwater reserves report more accident risks. The relative values, nonetheless, are not so clear, with results differing significantly every year.

Mentioning the words deepwater and ultra-deepwater may not be good proxies for actual E&P scenarios. It would be necessary to estimate the average depth of each company's reserves in order to perform the test.

5.2.3 Sensitive areas/access

Depending on the year, four to eight companies have no keywords for risks under the category of sensitive area/access; indeed, the overall count is relatively low (see Figure 5.1). Several explanations can be given for the meager references that these critical issues receive in the Form 10-K and equivalent reports. First, companies may not regard these issues as material; consequently, they discuss them only in their sustainability or annual reports. Second, investors, to whom the Form 10-Ks are directed, may be unfamiliar with the issues. For example, the word biodiversity appears only five times in four years in 24 company reports, although this is an issue that merits its own discussion group and publications within IPIECA. Third, O&G companies have always explored at the frontiers and have dealt with access and sensitive area issues previously; thus, the delays and costs incurred by these challenges have already been incorporated in corporate valuations.

The test to see whether companies with higher reserves report more sensitive area/access risks yielded mixed results, as reflected in Tables 5.3 and 5.4. The null hypothesis is accepted, and no difference exists between the reporting of the largest companies and the others. Thus, our assumption that companies with large reserves operate in more sensitive areas may not be valid. A further test with the reserves under conservation units would be ideal.

5.2.4 Water

According to the BDO (2014) report, companies in the U.S. expect imminent restrictive water legislation that will affect shale gas production. Water is becoming an increasing risk for O&G companies. In this study, we can reject the null hypothesis and affirm with 90% certainty that water risks are related to companies with heavy oil reserves greater than or equal to 15% or gas reserves greater than or equal to 55%, considering both absolute and relative risk factors. However, it is worth noting that since the numbers are very small, any error can influence the results considerably. The Golf of Mexico accident in 2010 probably reduced the percentage of the water risks suffered, although the absolute number increased. Thus, the p-value for 2010 seen in Table 5.3 is 0.202, the only one below 10%.

In sum, we have shown that three of the four material environmental issues are linked to the reserve profiles of the companies studied. For example, companies with heavy oil reserves report relatively more exposure to climate change risks, particularly emissions control. As predicted by CTI (2013), in a carbon-restricted scenario, these companies are likely to suffer more. A recent example of how this is reflected in the business of such companies is the delay in the approval of the Keystone pipeline project, which, in turn, has increased transportation costs and led to the suspension of further production capacity expansion (BRODER, 2013). Yet the relative percentage of heavy oil reserves is increasing, on average, among the 24 sampled companies.

Companies with ultra-deepwater and deepwater reserves may also be more exposed to the risk of accidents because they are particularly vulnerable to spills. According to Visiongain (2013), the global deepwater and ultra-deepwater market has been growing rapidly and will continue to increase from 2013 to 2023.

Further, companies with heavy oil reserves or those with a greater amount of natural gas reserves also report significantly more water risks. Both oil sands and shale gas require more water than conventional production (IEA, 2012; WILLIAMS, 2012). In addition, Freyman and Salmon (2013) claim that more than 20,000 O&G wells in the U.S. are located in areas with “high and extremely high water stress.” These factors could contribute to an increase in costs or an imposed restriction on operations or capacity expansion.

Nonetheless, current reserve reporting practices do not require companies to differentiate conventional natural gas from gas extracted through hydraulic fracturing; nor do companies have to identify the water depths from which oil and gas is being extracted. Thus, in the next chapter, we will use a reserve database (Cube Browser) to create a reserve profile for the 24 studied companies that will allow investors to easily identify the companies that are more exposed to climate change, accidents, and water risks.

6. A proposal for environmental risk indicators based on reserve profiles

The results of the statistical tests performed in Chapter 5 indicate three environmental risk issues that have clear connections with companies' reserve profiles: (1) greater climate change risks are reported by companies that have more bitumen reserves; (2) greater accident risks are present in companies that mention activities in deepwater or ultra-deepwater; and (3) companies with heavy oil reserves greater than or equal to 15% and with gas reserves greater than 55% report more water risks.

Many simplifications were used when developing each hypothesis to overcome the limitations in reported data, in this chapter, we will propose indicators that enable investors to identify exposure to such risks clearly. In addition, these indicators will be applied to the 24 companies studied in Chapter 5, but now using more complete reserve data from Rystad Energy's global database Cube Browser (RYSTAD ENERGY AS, 2015), instead of the reported reserves in the Forms 10k (and equivalent). Thus, it will be possible to distinguish the different types of unconventional oils and gas, and thus, identify companies more vulnerable to climate change, accident, and water risks.

6.1 Indicator Proposal

6.1.1 Climate change and water

Climate change and water risks are tied to the identification of the unconventional O&G reserves among the companies' reserve portfolios, as discussed in Chapter 5. Please see Chapter 3 for a discussion of conventional and unconventional oil definitions.

In hypothesis 1 in Chapter 5, only companies with bitumen and synthetic oil reserves were contemplated in “heavy” reserves because in current reporting requirements it is not possible to distinguish other unconventional oils such as extra-heavy and tight oil. However, Engelder (2011), Weber and Clavin (2012), Brandt (2009), CTI (2013) and ETSAP (2010) all argue that tight oil and extra-heavy oils reserves are also affected by a carbon restricted scenario.

Further, previously in Hypothesis 5 it was assumed that companies with a clear majority of gas reserves include at least some shale gas reserves, which are more water sensitive (FREYMAN and SALMON, 2013; WILLIAMS, 2012). However, the ideal is to be able to differentiate shale gas from traditional associated natural gas. Thus, for both climate change and water risks, being able to identify each type of unconventional reserves is necessary.

Hence, the proposed indicator would read as follows:

Companies should report the percentage of unconventional oil and gas reserves disaggregating the liquids into conventional oil[23], oil sands[24], extra heavy oil[25] and tight oil,[26] and the gas into conventional gas and unconventional gas.

6.1.2 Accidents

[23] Conventional oil in Cube Browser refers to conventional reservoirs (ie good permeability), conventional hydrocarbons (ie not extra heavy crude) or conventional recovery methods (ie not hydraulic fracturing)

[24] Oil sands in Cube Browser refers to oil extracted by either mining or SAGD (Steam Assisted Gravity Drainage)

[25] Extra Heavy Oil is crude with 10°<=API<=14° and viscosity between 100 and 10 000 cP.

[26] Tight oil in Cube Browser includes development that requires fracturing of the reservoir. This includes shale oil. Shale oil is a petroleum source rock with high content of immature hydrocarbons (kerogen), the rock is mined and can burn like coal, or oil and gas can be baked out from the mined rock by pyrolysis.

In the KWIC analysis performed in Chapter 5, companies that mention deepwater and ultra-deepwater in the Risk Section of their Form 10-K and equivalents are also the ones that report more accident risks. This was also an assumption since it is not possible to distinguish the location of reserves in terms of water depth. Vinnem (2010) and Muehlenbachs *et al.* (2013) both point to water depth as a possible leading indicator to potential accident risk.

Thus, the proposed indicator would read as follows:

Companies should report percentage of reserves on land, offshore shelf (0-125 m depth), deepwater (125 m - 1500 m depth) and ultradeepwater (deeper than 1500 m).

6.2 Application

As mentioned in Chapters 2 and 5, the US SEC does not require companies to report certain characteristics of their reserves that would aid investors and other market players to determine the exposure of their stocks to environmental risks. Other reporting standards analyzed (chapter 3), IPIECA (2011), CDP (2014) and the GRI (2012), also do not include any reserve characteristics among their indicators. Therefore, companies do not report water depths nor discriminate unconventional reserves from traditional oil and gas reserves. Hence, a private commercial database, Rystad Energy's Cube Browser (RYSTAD ENERGY AS, 2015), was acquired and used to develop the indicators.

6.2.1 Reserves in Cube Browser

Cube Browser does not work directly with reserves; instead, it works with resources. In the O&G industry, there is a distinction between resources and reserves. According to Babusiaux and Bauquis (2007), “resources correspond to hydrocarbons in the ground, whether or not they are recoverable." Reserves, according to the American Association of Petroleum Geologists (AAPG, 2000), the Society of Petroleum Engineers (SPE, 2000), and the World Petroleum Council (WPC, 2000), are "quantities of petroleum which are anticipated to be commercially recovered from known accumulations from a given date forward."

The resources in Cube Browser correspond to the expected ultimate recovery (EUR) of the fields, based on reported 1P[27] and 2P numbers as well as empirical studies and case-by-case judgments. The EUR in Cube Browser includes contributions from reserves (producing and planned), contingent resources (potential wells in known reservoirs), and prospective resources (potential exploratory wells in new reservoirs). Figure 6.1 below presents the different definitions of reserves that make up the total expected ultimate recovery of the total petroleum initially in place.

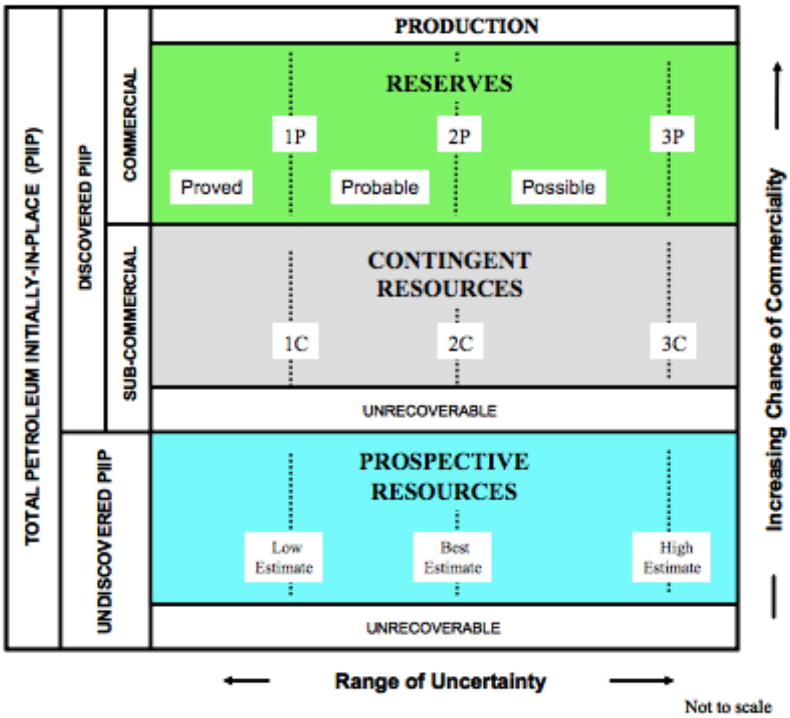


Figure 6.1 Resource classification system (source: SPE, 2011)

[27] Reserves may be assigned to the project, and the three estimates of the recoverable sales quantities are designated as 1P (Proved), 2P (Proved plus Probable), and 3P (Proved plus Probable plus Possible) Reserves. (SPE. 2011)

For companies listed on the NYSE, the SEC defines proven reserves as those whose existence has been proven on the basis of geological, technological, and economic data with reasonable certainty. According to Babusiaux and Bauquis (2007), these reserves are fairly conservative estimates because companies are constantly reevaluating upward by a significant magnitude. The reserves available to companies complying with the SEC norms represent approximately 5% of global reserves (BABUSIAUX and BAUQUIS, 2007).

In order to construct the indicators, it was first necessary to transform the resources in Cube Browser to reserves equivalent to those required by the SEC. To achieve this, the Cube Browser software developers recommend using filters in the Resource Classification Proxy[28] (selecting "P90"[29]) and Life Cycle category[30] (selecting "producing" and "under development"). Further, in the Entitlement category,[31] "company only" was selected, thus excluding governments.

Table 6.1 presents the reserves in 2012 collected from Form 10-Ks and equivalents (presented in table 5.1), and compares them to the reserves in Cube Browser for the

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[28] The Resources variable can be split by the Resource Classification Proxy. This split is modeled; the purpose is to simulate the process of maturing the resources at asset level. Before the license is awarded, the resources are "prospective unawarded." Through seismic interpretation, exploration, appraisal, and field development, the resources are gradually matured to P50 and P90 resources, and the remaining resources decrease as resources are produced. Note that since P50 includes P90, and Pmean includes P50, we display the additive "P50 (increment)" and "Pmean (increment)." Thus P50 = P90 + P50 (increment). The Resource Classification Proxy can be used to analyze how companies mature their portfolios, and to estimate 1P and 2P-values at portfolio level.

[29] In Cube Browser, P90 is defined as "a low estimate of the remaining recoverable volumes. The engineering term P90 refers to 90 percent engineering probability, is a commonly accepted specific definition by the Society of Petroleum Engineers, and does not take into account anything except technical concerns. Therefore, it is different from the business term that does take into account current break-even profitability, and regulatory and contractual approval, but is considered a very rough equivalent. The definition is certainly not universal. The Energy Watch Group uses a different definition, P95."

[30] The Life Cycle category splits Values among currently producing assets, abandoned assets, assets under development, discoveries, and undiscovered assets.

[31] The Entitlement split allows us to separate a company's net entitlement production from the gross wellhead production. The difference is due to Royalty and special participation effects.

24 companies. The average error of 17% is due to the difference in ownership consolidation in Cube Browser.[32] For instance, with regard to Imperial, which presents a difference of 70%, Cube Browser only accounts for the 30% reserves and cash flows that are not owned by Exxon. In the case of BP, Cube Browser does not account for the 20% ownership in Rosneft.

Table 6.1 Comparison between Cube Browser reserves and SEC

Companies	Reserves in 2012 (MBOE)		Difference (%)
	Cube Browser	SEC*	
Exxon	21464	25165	15
PetroChina Company Limited	21802	28066	22
Chevron Corp.	10989	11347	3
Shell	15547	13328	-17
BP	9369	16768	44
Total	9313	10831	14
Petrobras	10809	12896	16
China Petroleum and Chemical Corp.	4532	3965	-14
CNOOC Limited	3810	3182	-20
ENI	6678	6843	2
Statoil	6174	5227	-18
Conoco Phillips	8072	8642	7
Occidental Petroleum Corp.	3305	3296	0
Suncor	2568	4099	37
Anadarko	2750	2560	-7
EOG	1953	1810	-8
Imperial	1070	3574	70
Canadian Natural Resources	4522	5018	10
Apache	2107	2852	26
Hess	1254	1554	19
Marathon	1699	1800	6
Cenovus	1237	2175	43

[32] Most companies operating in multiple countries are operated locally by fully owned daughter companies. Cube Browser does not distinguish between these companies, which are fully consolidated.
In some countries, operations are undertaken through joint venture operating companies. Examples are BPTT and BPTNK. In these cases, equity production is consolidated; that is, the owners may be BP and TNK but the operator is BPTNK. Further, some companies have bought into other companies. In this case, the main rule is that equity production is consolidated when the owner's share is 50% or above.

Devon	2811	2963	5
Noble	1149	1184	3

Notes:
* SEC corresponds to the reserves found in the Form 10-K reports and equivalents presented in Chapter 5 (source: developed by author).
MBOE is one million barrels of oil equivalents.

6.2.2 Applying indicators using Cube Browser

For climate change and water indicators, it is necessary to distinguish all the different types of unconventional reserves. In Cube Browser, this means adding categories for the data split, including the Oil and Gas Group, which disaggregates the data in liquids and gas. A further split is then performed with the Unconventional category, which disaggregates the liquids into conventional oil,[33] oil sands,[34] extra heavy oil,[35] and tight oil,[36] and the gas into conventional gas and unconventional gas.[37]

The accidents reserve indicator requires water depth location. Therefore, in order to develop a reserve depth, a category was added to split the data, the Well Water Depth Group, in Cube Browser. The Well Water Depth Group splits the selected reserves between land, offshore shelves (0-125 m depth), deepwater (125-1500 m depth), and ultra-deepwater (deeper than 1500 m).

[33] Conventional oil in Cube Browser refers to conventional reservoirs (i.e., good permeability), conventional hydrocarbons (i.e., not extra-heavy crude), or conventional recovery methods (i.e., not hydraulic fracturing).

[34] Oil sands in Cube Browser refers to oil extracted by either mining or SAGD (steam-assisted gravity drainage).

[35] Extra-heavy oil is crude with 10°≤API≤14° and viscosity between 100 and 10,000 cP.

[36] Tight oil in Cube Browser includes development that requires fracturing of the reservoir. This includes shale oil. Shale oil is a petroleum source rock with a high content of immature hydrocarbons (kerogen). The rock is mined and can burn like coal, or oil and gas can be baked out from the mined rock by pyrolysis.

[37] Unconventional gas in Cube Browser refers to shale gas, tight gas, and coalbed methane.

6.2.3 Results

The SEC requires that reserves must be disclosed as an aggregate, by geographic area, and for each country that contains 15% or more of the company's proven total of global oil and gas reserves. According to EY (2009), the SEC generally believes that investors benefit from more specific geographic disclosure, rather than disclosing reserves within "groups of countries," because some countries with significant reserves can be subject to unique risks such as political instability. The SEC believes these geographic disclosures provide the necessary detail for investors to make decisions without detracting from overall disclosure.

Applying the same 15% threshold to environmental risks, we propose that in the case of climate change, companies disclose unconventional oil reserves that are 15% or more of their proven total of global oil and gas reserves. Tables C1 and C2 in Appendix C present the companies' reserve profiles using data from Cube Browser.

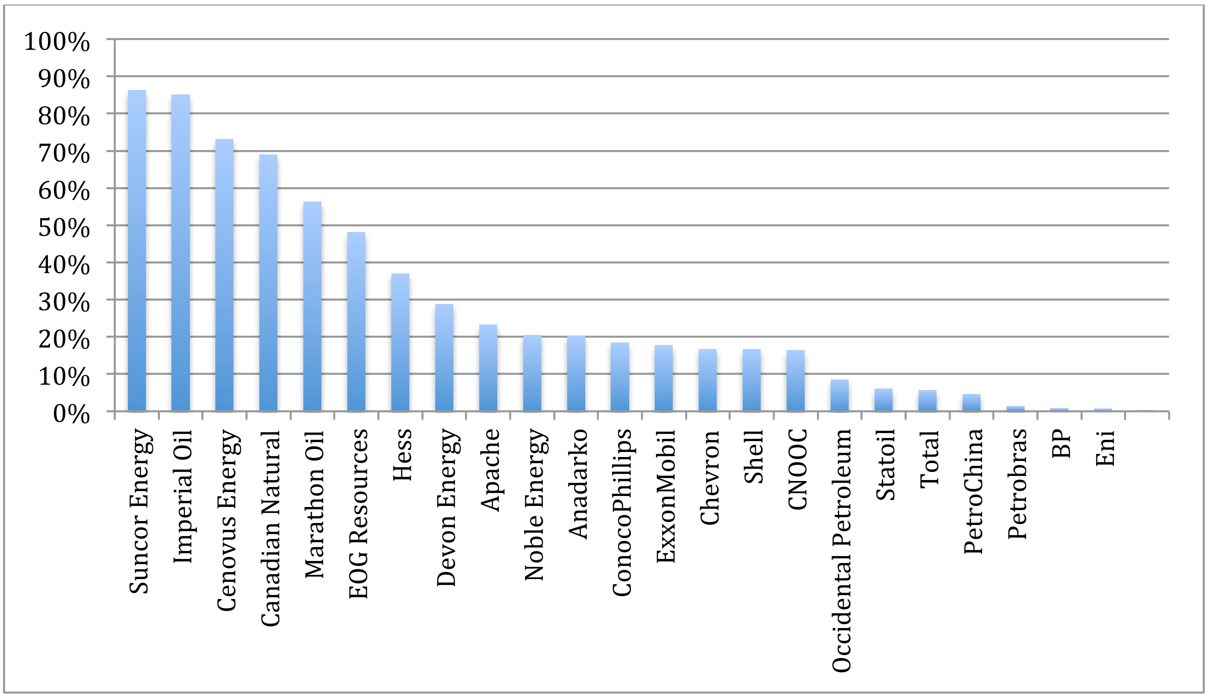
Under current SEC reporting guidelines, it is already possible to distinguish bitumen and synthetic oil (oil sands) from conventional oil production, but extra-heavy and tight oils are not identifiable. According to the sources included in the discussion in Chapter 5, all unconventional oils (oil sands, tight oil, and extra-heavy oil) significantly increase GHG emissions and thus pose a risk to companies that hold these reserves because of the possibility of tighter climate change restrictions. In addition, oil substitution due to climate change restrictions can also decrease demand and lower prices, which would affect unconventionals significantly (CTI, 2014). Table 6.2 presents the differences between the data gathered from Form 10-Ks and the equivalents, presented in Table 5.1 (under the Heavy category), and the data found using Cube Browser.

Table 6.2 Identifiable unconventional oil reserves (%) (year: 2012)

FORM 10-K		CUBE BROWSER	
Imperial	96	Suncor	86
Suncor	88	Imperial	85
Cenovus	79	Cenovus	73
Canadian Natural Resources	66	Canadian Natural Resources	69
Marathon	35	Marathon	56
Conoco Phillips	22	EOG	48
Devon	18	Hess	37
Exxon	17	Devon	29
Shell	14	Apache	23
Total	10	Noble	20
Chevron Corp.	7	Anadarko	20
CNOOC Limited	5	Conoco Phillips	18
BP	1	Exxon	18
Petrobras	0	Chevron	17
PetroChina Company Limited	0	Shell	17
China Petroleum and Chemical Corp.	0	CNOOC Limited	16
ENI	0	Occidental Petroleum Corp.	8
Statoil	0	Statoil	6
Occidental Petroleum Corp.	0	Total	6
Anadarko	0	PetroChina Company Limited	5
EOG	0	Petrobras	1
Apache	0	BP	1
Hess	0	ENI	1
Noble	0	China Petroleum and Chemical Corp.	0

Source: developed by author.

In Cube Browser, 16 companies were identified as having unconventional oil reserves above the 15% threshold in 2012 (see Figure 6.2), whereas the current SEC requirements enable investors to identify only 8 corporations. We can infer that currently investors are unable to identify 50% of the current stocks in the sample that are subject to climate change risks; that is, the market may be unaware of the risks in these stocks.



Source: developed by author from Cube Browser data.

Figure 6.2 Unconventional oil reserves (year: 2012)

No relationship was found to reinforce Spedding *et al.*'s (2013) proposal that natural gas "would be less affected in a low-carbon world." However, given the controversy regarding the life cycle emissions of shale gas (WEBER and CLAVIN, 2012), in addition to the water scarcity and pollution issues, it is crucial for the market to distinguish between conventional and unconventional gas reserves. With current SEC reporting requirements, this distinction is not mandatory, as seen in Table 5.1. Hence, Table 6.3 presents the conventional gas reserves gathered in Cube Browser compared with the total gas reserves collected from the Form 10-K and equivalents for the year 2012.

Table 6.3 Identifiable conventional gas reserves (%) (year: 2012)

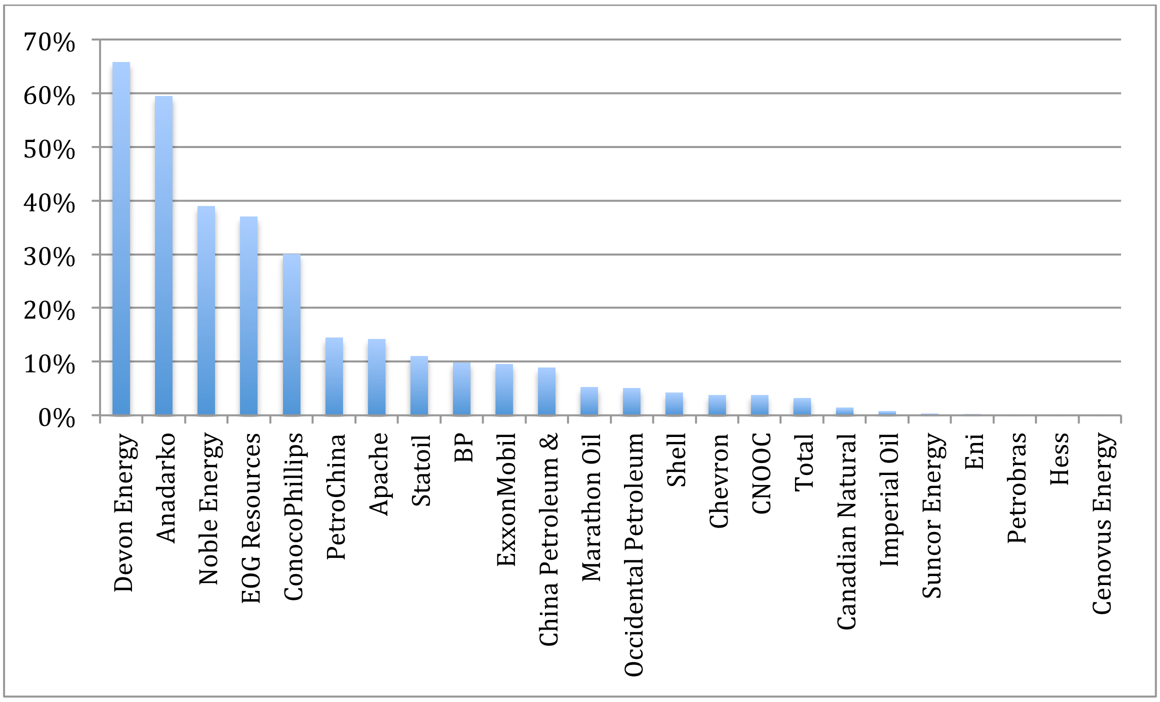
FORM 10-K		CUBE BROWSER	
Noble	70	Statoil	49
Statoil	54	ENI	48
Anadarko	54	Total	44
Shell	54	Shell	42
Devon	53	Chevron	41
ENI	51	Exxon	39
Apache	49	Occidental Petroleum Corp.	38

Exxon	49	BP	37
Total	48	Apache	32
EOG	44	Noble	30
Chevron	43	PetroChina Company Limited	29
PetroChina Company Limited	40	Conoco Phillips	26
BP	40	CNOOC Limited	23
Conoco Phillips	38	China Petroleum and Chemical Corp.	18
CNOOC Limited	31	Petrobras	17
China Petroleum and Chemical Corp.	28	Hess	14
Occidental Petroleum Corp.	28	Cenovus	13
Marathon	25	Canadian Natural Resources	13
Hess	25	EOG	12
Petrobras	15	Marathon	10
Canadian Natural Resources	14	Anadarko	4
Cenovus	7	Imperial	3
Suncor	3	Devon	2
Imperial	2	Suncor	0

Source: developed by author.

For 2012, Noble, Anadarko, and Devon reported gas reserves above 50% on their Form 10-Ks (see table 5.1). However, according to the Cube Browser conventional gas reserves, these three companies have 30%, 4%, and 2% respectively. EOG gas reserves also changes significantly when excluding shale gas, from 44% to 12%. The difference between such values is explained by the SEC's adoption of rules in 2009 that revised the definition of ''oil and gas producing activities'' to include the extraction of saleable hydrocarbons, in the solid, liquid, or gaseous state, from oil sands, shale, coalbeds, or other nonrenewable natural resources which are intended to be upgraded into synthetic oil or gas, and activities undertaken with a view to such extraction"(SEC, 2009). Hence, companies are required to report unconventional production and reserves together with conventional, without being necessary to differentiate among them. Note that in the Modernization of Oil and Gas Reporting (SEC, 2014) there is a provision for companies to optionally disclosure of oil and gas reserves' sensitivity to price, which according to CTI (2014) would also indicate unconventional reserves that are more costly than traditional oil.

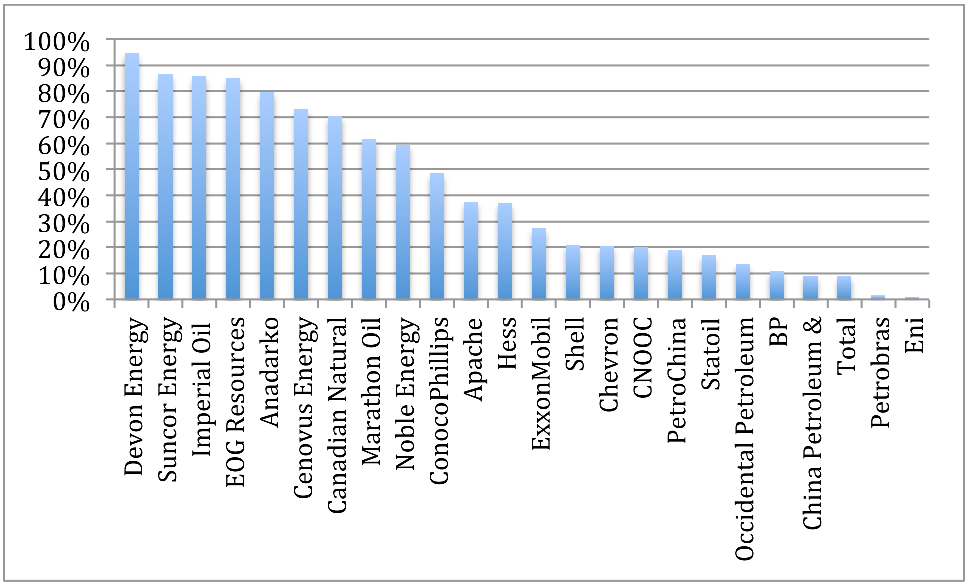
According to Table 6.3, the companies with less climate change risk (that is, with more conventional gas reserves) are Statoil, ENI, Total, Shell, and Chevron, assuming Spedding *et al.*'s (2013) proposal is correct, that conventional natural gas will be a winning technology in a low carbon world. In contrast, considering only liquids production, the companies with more exposure to climate change risk (as shown in Figure 6.2) are Suncor, Imperial, Cenovus, Canadian Natural Resources, and Marathon.



Source: developed by author from Cube Browser data.

Figure 6.3 Unconventional gas reserves (year: 2012)

The discussion and test results in Chapter 5 suggest unconventional oil and gas may face restrictions from water issues, whether from the perspective of consumption or pollution (IEA, 2012; WILLIAMS, 2012; FREYMAN and SALMON, 2013); therefore, we find that companies with more unconventional oil and gas reserves report more water risks. Figures 6.2 and 6.3 present companies with most percentage reserves of unconventional oil and gas, respectively. Figure 6.4 shows the percentage of unconventional reserves, oil and gas combined, of the 24 companies in the study sample.



Source: developed by author from Cube Browser data.

Figure 6.4 Unconventional O&G reserves (year: 2012)

After applying the determined threshold, only six of the 24 companies analyzed have less than 15% unconventional oil types reserves (the Occidental Petroleum Corp., BP, the China Petroleum and Chemical Corp., Total, Petrobras, and ENI). Hence, the companies most exposed to water risks; i.e., with reserves containing oil sands, extra heavy oil, tight oil and shale gas; are Devon (95%), Suncor (87%), Imperial (86%), EOG (85%), and Anadarko (80%).

Finally, companies that mention deepwater in the Risk Section of Form 10-Ks and the equivalents report more accident risks. Thus, investors need to know the depth of the companies' reserves. The depth categories fro deep and ultra-deepwater used by Cube Browser (described in section 6.2.2) are very similar to those used by the EIA (2009) (shallow: 0-999 ft (0-304 m); deepwater: 1000-4,999 ft; (304-1523 m) and ultra-deepwater: 5,000+ ft (1524m+)

Only two companies have ultra-deepwater reserves above the threshold, Petrobras (40%) and Noble (16%), as shown in Figure 6.5. But when ultra-deepwater reserves are added to deepwater reserves (as shown in Figure 6.6), that number increases to nine companies, the top five being Petrobras (86%), Statoil (69%), Chevron (27%), ENI (27%), and BP (26%).

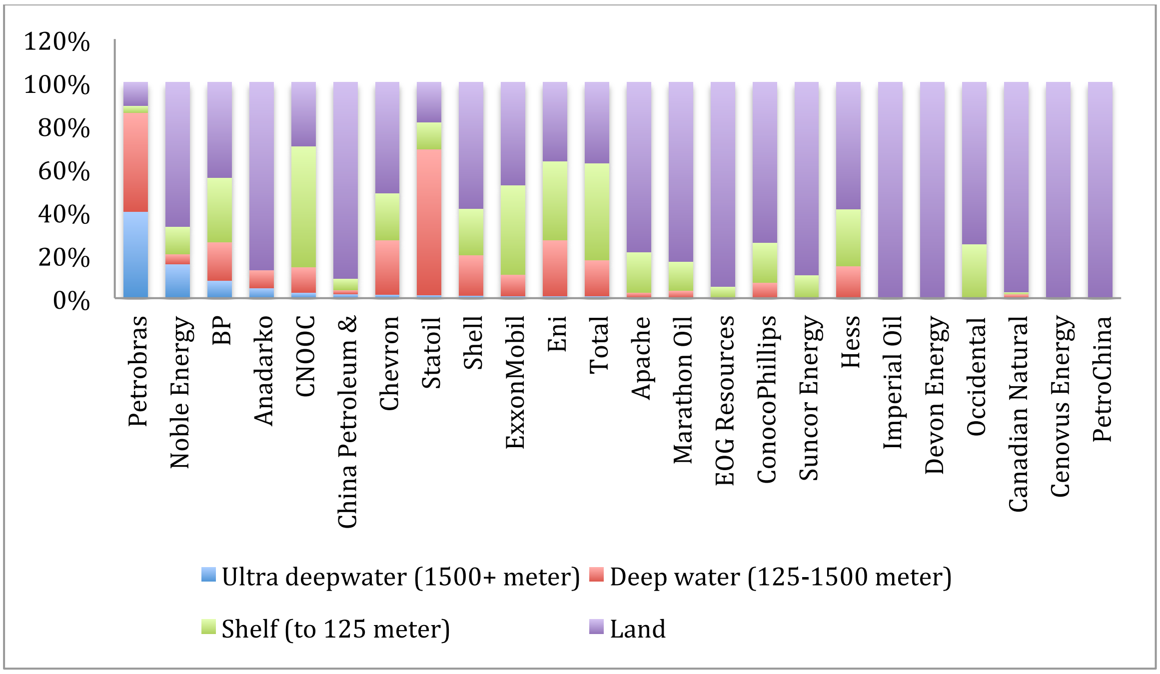


Figure 6.5 Ultra-deepwater, deepwater, shelf, and land reserves (year: 2012)

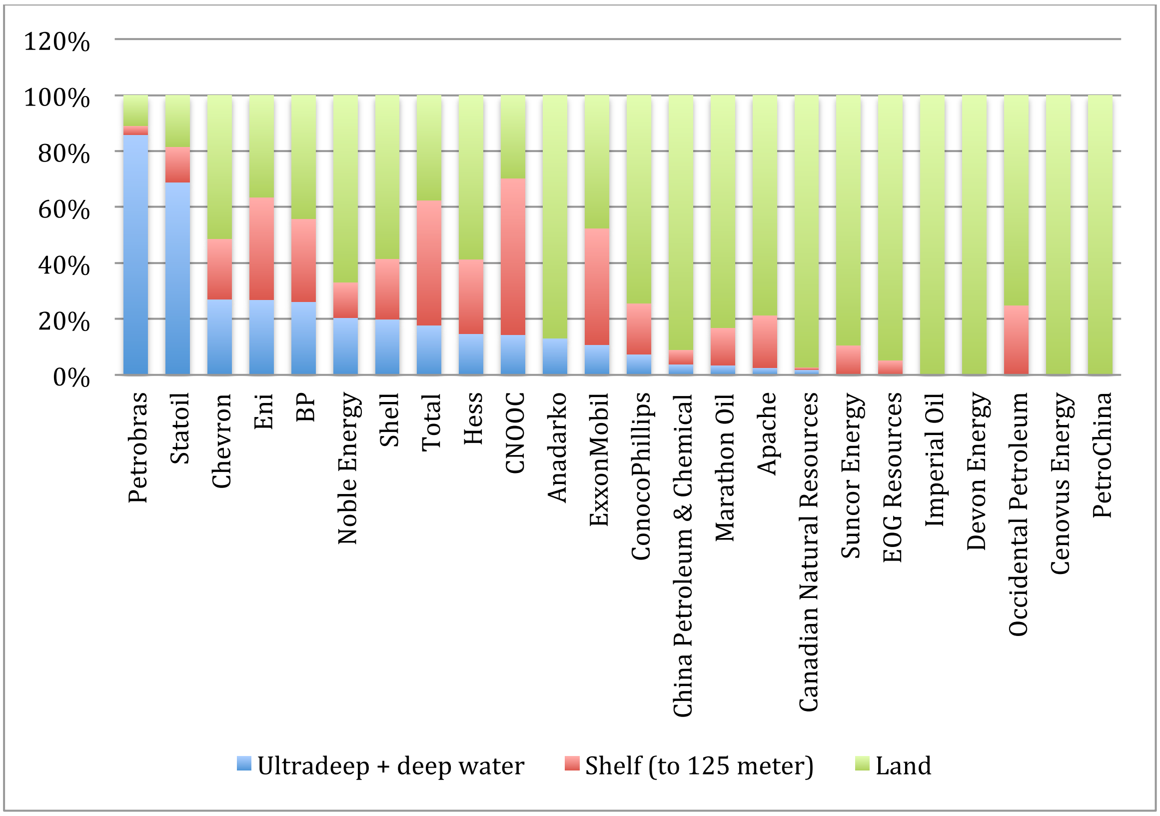


Figure 6.6 Deep and ultra-deepwater, shelf, and land reserves (year: 2012)

Clearly, listed companies are significantly exposed to climate change, water risks, and accident risks, and current SEC disclosure requirements do not enable investors to identify them correctly. This can lead to inept decision-making, exposing pension funds and other market players to risks they could be unaware of.

7.0 Final Considerations

The Deepwater Horizon Accident may have shaken the sustainability ratings and indexes credibility, but it also reinforced their importance. The O&G E&P is a highly impacting sector, as seen in chapter two, and as unconventional production grows, so do the environmental risks. As discussed in chapter three, there is already a plethora of sustainability raters using a variety of definitions, indicators and methodologies. However, it is important to note that they are all unregulated as are the voluntary reporting standards. In addition, weather or not ESG management results in better financial performance in O&G is still not clear. However, there are environmental risks that can bring material losses (or gains) to companies exploring oil and gas (observed in chapter four), and thus should be carefully analyzed when selecting companies to invest in. In chapter 5 it was clear that some of these risks, for instance, climate change, accidents, and water, are directly related to the type of reserves the company is or will be exploring. Thus, a new set of forward-looking quantitative indicators was proposed to assist investors, credit agencies and sustainability raters and indexes to easily identify companies that are more exposed to each of these risks.

In Chapter 2, seven main environmental issues the E&P industry were presented showing how the new frontier oils are exacerbating these challenges, as can be seen in Figure 7.1. When placed under a materiality lens in a literature review, four issues were selected as impacting the bottom line of companies. It was not possible to identify clearly a relationship to reserves for the sensitive area/access issue, thus two quantitative indicators were developed that can be used as proxy of environmental risk for climate change, water and accidents.

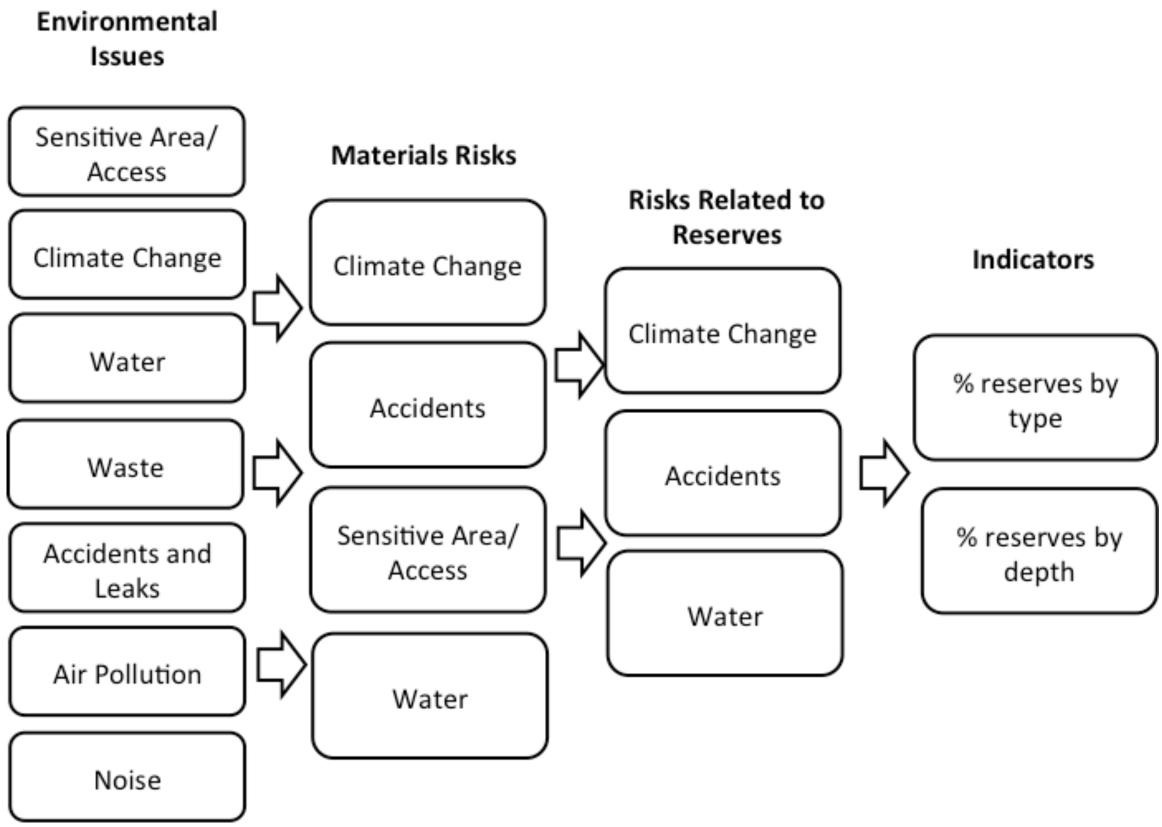


Figure 7.1 From Issues to Indicators (source: developed by author)

The objective of this study was to contribute to the improvement of corporate sustainability valuations by proposing quantitative indicators that use reserve characteristics as proxy for environmental risk. The financial market must understand risk factors that O&G companies are exposed to, and be able to evaluate and compare them to make investment decisions. This study has shown that several material environmental risks are embedded with the oil and gas reserves and that current reporting practices do not expose them properly. These findings have broad implications for government and financial industry, investors and lenders alike.

It is the task of regulating agencies to ensure the publication of reliable and comparable information that can reduce "information asymmetries" among investors and company insiders. Companies are required to publish the percentage of reserves located in different countries to enable the market to assess political risk.

Why should environmental risks be any different? On this note, it is recommended that agencies responsible for regulating the markets should review the disclosure requirements of O&G companies and include differentiation of unconventional oil and gas from conventional resources. Currently, these are reported together, as discussed in this study. Yet they have very different risks when it comes to water capture and pollution, which could increase costs or lead to an imposed restriction on operations or on capacity expansion.

Under current SEC reporting guidelines, it is already possible to distinguish bitumen (oil sands) from conventional oil production, but extra-heavy and shale gas, which can pose significant climate risk, are not identifiable. Companies with heavy oil reserves report relatively more exposure to climate change risks, particularly emissions control. As predicted by CTI (2013 and 2014), in a carbon-restricted scenario these companies are likely to suffer more controls. A recent example of how this is reflected on the business of these companies is the recent delays for the approval of the Keystone pipeline project (and possible presidential veto), which, in turn, increases transportation costs and suspends further production capacity expansion (Broder, 2013). Despite this risk, reported heavy oil reserves increased their participation in the profiles of the sampled companies' reserves from 17% in 2009 to 19% in 2012 (as presented in Table 5.1). In Cube Browser, sixteen companies were identified as having unconventional oil reserves above the 15% threshold in 2012, whereas in the current SEC requirements investors would only be able to identify eight corporations. It can be inferred that currently investors are not able to identify 50% of the current stocks in the sample that are subjected to climate change risks; that is, the market may be unaware of the risks in these stocks.

Disclosing reserves located in deepwater (125 m - 1500 m depth) and ultra-deepwater (deeper than 1500 m) is also advisable to allow the market to easily identify accident risks. This information is not reported by companies, but when using Cube Browser nine companies were identified as having deepwater plus ultra-deepwater reserves above the 15% threshold.

For rating agencies, these forward-looking indicators could complement the historical performance measurements, could help point critical issues and distribute weights among the performance metrics. For example, when reviewing a corporate climate change performance, the past GHG emissions inventory could be paired with the percentage unconventional oil reserves in order to fully understand the climate change risk to a certain company. In addition, these reserve indicators point out what management indicators are more relevant to a company. For instance, Petrobras has 86% deep and ultra-deepwater reserves and only 1.4% oil sands, shale gas, oil shale and tight oil reserves (as can be calculated form the data presented in Appendix D, Table D.1). Following the rationale laid out in this study, the Brazilian company's E&P activities are less exposed to water issues and climate change than accidents risks. Thus, when evaluating the sustainability of this company in particular, safety performance and managerial practices would be critical to predict future performance. Note that this study exclusively discusses E&P activities, and not considering downstream installations that may be exposed to water drought situations.

In the case of BP, whose shares were held in high regard by the SRI community at the time of Deepwater Horizon Accident, what could have happened is that the safety indicators may have been diluted by other sustainability metrics in the overall evaluation. If investors had paired BP's reserve characteristics with historical performance, they may have been able to identify that 25% of BPs reserves were in deep plus ultra-deepwater, and thus safety indicators and management practices were critical to the company.

These results can also add to the empirical literature that links corporate financial performance to corporate social performance (for a review see HOEPNER, 2007). If the metrics are not adequate to indicate true CSR activities, those studies finding little correlation between sustainability and financial performance are not measuring this relationship. Reviewing historical performance for a certain issue together with reserve characteristics for E&P O&G companies may avoid idiosyncrasies, for instance, a company whose corporate policy states it's committed to climate change but invests heavily in carbon intense reserves (such as oil sands). Analyzing core business practices with performance may also be applicable to other industries. For instance, News Corp Inc., who owns the well know climate skeptic Fox News, was one of the first news corporations to become carbon neutral in 2010 (SHEPPARD, 2009 and RUDOLF, 2011). Thus, when rating this company in terms of climate change, is it more relevant for rating agencies and investors to consider the company's emissions or the content it portrays to the public? Or both, analyzing historical performance in the light of core business practices?

Credit rating agencies have only one objective: measure the probability that company will default in repaying its debt in full and on time (WHITE, 2014). Thus, these ratings are regarded as a vital tool for investors – not only for determining a company's cost of capital, but also for ensuring market stability and fairness (WHITE, 2014). They have been evolving over the past one hundred years, overcoming many shocks and changing their methodologies. Sustainability rating agencies must also have a common objective: measure the probability that company will perform sustainably over time (WHITE, 2014). Simple, objective and quantitative indicators such as the ones proposed in this study can contribute to this objective.

Thus, as argued above, quantitative indicators to better assess the environmental risks of O&G corporations would be helpful to government, company managers, investors and rating agencies. Reserve profiles can help detect the environmental risks to which companies are exposed, bringing to light information that is buried deep.

7.1. Limitations and Suggestions for Future Research

There are several limitations to this study that require further research in order to close the gaps. The relationship between accidents and water depth established here was based primarily on Muehlenbachs (2013)'s work. The deepwater frontier has been pushed relatively recently, thus the absence of other studies to confirm Muehlenbachs 2013) findings. In addition, research is still needed to understand frequency and consequences of accidents involving shale gas, oil sands and other unconventional resources.

The result for sensitive area/access is mixed and thus not possible to determine a relationship to reserve profiles. Because of the lack of specific reserve data, such as percent located in conservation units, assumptions were made that may not hold true. Further study is necessary to determine if biodiversity risk has a clear relationship to reserves. It would be interesting to verify the percentage of reserves located in sensitive areas that are thus more difficult to extract, either due to technological challenges or permitting difficulties. This could be done by overlapping Cube Browser's database with IUCN's world database on protected areas. It is interesting to note that references to biodiversity words were very sparse in all reports reviewed (as discussed in chapter 5), although E&P companies have been exploring in sensitive areas and opening frontiers for quite some time. This may be an issue that the market has already incorporated delays and costs incurred by these challenges, or it is an emerging issue and, like climate change that Austin and Saur (2002) registered meager references fifteen years ago, the communication to investors is still maturing.

The exposure of companies to climate incidents (such as storms, droughts and others) and the relationship to reserves would also be an interesting topic for research. For instance, are deepwater and ultradeepwater reserves more vulnerable to climate change?

Furthermore, it would also be interesting to understand if there is a relationship between core business practices and sustainability performance, in the E&P sector. A line of research could investigate if reserve types also influence the performance of companies. In other words, if there is a relationship between historical performance and the types of reserves being extracted. This could be expanded to an understanding of how the interactions among historical performance, reserve types, regulatory environment and corporate culture can influence future performance and risks, and thus improve predictability in terms of future sustainability performance.

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Appendix A

Table A.1 GRI and IPIECA Indicator Correlation (Source: GRI and IPIECA, 2012)

IPIECA 2010 Indicators		GRI 3.1 and OGSS Indicators		Alignment of intent	Comment
Code	Title	Code	Description		
Environmental indicators					
Issue	Climate change and energy: page 35	DMA EN	Disclosure on Management Approach - Environment - Energy Aspect	High	Both GRI and IPIECA recognise the importance of managing energy and the relationship to climate change risks (also see E1, E2 and E3)
		EC2	Financial implications and other risks and opportunities for the organization's activities due to climate change.	Low	Not included as a separate indicator, instead IPIECA provides issue guidance and examples on how to report
E1	Greenhouse gas emissions	DMA EN	Disclosure on Management Approach - Environment - Energy Aspect	High	Both GRI and IPIECA recognise the importance of managing energy and the relationship to climate change risks
		DMA EN	Disclosure on Management Approach - Environment - Emissions, effluents and waste Aspect	High	Common aim of both IPIECA and GRI is comprehensive disclosure of quantitative GHG performance data but both provide for approach to be described
		DMA EN	Disclosure on Management Approach - Environment - Transport Aspect	Low	Not a separate aspect in IPIECA guidance, but significant impacts of marine and other transport covered.
		EN16	Total direct and indirect greenhouse gas emissions by weight.	High	Good alignment on quantitative measures
		EN17	Other relevant indirect greenhouse gas emissions by weight.	High	Alignment on quantitative measures but not a separate indicator
		EN18	Initiatives to reduce greenhouse gas emissions and reductions achieved.	High	Very similar approach
		EN29	Significant environmental impacts of transporting products and other goods and materials used for the organization's operations, and transporting members of the workforce.	Low	Not a separate indicator in IPIECA guidance, but significant impacts of marine and other transport covered.
E2	Energy use	DMA EN	Disclosure on Management Approach - Environment - Energy Aspect	High	Both GRI and IPIECA recognise the importance of managing energy and the relationship to climate change risks
		EN3	Direct energy consumption by primary energy source.	High	Good alignment on quantitative measures
		EN4	Indirect energy consumption by primary source.	High	Good alignment on quantitative measures
		EN5	Energy saved due to conservation and efficiency improvements.	Medium	IPIECA aims for more explicit narrative descriptions whereas GRI aims for a single numerical indicator
		EN7	Initiatives to reduce indirect energy consumption and reductions achieved.	High	Very similar approach
E3	Alternative energy sources	DMA EN	Disclosure on Management Approach - Environment - Energy Aspect	High	Both GRI and IPIECA recognise the importance of managing energy and the relationship to climate change risks
		DMA PR	Disclosure on Management Approach - Product responsibility - Fossil fuel substitutes Aspect	High	Reflects recent concern over biofuels.
		OG2	Total amount invested in renewable energy	Medium	IPIECA aims for more explicit narrative descriptions whereas GRI aims for a numerical indicator
		OG3	Total amount of renewable energy generated by source	High	Good alignment on quantitative measures
		EN6	Initiatives to provide energy-efficient or renewable energy-based products and services, and reductions in energy requirements as a result of these initiatives.	High	Very similar approach
		OG14	Volume of biofuels produced and purchased meeting sustainability criteria.	High	GRI indicator is explicitly concerned with biofuels. IPIECA indicator is more generic but requests similar data.
E4	Flared gas	OG6	Volume of flared and vented hydrocarbon	High	Alignment on quantitative measures, IPIECA request more detailed narrative
Issue	Ecosystem services: page 47	DMA EN	Disclosure on Management Approach - Environment - Water Aspect	High	Increasing importance recognised, with similar and consistent approach (also see E6)
		DMA EN	Disclosure on Management Approach - Environment - Ecosystem services including Biodiversity - Aspect	High	Both GRI and IPIECA recognise the importance of these issues to the sector (also see E5)

Table A.1 GRI and IPIECA Indicator Correlation (Source: GRI and IPIECA, 2012) Continued…

IPIECA 2010 Indicators Code	Title	GRI 3.1 and OGSS Indicators Code	Description	Alignment of intent	Comment
Environmental indicator, continued					
E5	Biodiversity and ecosystem services	DMA EN	Disclosure on Management Approach - Environment - Ecosystem services including Biodiversity - Aspect	High	Both GRI and IPIECA recognise the importance of these issues to the sector
		EN11	Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.	Medium	GRI aims for disclosure of site information whereas IPIECA focuses on general company approach, actions and examples.
		EN12	Description of significant impacts of activities, products, and service on biodiversity in protected areas and areas of high biodiversity value outside protected areas.	Medium	GRI aims for details of biodiversity impacts whereas IPIECA focuses on approach and actions to manage impacts.
		EN13	Habitats protected or restored.	Medium	GRI describes and quantifies areas protected or restored, whereas IPIECA is limited to approach, plans and case study examples.
		EN14	Strategies, current actions, and future plans for managing impacts on biodiversity.	High	Very similar approach
		OG4	Number and percentage of significant operating sites in which biodiversity risk has been assessed and monitored.	Medium	GRI requests more detailed information whereas IPIECA limits to percentage with action plans and examples
		EN15	Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk.	Low	IPIECA only asks for inclusion of criteria applied, not specifically Red List
		EN25	Identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the reporting organization's discharges of water and runoff.	Medium	Not an explicit IPIECA indicator, but intent covered by E5 and E9
E6	Fresh water	DMA EN	Disclosure on Management Approach - Environment - Water Aspect	High	Increasing importance recognised, with similar and consistent approach.
		EN8	Total water withdrawal by source.	High	Good alignment on quantitative measures
		EN9	Water sources significantly affected by withdrawal of water.	High	Very similar approach
		EN10	Percentage and total volume of water recycled and reused	High	IPIECA suggests information and examples rather than quantified data, however data is available as part of the IPIECA E6 scope (see Figure 6)
Issue	Local environmental impact: page 54	DMA EN	Disclosure on Management Approach - Environment - Materials Aspect	Medium	IPIECA focus is on recycling and waste management, rather than material use (also see E10)
		EMA EN	Disclosure on Management Approach - Environment - Emissions, effluents and waste Aspect	High	Similar approach for issue managed and regulated consistently across the sector, particularly details on spills as emphasised by the OGSS (also see E7, E8 and E9)
E7	Other air emissions	EMA EN	Disclosure on Management Approach - Environment - Emissions, effluents and waste Aspect	High	Similar approach for issue managed and regulated consistently across the sector, particularly details on spills as emphasised by the OGSS
		EN19	Emissions of ozone-depleting substances by weight.	High	Alignment on quantitative measures but not a separate indicator
		EN20	NOx, SOx, and other significant air emissions by type and weight.	High	Good alignment on quantitative measures

IPIECA 2010 Indicators Code	Title	GRI 3.1 and OGSS Indicators Code	Description	Alignment of intent	Comment
Environmental indicator, continued					
E8	Spills to the environment	DMA EN	Disclosure on Management Approach - Environment - Emissions, effluents and waste Aspect	High	Similar approach for issue managed and regulated consistently across the sector, particularly details on spills as emphasised by the OGSS
		DMA EN	Disclosure on Management Approach - Environment - Transport Aspect	Low	Not a separate aspect in IPIECA guidance, but significant impacts of marine and other transport covered.
		EN23	Total number and volume of significant spills.	High	Alignment on quantitative measures, IPIECA request more detailed narrative
		EN29	Significant environmental impacts of transporting products and other goods and materials used for the organization's operations, and transporting members of the workforce.	Low	Not a separate indicator in IPIECA guidance, but significant impacts of marine and other transport covered.
E9	Discharges to water	DMA EN	Disclosure on Management Approach - Environment - Emissions, effluents and waste Aspect	High	Similar approach for issue managed and regulated consistently across the sector, particularly details on spills as emphasised by the OGSS
		EN 21	Total water discharge by quality and destination	High	Very similar intent though some difference in measurement parameters (see OG5 comment)
		OG5	Volume and disposal of formation or produced water	Medium	Similar intent, but different metric; IPIECA requests quantity of hydrocarbon in produced water while GRI asks for total volume and disposal of this type of water
		EN25	Identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the reporting organization's discharges of water and runoff.	Medium	Not an explicit IPIECA indicator, but intent covered by E5 and E9
E10	Waste	DMA EN	Disclosure on Management Approach - Environment - Materials Aspect	Medium	IPIECA focus is on recycling and waste management, rather than material use
		DMA EN	Disclosure on Management Approach - Environment - Emissions, effluents and waste Aspect	High	Similar basis focused on performance to minimise waste impacts, approach to reporting is detailed through the IPIECA E10 Scope and by the GRI DMA
		EN2	Percentage of materials used that are recycled input materials.	Low	GRI focuses on proportion of recycled input materials and IPECA focuses on recycling / reuse of materials defined as waste
		EN22	Total waste by type and disposal method	High	Good alignment on quantitative measures
		OG7	Amount of drilling waste (drill mud and cuttings) and strategies for treatment and disposal.	Medium	IPIECA exclude amount of drilling waste from their quantitative reporting elements, but provide the option to additionally report on drill related waste.
		EN24	Weight of transported, imported, exported, or treated waste deemed hazardous under the terms of the Basel Convention Annex I, II, III, and VIII, and percentage of transported waste shipped internationally.	Medium	Similar intent though IPIECA basis is local regulatory requirements rather than Basel Convention focus of GRI

Table A.1 GRI and IPIECA Indicator Correlation (Source: GRI and IPIECA, 2012) Continued…

IPIECA 2010 Indicators		GRI 3.1 and OGSS Indicators		Alignment of intent	Comment
Code	Title	Code	Description		
Health and safety indicators					
Issue	Workforce protection: page 66 and 67	DMA LA	Disclosure on Management Approach - Labour Practices and Decent Work-Occupational health and safety Aspect	High	Strong coverage and alignment, including OGSS emphasis on workforce participation and potential accidents (i.e. near-miss) investigation. (also see HS1, HS2 and HS3)
HS1	Workforce participation	DMA LA	Disclosure on Management Approach - Labour Practices and Decent Work-Occupational health and safety Aspect	High	Strong coverage and alignment, including OGSS emphasis on workforce participation and potential accidents (i.e. near-miss) investigation.
		LA6	Percentage of total workforce represented in formal joint management-worker health and safety committees that help monitor and advise on occupational health and safety programs.	High	IPIECA is qualitative whereas GRI requests percentage data
		LA9	Health and safety topics covered in formal agreements with trade unions.	Low	GRI focused on trade union agreements whereas IPIECA indicators have broader intent
HS2	Workforce health	DMA LA	Disclosure on Management Approach - Labour Practices and Decent Work-Occupational health and safety Aspect	High	Strong coverage and alignment, including OGSS emphasis on workforce participation and potential accidents (i.e. near-miss) investigation.
		LA8	Education, training, counselling, prevention , and risk-control programs in place to assist workforce members, their families or community members regarding serious diseases.	High	LA8 more focused on serious diseases, IPIECA broader but also inclusive of serious diseases and can include public health.
HS3	Occupational injury and illness incidents	DMA LA	Disclosure on Management Approach - Labour Practices and Decent Work-Occupational health and safety Aspect	High	Strong coverage and alignment, including OGSS emphasis on workforce participation and potential accidents (i.e. near-miss) investigation.
		LA7	Rates of injury, occupational diseases, lost days, and absenteeism, and total number of work-related fatalities by region.	High	These measures are very well established across the oil & gas sector
HS4	Product stewardship	DMA EN	Disclosure on Management Approach - Environment - Products and services Aspect	Low	IPIECA have not covered this as a separate aspect except from a product stewardship perspective
		DMA PR	Disclosure on Management Approach - Product responsibility - Customer health and safety Aspect	High	Important issue on safety and strong alignment of approach.
		DMA PR	Disclosure on Management Approach - Product responsibility - Product and service labelling - Aspect	Medium	Reasonable alignment of intent.
		DMA PR	Disclosure on Management Approach - Product responsibility - Marketing communications Aspect	Medium	Reasonably good alignment of intent
		DMA SO	Disclosure on Management Approach - Society - Compliance Aspect	High	Aspect covers compliance areas of significant important to the sector
		EN26	Initiatives to mitigate environmental impacts of products and services, and extent of impact mitigation.	Medium	IPIECA covers H, S & E impacts, but GRI puts explicit emphasis on fuel products
		PR1	Life cycle stages in which the health and safety impacts of products are assessed for improvement, and percentage of significant products and services categories subject to such procedures.	High	Strong alignment
		PR2	Total number of incidents of non-compliance with regulations and voluntary codes concerning health and safety impacts of products and services by type of outcome.	Medium	Reasonably good alignment of intent, though GRI request quantitative detail
		PR3	Type of product and service information required by procedures, and percentage of significant products and services subject to such information requirements.	Medium	Reasonable alignment of intent.
		PR4	Total number of incidents of non-compliance with regulations and voluntary codes concerning product and service information and labelling, by type of outcome.	Medium	Reasonably good alignment of intent, though GRI request quantitative detail
		PR6	Programs for adherence to laws, standards, and voluntary codes related to marketing communications, including advertising, promotion, and sponsorship.	Medium	Reasonable alignment of intent.
		PR7	Total number of incidents of non-compliance with regulations and voluntary codes concerning marketing communications, including advertising, promotion, and sponsorship by type of outcomes.	Medium	Reasonably good alignment of intent, though GRI request quantitative detail
HS5	Process safety	DMA SO	Disclosure on Management Approach - Society - Compliance Aspect	High	Aspect covers compliance areas of significant important to the sector
		DMA SO	Disclosure on Management Approach - Society - Asset Integrity and Process Safety Aspect	High	Strong alignment on key sector issue.
		OG13	Number of process safety events, by business activity.	High	Both GRI and IPIECA aligned with API/OGP standards

Appendix B

Table B1. Total number of keywords per category - 2009

2009																				
	Accident							Climate Change					Sensitive Areas/Access				Water			TOTAL
COMPANIES	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Scarsity	Pollution	SUM	
ANADARKO	1	6	3	1	4	4	19	4		7	2	13		1		1		1	1	34
APACHE	2	8	2	3	1	2	18	5		11	3	19	1	1		2		2	2	41
BP	2	1	9	6	1		19			1	2	3			2	2			0	24
CANADIAN		3	3	1	3		10	27	1	2		30			1	1	1		1	42
CENOVUS	3	6	1	2	5	1	18	9		3	1	13	1		1	2			0	33
CHEVRON	1	2	1	2	1		7	15	1	3	2	21			2	2			0	30
CHINA PETROLEUM	2		6	4			12					0				0		1	1	13
CNOOC					1		1			3		3				0			0	4
CONOCO			4	2	1	2	9	3		1		4	1			1			0	14
DEVON	1	7	2	3	1	1	15			5		5		1		1			0	21
ENI	4	4	16	12	4	4	44	6	3	5		14	1	1	9	11			0	69
EOG	2	4	4	3	1		14	4		15	1	20	1			1		1	1	36
EXXON			2		2		4	5	1	3	2	11				0			0	15
HESS		5		1	4	3	13	4		3	4	11			1	1		1	1	26
IMPERIAL		3	2	1	3	1	10	16	1	1	2	20				0			0	30
MARATHON	1	10	11	6	8	1	37	24		11	1	36		1		1		3	3	77
NOBLE	1	8	6	4	2	1	22	15	2	4	2	23			2	2	1	4	5	52
OCCIDENTAL	1	4	1		1		7	1		3	2	6				0			0	13
PETROBRAS	2	1	1	3	2	1	10	1		1	1	3				0			0	13
PETROCHINA	1	3	4	6	1		15			4	1	5				0			0	20
SHELL	2	1	6	6	1		16	8		1	2	11	1		1	2			0	29
STATOIL	3	5	9	6	6	2	31	3	9	4	2	18		2	3	5		1	1	55
SUNCOR	2	8	6	2	4	1	23	13		4	3	20	1		1	2	2	3	5	50
TOTAL	3	1	4	4		1	13	**1**		**3**	**2**	6			**2**	2		1	1	22
SUM	**34**	**90**	**103**	**78**	**57**	**25**	**387**	**164**	**18**	**98**	**35**	**315**	**7**	**7**	**25**	**39**	**4**	**18**	**22**	**763**

Table B2. Total number of keywords per category – 2010

2010																				
	Accident							Climate Change					Sensitive Areas/Access				Water			TOTAL
COMPANIES	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Pollution	Access	SUM	
ANADARKO	1	18	14	3	24	7	67	5		8	2	15	2	1		3	2		2	87
APACHE	6	19	7	5	7	3	47	5		16	3	24	2	1		3	2		2	76
BP	37	8	20	12	24	4	105			1	3	4	1		7	8	2		2	119
CANADIAN		3	3	2	4		12	28	1	4		33			1	1			0	46
CENOVUS	2	7	5	1	5	1	21	14		7	5	26	2			2	1	11	12	61
CHEVRON	3	3	5	4	2		17	14		3	1	18			2	2			0	37
CHINA PETROLEUM	2		6	4			12	3			4	7				0	1		1	20
CNOOC	4	9		1	2		16			4		4				0			0	20
CONOCO	1		4	2	1	2	10	2		1		3	1	1		2			0	15
DEVON	2	7	2	3	1	1	16	8		3	2	13			1	1	1		1	31
ENI	8	5	19	16	5	6	59	5	1	6		12		1	10	11	1		1	83
EOG	2	4	4	3	1		14	5		15	2	22				0	1	2	3	39
EXXON			2		2		4	5	1	3	2	11				0		1	1	16
HESS	3	5	2	1	7	3	21	4		3	4	11				0	1		1	33
IMPERIAL		4	2	1	3	1	11	14	1	1	2	18				0			0	29
MARATHON	1	10	10	5	8	2	36	29		11	1	41		2		2			0	79
NOBLE	10	9	10	6	8	2	45	20	3	6		29		1	1	2	6	1	7	83
OCCIDENTAL	1	4	1		1		7	3	1	3	2	9				0		1	1	17
PETROBRAS	4	2	1	5	2	2	16	2		1	1	4			1	1			0	21
PETROCHINA	1	3	5	4	1		14			2	1	3				0			0	17
SHELL	3	1	7	7	1		19	5		1	1	7	1	1	1	3			0	29
STATOIL	7	5	9	5	6	3	35	2	9	4	2	17	1	2	3	6	1		1	59
SUNCOR	2	9	8	8	5		32	24	3	7	7	41	1		1	2	2	2	4	79
TOTAL	4	5	7	10	5	2	33	**4**		**3**	**2**	9	**4**	**3**	**2**	9	2		2	53
SUM	**104**	**140**	**153**	**108**	**125**	**39**	**669**	**201**	**20**	**113**	**47**	**381**	**15**	**13**	**30**	**58**	**23**	**18**	**41**	**1149**

Table B3. Total number of keywords per category - 2011

2011																				
	Accident							Climate Change				Sensitive Areas/Access					Water			
COMPANIES	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Pollution	Access	SUM	TOTAL
ANADARKO	2	8	13	2	12	2	39	13		8	1	22	4	1		5	7		7	73
APACHE	7	16	4	5	3	3	38	3		16	1	20		1		1	2		2	61
BP	34	9	22	12	25	4	106			1	3	4	1		8	9	2		2	121
CANADIAN		3	3	2	3		11	29	1	4		34			1	1			0	46
CENOVUS	2	7	5	2	5	1	22	13		7	4	24	1			1	1	11	12	59
CHEVRON	6	2	5	4	2		19	7		4	1	12			2	2			0	33
CHINA PETROLEUM	2		6	4			12	3			4	7			1	1			0	20
CNOOC	8	9	6	3	4		30			4		4	1			1			0	35
CONOCO	1	2	8		3	2	16	2		2		4		1		1			0	21
DEVON	3	8	6	3	1	1	22	9		3	2	14				0			0	36
ENI	14	8	28	22	9	11	92	7	4	12	3	26		3	11	14	2		2	134
EOG	2	5	4	3	4	2	20	5		21	2	28				0	2	2	4	52
EXXON			3		2		5	4	1	3	2	10				0		1	1	16
HESS	3	5	2	1	7	3	21	4		3	4	11			1	1	1		1	34
IMPERIAL		4	2	1	3	1	11	14	1	1	2	18				0			0	29
MARATHON	2	12	9	5	7	2	37	7		9	2	18		1		1	1	2	3	59
NOBLE	20	11	12	7	21	2	73	18	3	6		27	1		3	4	12	14	26	130
OCCIDENTAL	1	4	1		1		7	3	1	3	2	9				0		1	1	17
PETROBRAS	4	2	6	8	3	2	25	2		1	1	4			1	1			0	30
PETROCHINA	9	5	8	6	2		30	2		2	3	7				0			0	37
SHELL	5	1	7	7	1		21	5		1	1	7	1	1	4	6			0	34
STATOIL	6	5	13	5	8	3	40	4	8	7	3	22	1	1	4	6	2		2	70
SUNCOR	4	7	10	5	6	1	33	14		7	5	26	1		1	2	3	2	5	66
TOTAL	6	8	7	12	5	2	40	4		4	5	13	4	3	2	9	2		2	64
SUM	141	141	190	119	137	42	770	172	19	129	51	371	15	12	39	66	37	33	70	1277

Table B4. Total number of keywords per category – 2012

2012																				
	Accident							Climate Change				Sensitive Areas/Access					Water			
COMPANIES	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Pollution	Access	SUM	TOTAL
ANADARKO	4	7	7	2	8	2	30	7		8	1	16	4	1		5	7		7	58
APACHE	6	15	4	5	5	3	38	2		15	1	18		1		1	5		5	62
BP	39	8	26	12	20	3	108			1	3	4	1		10	11	6		6	129
CANADIAN		3	3	2	3		11	28	1	4		33			1	1			0	45
CENOVUS	2	7	6	2	5	1	23	13		7	4	24	8		1	9	2	11	13	69
CHEVRON	6	2	5	4	2		19	7		4	1	12			2	2			0	33
CHINA PETROLEUM	4	2	7	4	1		18	4		1	3	8			1	1			0	27
CNOOC	8	11	6	3	4		32			4		4	1			1			0	37
CONOCO	1	2	7		3	1	14	3		2		5		1		1			0	20
DEVON	3	8	6	3	1	1	22	13		3	2	18				0			0	40
ENI	17	7	33	23	10	10	100	6	3	11	3	23	4	3	9	16	2		2	141
EOG	2	5	4	3	4	2	20	4		21	4	29			1	1	1	1	2	52
EXXON			3		2		5	5	1	3	2	11				0		1	1	17
HESS	3	5	2	1	6	3	20	5		5	4	14			1	1	1	1	2	37
IMPERIAL		4	2	1	3	1	11	14	2	1	2	19				0			0	30
MARATHON	2	12	9	5	7	2	37	7		9	2	18	1	1		2	1	2	3	60
NOBLE	23	12	14	10	22	3	84	29	3	16		48	3	2	15	20	12	14	26	178
OCCIDENTAL	1	4	1		1		7	3	1	3	1	8				0		1	1	16
PETROBRAS	4	2	6	8	2	2	24	2			1	3			1	1			0	28
PETROCHINA	1	3	5	4	1		14	2		2	3	7				0			0	21
SHELL	4	1	7	7	1	1	21	6		1	2	9	1	2	3	6			0	36
STATOIL	5	5	15	5	8	3	41	4	8	7	3	22	1	1	4	6	1		1	70
SUNCOR	4	7	10	5	6	1	33	13		9	5	27	2		2	4	3	10	13	77
TOTAL	9	8	7	13	6	2	45	6		4	4	14	4	3	2	9	2		2	70
SUM	148	140	195	122	131	41	777	183	19	141	51	394	30	15	53	98	43	41	84	1353

Table B5. Relative number of keywords per category – 2009

2009																				
	Accident							Climate Change				Sensitive Areas/Access					Water			TOTAL
	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Scarsity	Pollution	SUM	
ANADARKO	3%	18%	9%	3%	12%	12%	56%	12%	0%	21%	6%	38%	0%	3%	0%	3%	0%	3%	3%	1
APACHE	5%	20%	5%	7%	2%	5%	44%	12%	0%	27%	7%	46%	2%	2%	0%	5%	0%	5%	5%	1
BP	8%	4%	38%	25%	4%	0%	79%	0%	0%	4%	8%	13%	0%	0%	8%	8%	0%	0%	0%	1
CANADIAN	0%	7%	7%	2%	7%	0%	24%	64%	2%	5%	0%	71%	0%	0%	2%	2%	2%	0%	2%	1
CENOVUS	9%	18%	3%	6%	15%	3%	55%	27%	0%	9%	3%	39%	3%	0%	3%	6%	0%	0%	0%	1
CHEVRON	3%	7%	3%	7%	3%	0%	23%	50%	3%	10%	7%	70%	0%	0%	7%	7%	0%	0%	0%	1
CHINA PETROLEUM	15%	0%	46%	31%	0%	0%	92%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	8%	1
CNOOC	0%	0%	0%	0%	25%	0%	25%	0%	0%	75%	0%	75%	0%	0%	0%	0%	0%	0%	0%	1
CONOCO	0%	0%	29%	14%	7%	14%	64%	21%	0%	7%	0%	29%	7%	0%	0%	7%	0%	0%	0%	1
DEVON	5%	33%	10%	14%	5%	5%	71%	0%	0%	24%	0%	24%	0%	5%	0%	5%	0%	0%	0%	1
ENI	6%	6%	23%	17%	6%	6%	64%	9%	4%	7%	0%	20%	1%	1%	13%	16%	0%	0%	0%	1
EOG	6%	11%	11%	8%	3%	0%	39%	11%	0%	42%	3%	56%	3%	0%	0%	3%	0%	3%	3%	1
EXXON	0%	0%	13%	0%	13%	0%	27%	33%	7%	20%	13%	73%	0%	0%	0%	0%	0%	0%	0%	1
HESS	0%	19%	0%	4%	15%	12%	50%	15%	0%	12%	15%	42%	0%	0%	4%	4%	0%	4%	4%	1
IMPERIAL	0%	10%	7%	3%	10%	3%	33%	53%	3%	3%	7%	67%	0%	0%	0%	0%	0%	0%	0%	1
MARATHON	1%	13%	14%	8%	10%	1%	48%	31%	0%	14%	1%	47%	0%	1%	0%	1%	0%	4%	4%	1
NOBLE	2%	15%	12%	8%	4%	2%	42%	29%	4%	8%	4%	44%	0%	0%	4%	4%	2%	8%	10%	1
OCCIDENTAL	8%	31%	8%	0%	8%	0%	54%	8%	0%	23%	15%	46%	0%	0%	0%	0%	0%	0%	0%	1
PETROBRAS	15%	8%	8%	23%	15%	8%	77%	8%	0%	8%	8%	23%	0%	0%	0%	0%	0%	0%	0%	1
PETROCHINA	5%	15%	20%	30%	5%	0%	75%	0%	0%	20%	5%	25%	0%	0%	0%	0%	0%	0%	0%	1
SHELL	7%	3%	21%	21%	3%	0%	55%	28%	0%	3%	7%	38%	3%	0%	3%	7%	0%	0%	0%	1
STATOIL	5%	9%	16%	11%	11%	4%	56%	5%	16%	7%	4%	33%	0%	4%	5%	9%	0%	2%	2%	1
SUNCOR	4%	16%	12%	4%	8%	2%	46%	26%	0%	8%	6%	40%	2%	0%	2%	4%	4%	6%	10%	1
TOTAL	14%	5%	18%	18%	0%	5%	59%	5%	0%	14%	9%	27%	0%	0%	9%	9%	0%	5%	5%	1
SUM	4%	12%	13%	10%	7%	3%	51%	21%	2%	13%	5%	41%	1%	1%	3%	5%	1%	2%	3%	1

Table B6. Relative number of keywords per category – 2010

2010																				
	Accident							Climate Change				Sensitive Areas/Access					Water			TOTAL
	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Pollution	Access	SUM	
ANADARKO	1%	21%	16%	3%	28%	8%	77%	6%	0%	9%	2%	17%	2%	1%	0%	3%	2%	0%	2%	1
APACHE	8%	25%	9%	7%	9%	4%	62%	7%	0%	21%	4%	32%	3%	1%	0%	4%	3%	0%	3%	1
BP	31%	7%	17%	10%	20%	3%	88%	0%	0%	1%	3%	3%	1%	0%	6%	7%	2%	0%	2%	1
CANADIAN	0%	7%	7%	4%	9%	0%	26%	61%	2%	9%	0%	72%	0%	0%	2%	2%	0%	0%	0%	1
CENOVUS	3%	11%	8%	2%	8%	2%	34%	23%	0%	11%	8%	43%	3%	0%	0%	3%	2%	18%	20%	1
CHEVRON	8%	8%	14%	11%	5%	0%	46%	38%	0%	8%	3%	49%	0%	0%	5%	5%	0%	0%	0%	1
CHINA PETROLEUM	10%	0%	30%	20%	0%	0%	60%	15%	0%	0%	20%	35%	0%	0%	0%	0%	5%	0%	5%	1
CNOOC	20%	45%	0%	5%	10%	0%	80%	0%	0%	20%	0%	20%	0%	0%	0%	0%	0%	0%	0%	1
CONOCO	7%	0%	27%	13%	7%	13%	67%	13%	0%	7%	0%	20%	7%	7%	0%	13%	0%	0%	0%	1
DEVON	6%	23%	6%	10%	3%	3%	52%	26%	0%	10%	6%	42%	0%	0%	3%	3%	3%	0%	3%	1
ENI	10%	6%	23%	19%	6%	7%	71%	6%	1%	7%	0%	14%	0%	1%	12%	13%	1%	0%	1%	1
EOG	5%	10%	10%	8%	3%	0%	36%	13%	0%	38%	5%	56%	0%	0%	0%	0%	3%	5%	8%	1
EXXON	0%	0%	13%	0%	13%	0%	25%	31%	6%	19%	13%	69%	0%	0%	0%	0%	0%	6%	6%	1
HESS	9%	15%	6%	3%	21%	9%	64%	12%	0%	9%	12%	33%	0%	0%	0%	0%	3%	0%	3%	1
IMPERIAL	0%	14%	7%	3%	10%	3%	38%	48%	3%	3%	7%	62%	0%	0%	0%	0%	0%	0%	0%	1
MARATHON	1%	13%	13%	6%	10%	3%	46%	37%	0%	14%	1%	52%	0%	3%	0%	3%	0%	0%	0%	1
NOBLE	12%	11%	12%	7%	10%	2%	54%	24%	4%	7%	0%	35%	0%	1%	1%	2%	7%	1%	8%	1
OCCIDENTAL	6%	24%	6%	0%	6%	0%	41%	18%	6%	18%	12%	53%	0%	0%	0%	0%	0%	6%	6%	1
PETROBRAS	19%	10%	5%	24%	10%	10%	76%	10%	0%	5%	5%	19%	0%	0%	5%	5%	0%	0%	0%	1
PETROCHINA	6%	18%	29%	24%	6%	0%	82%	0%	0%	12%	6%	18%	0%	0%	0%	0%	0%	0%	0%	1
SHELL	10%	3%	24%	24%	3%	0%	66%	17%	0%	3%	3%	24%	3%	3%	3%	10%	0%	0%	0%	1
STATOIL	12%	8%	15%	8%	10%	5%	59%	3%	15%	7%	3%	29%	2%	3%	5%	10%	2%	0%	2%	1
SUNCOR	3%	11%	10%	10%	6%	0%	41%	30%	4%	9%	9%	52%	1%	0%	1%	3%	3%	3%	5%	1
TOTAL	8%	9%	13%	19%	9%	4%	62%	8%	0%	6%	4%	17%	8%	6%	4%	17%	4%	0%	4%	1
SUM	9%	12%	13%	9%	11%	3%	58%	17%	2%	10%	4%	33%	1%	1%	3%	5%	2%	2%	4%	1

Table B7. Relative number of keywords per category – 2011

2011																				
	Accident							Climate Change					Sensitive Areas/Access				Water			TOTAL
	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Pollution	Access	SUM	
ANADARKO	3%	11%	18%	3%	16%	3%	53%	18%	0%	11%	1%	30%	5%	1%	0%	7%	10%	0%	10%	1
APACHE	11%	26%	7%	8%	5%	5%	62%	5%	0%	26%	2%	33%	0%	2%	0%	2%	3%	0%	3%	1
BP	28%	7%	18%	10%	21%	3%	88%	0%	0%	1%	2%	3%	1%	0%	7%	7%	2%	0%	2%	1
CANADIAN	0%	7%	7%	4%	7%	0%	24%	63%	2%	9%	0%	74%	0%	0%	2%	2%	0%	0%	0%	1
CENOVUS	3%	12%	8%	3%	8%	2%	37%	22%	0%	12%	7%	41%	2%	0%	0%	2%	2%	19%	20%	1
CHEVRON	18%	6%	15%	12%	6%	0%	58%	21%	0%	12%	3%	36%	0%	0%	6%	6%	0%	0%	0%	1
CHINA PETROLEUM	10%	0%	30%	20%	0%	0%	60%	15%	0%	0%	20%	35%	0%	0%	5%	5%	0%	0%	0%	1
CNOOC	23%	26%	17%	9%	11%	0%	86%	0%	0%	11%	0%	11%	3%	0%	0%	3%	0%	0%	0%	1
CONOCO	5%	10%	38%	0%	14%	10%	76%	10%	0%	10%	0%	19%	0%	5%	0%	5%	0%	0%	0%	1
DEVON	8%	22%	17%	8%	3%	3%	61%	25%	0%	8%	6%	39%	0%	0%	0%	0%	0%	0%	0%	1
ENI	10%	6%	21%	16%	7%	8%	69%	5%	3%	9%	2%	19%	0%	2%	8%	10%	1%	0%	1%	1
EOG	4%	10%	8%	6%	8%	4%	38%	10%	0%	40%	4%	54%	0%	0%	0%	0%	4%	4%	8%	1
EUUON	0%	0%	19%	0%	13%	0%	31%	25%	6%	19%	13%	63%	0%	0%	0%	0%	0%	6%	6%	1
HESS	9%	15%	6%	3%	21%	9%	62%	12%	0%	9%	12%	32%	0%	0%	3%	3%	3%	0%	3%	1
IMPERIAL	0%	14%	7%	3%	10%	3%	38%	48%	3%	3%	7%	62%	0%	0%	0%	0%	0%	0%	0%	1
MARATHON	3%	20%	15%	8%	12%	3%	63%	12%	0%	15%	3%	31%	0%	2%	0%	2%	2%	3%	5%	1
NOBLE	15%	8%	9%	5%	16%	2%	56%	14%	2%	5%	0%	21%	1%	0%	2%	3%	9%	11%	20%	1
OCCIDENTAL	6%	24%	6%	0%	6%	0%	41%	18%	6%	18%	12%	53%	0%	0%	0%	0%	0%	6%	6%	1
PETROBRAS	13%	7%	20%	27%	10%	7%	83%	7%	0%	3%	3%	13%	0%	0%	3%	3%	0%	0%	0%	1
PETROCHINA	24%	14%	22%	16%	5%	0%	81%	5%	0%	5%	8%	19%	0%	0%	0%	0%	0%	0%	0%	1
SHELL	15%	3%	21%	21%	3%	0%	62%	15%	0%	3%	3%	21%	3%	3%	12%	18%	0%	0%	0%	1
STATOIL	9%	7%	19%	7%	11%	4%	57%	6%	11%	10%	4%	31%	1%	1%	6%	9%	3%	0%	3%	1
SUNCOR	6%	11%	15%	8%	9%	2%	50%	21%	0%	11%	8%	39%	2%	0%	2%	3%	5%	3%	8%	1
TOTAL	9%	13%	11%	19%	8%	3%	63%	6%	0%	6%	8%	20%	6%	5%	3%	14%	3%	0%	3%	1
SUM	11%	11%	15%	9%	11%	3%	60%	**13%**	**1%**	**10%**	**4%**	29%	**1%**	**1%**	**3%**	5%	3%	3%	5%	1

Table B8. Relative number of keywords per category – 2012

2012																				
	Accident							Climate Change					Sensitive Areas/Access				Water			TOTAL
	Accident	accident type	safety	health	spills	remediation	SUM	Emissions Control	Renewable Energy	Physical Effects	Climate Change	SUM	Sensitive	Ecossystem	Access	SUM	Pollution	Access	SUM	
ANADARKO	7%	12%	12%	3%	14%	3%	52%	12%	0%	14%	2%	28%	7%	2%	0%	9%	12%	0%	12%	1
APACHE	10%	24%	6%	8%	8%	5%	61%	3%	0%	24%	2%	29%	0%	2%	0%	2%	8%	0%	8%	1
BP	30%	6%	20%	9%	16%	2%	84%	0%	0%	1%	2%	3%	1%	0%	8%	9%	5%	0%	5%	1
CANADIAN	0%	7%	7%	4%	7%	0%	24%	62%	2%	9%	0%	73%	0%	0%	2%	2%	0%	0%	0%	1
CENOVUS	3%	10%	9%	3%	7%	1%	33%	19%	0%	10%	6%	35%	12%	0%	1%	13%	3%	16%	19%	1
CHEVRON	18%	6%	15%	12%	6%	0%	58%	21%	0%	12%	3%	36%	0%	0%	6%	6%	0%	0%	0%	1
CHINA PETROLEUM	15%	7%	26%	15%	4%	0%	67%	15%	0%	4%	11%	30%	0%	0%	4%	4%	0%	0%	0%	1
CNOOC	22%	30%	16%	8%	11%	0%	86%	0%	0%	11%	0%	11%	3%	0%	0%	3%	0%	0%	0%	1
CONOCO	5%	10%	35%	0%	15%	5%	70%	15%	0%	10%	0%	25%	0%	5%	0%	5%	0%	0%	0%	1
DEVON	8%	20%	15%	8%	3%	3%	55%	33%	0%	8%	5%	45%	0%	0%	0%	0%	0%	0%	0%	1
ENI	12%	5%	23%	16%	7%	7%	71%	4%	2%	8%	2%	16%	3%	2%	6%	11%	1%	0%	1%	1
EOG	4%	10%	8%	6%	8%	4%	38%	8%	0%	40%	8%	56%	0%	0%	2%	2%	2%	2%	4%	1
EXXON	0%	0%	18%	0%	12%	0%	29%	29%	6%	18%	12%	65%	0%	0%	0%	0%	0%	6%	6%	1
HESS	8%	14%	5%	3%	16%	8%	54%	14%	0%	14%	11%	38%	0%	0%	3%	3%	3%	3%	5%	1
IMPERIAL	0%	13%	7%	3%	10%	3%	37%	47%	7%	3%	7%	63%	0%	0%	0%	0%	0%	0%	0%	1
MARATHON	3%	20%	15%	8%	12%	3%	62%	12%	0%	15%	3%	30%	2%	2%	0%	3%	2%	3%	5%	1
NOBLE	13%	7%	8%	6%	12%	2%	47%	16%	2%	9%	0%	27%	2%	1%	8%	11%	7%	8%	15%	1
OCCIDENTAL	6%	25%	6%	0%	6%	0%	44%	19%	6%	19%	6%	50%	0%	0%	0%	0%	0%	6%	6%	1
PETROBRAS	14%	7%	21%	29%	7%	7%	86%	7%	0%	0%	4%	11%	0%	0%	4%	4%	0%	0%	0%	1
PETROCHINA	5%	14%	24%	19%	5%	0%	67%	10%	0%	10%	14%	33%	0%	0%	0%	0%	0%	0%	0%	1
SHELL	11%	3%	19%	19%	3%	3%	58%	17%	0%	3%	6%	25%	3%	6%	8%	17%	0%	0%	0%	1
STATOIL	7%	7%	21%	7%	11%	4%	59%	6%	11%	10%	4%	31%	1%	1%	6%	9%	1%	0%	1%	1
SUNCOR	5%	9%	13%	6%	8%	1%	43%	17%	0%	12%	6%	35%	3%	0%	3%	5%	4%	13%	17%	1
TOTAL	13%	11%	10%	19%	9%	3%	64%	9%	0%	6%	6%	20%	6%	4%	3%	13%	3%	0%	3%	1
SUM	11%	10%	14%	9%	10%	3%	57%	**14%**	**1%**	**10%**	**4%**	29%	**2%**	**1%**	**4%**	7%	3%	3%	6%	1

Appendix C.

Table C1. Companies tested in Hypothesis 1

2009	2010	2011	2012
>= 15% heavy reserves	>= 15% heavy reserves	>= 15% heavy reserves	>= 15% heavy reserves
Suncor	Conoco	Exxon	Exxon
Imperial	Suncor	Conoco	Conoco
Canadian	Imperial	Suncor	Suncor
Marathon	Canadian	Imperial	Imperial
Cenovus	Marathon	Canadian	Canadian
Devon	Cenovus	Marathon	Marathon
	Devon	Cenovus	Cenovus
		Devon	Devon

Table C2. Companies tested in Hypothesis 2

2009	2010	2011	2012
>= 55% gas and no heavy reserves	>= 55% gas and no heavy reserves	>= 55% gas and no heavy reserves	>= 55% gas and no heavy reserves
Statoil	Statoil	Statoil	Noble
Anadarko	Anadarko	Anadarko	
EOG	EOG	EOG	
Apache	Apache	Apache	
Noble	Noble	Noble	

Table C3. Companies tested in Hypothesis 3

2009	2010	2011	2012
Mention deepwater or ultradeepwater	Mention deepwater or ultradeepwater	Mention deepwater or ultradeepwater	Mention deepwater or ultradeepwater
Anadarko	Anadarko	Anadarko	Anadarko
Eni	Statoil	Statoil	Statoil
Noble	Apache	Apache	Apache
Petrobras	Noble	Noble	Noble
Statoil	BP	BP	BP
	Eni	Eni	Eni
	Imperial	Imperial	Imperial
	Marathon	Marathon	Marathon
	Shell	Shell	Shell
	Petrobras	Petrobras	Petrobras
		CNOOC	CNOOC

Table C4. Companies tested in Hypothesis 4

2009	2010	2011	2012
Top 50%, measured by reserve size	Top 50%, measured by reserve size	Top 50%, measured by reserve size	Top 50%, measured by reserve size
Exxon	Exxon	Exxon	Exxon
PetroChina	PetroChina	PetroChina	PetroChina
BP	BP	BP	BP

Shell	Shell	Shell	Shell
Petrobras	Petrobras	Petrobras	Petrobras
Chevron	Chevron	Chevron	Chevron
Conoco Phillips	Conoco Phillips	Conoco Phillips	Conoco Phillips
Total	Total	Total	Total
ENI	ENI	ENI	ENI
Statoil	Statoil	Statoil	Statoil
China	China	China	Suncor
Canadian	Canadian	Canadian	Canadian

Table CB5. Companies tested in Hypothesis 5

2009	2010	2011	2012
>= 15% heavy or >= 55% gas reserves	>= 15% heavy or >= 55% gas reserves	>= 15% heavy or >= 55% gas reserves	>= 15% heavy or >= 55% gas reserves
Imperial	Imperial	Imperial	Imperial
Canadian	Canadian	Canadian	Canadian
Marathon	Marathon	Marathon	Marathon
Cenovus	Cenovus	Cenovus	Cenovus
Devon	Devon	Devon	Devon
Suncor	Suncor	Suncor	Suncor
Statoil	Statoil	Statoil	Statoil
Anadarko	Anadarko	Anadarko	Exxon
EOG	EOG	EOG	Noble
Apache	Apache	Apache	
Noble	Noble	Noble	
Shell	Shell	Shell	
		Exxon	

Appendix D

Table D.1 Reserves Split Conventional and Unconventional Oil and Gas (in Mbbl)

Company	Year	Liquids				Gas		Sum of Reserves
		Conventional	Oil sands	Extra heavy oil	Tight oil	Conventional	Unconventional gas	
ExxonMobil	2009	7719	2675	305	329	8688	10618	21811
	2010	7608	2696	297	430	8622	10547	21739
	2011	7473	2797	289	551	8448	10347	21635
	2012	7307	2851	281	670	8304	10176	21464
	2013	7088	2985	274	747	8108	9947	21221
BP	2009	5294	32	0	0	3806	4555	10002
	2010	5167	60	0	0	3690	4472	9824
	2011	5055	68	0	0	3591	4378	9631
	2012	4893	77	0	0	3478	4266	9369
	2013	4739	85	0	0	3317	4127	9092
Shell	2009	5819	2028	330	117	6954	7442	15780
	2010	5763	2034	322	171	6825	7402	15741
	2011	5802	2041	313	212	6658	7249	15667
	2012	5803	2028	305	256	6505	7104	15547
	2013	5804	2003	297	288	6343	6961	15408
Chevron	2009	4779	647	962	99	4732	4986	11482
	2010	4618	647	950	178	4668	4909	11316
	2011	4426	647	932	228	4595	4901	11155
	2012	4210	640	914	284	4526	4913	10989
	2013	4005	629	895	346	4469	4960	10879
Total	2009	4670	173	208	0	4289	4552	9613
	2010	4564	178	210	33	4232	4505	9499
	2011	4468	190	212	33	4160	4437	9349
	2012	4401	237	213	79	4089	4374	9313
	2013	4282	283	212	126	4013	4304	9216
ConocoPhillips	2009	2354	691	0	153	2245	4367	7931
	2010	2265	768	0	171	2184	4285	7850
	2011	2186	876	0	366	2120	4204	7985
	2012	2108	956	0	528	2059	4129	8072
	2013	2041	1021	0	609	1987	4036	8051
Eni	2009	3633	0	18	1	3366	3382	7034
	2010	3567	0	19	1	3321	3338	6925
	2011	3483	0	26	1	3289	3306	6817
	2012	3400	0	39	10	3214	3230	6678
	2013	3298	0	58	12	3110	3126	6494
Petrobras	2009	8173	0	126	0	1558	1558	9857
	2010	8470	0	141	0	1684	1684	10295
	2011	8571	0	147	0	1750	1750	10468
	2012	8803	0	153	0	1854	1854	10809
	2013	8805	0	159	0	1884	1884	10847
Statoil	2009	2280	29	177	32	3298	3732	6289
	2010	2224	48	185	43	3222	3680	6235
	2011	2153	53	193	68	3136	3645	6198
	2012	2081	58	199	114	3042	3604	6174
	2013	2016	61	213	147	2932	3542	6129
Suncor Energy	2009	389	2055	0	0	14	15	2460
	2010	369	2052	0	0	14	17	2439
	2011	354	2109	0	0	11	16	2480
	2012	340	2214	0	1	6	13	2568
	2013	321	2270	0	1	6	14	2606
Hess	2009	667	0	0	401	185	185	1253
	2010	656	0	0	418	179	179	1253
	2011	634	0	0	447	170	170	1251
	2012	619	0	0	464	171	171	1254
	2013	601	0	0	498	162	162	1261
Marathon Oil	2009	554	647	0	119	218	266	1601
	2010	527	647	0	145	203	267	1610
	2011	501	647	0	174	190	252	1602
	2012	480	640	0	316	175	235	1699
	2013	457	629	0	481	159	217	1812

Table D.1 Reserves Split by Conventional and Unconventional Oil and Gas (in Mbbl) Continued…

Company	Year	Liquids				Gas		Sum of Reserves
		Conventional	Oil sands	Extra heavy oil	Tight oil	Conventional	Unconventional gas	
Imperial Oil	2009	121	866	0	1	40	43	1031
	2010	121	869	0	2	38	40	1032
	2011	120	894	0	2	35	39	1056
	2012	120	907	0	3	32	39	1070
	2013	120	942	0	3	30	39	1105
Anadarko	2009	400	0	0	305	130	1206	2165
	2010	418	0	0	341	128	1354	2354
	2011	428	0	0	430	126	1384	2503
	2012	432	0	0	559	123	1508	2750
	2013	430	0	0	691	121	1479	2844
Devon Energy	2009	112	486	0	114	74	1265	2372
	2010	106	493	0	136	67	1264	2425
	2011	99	518	0	172	63	1298	2647
	2012	93	527	0	281	60	1303	2811
	2013	87	532	0	323	58	1304	2887
Oxy	2009	1703	0	0	107	1330	1488	3331
	2010	1675	0	0	160	1308	1459	3325
	2011	1634	0	0	223	1289	1436	3320
	2012	1589	0	0	281	1268	1409	3305
	2013	1543	0	0	351	1234	1371	3289
Apache	2009	757	0	0	191	829	1007	1981
	2010	721	0	0	282	776	969	1997
	2011	684	0	0	340	729	938	1987
	2012	642	0	0	489	677	937	2107
	2013	605	0	0	716	628	926	2299
EOG Resources	2009	60	0	0	411	282	805	1317
	2010	58	0	0	560	271	836	1494
	2011	56	0	0	762	253	851	1709
	2012	54	0	0	939	239	919	1953
	2013	52	0	0	1127	223	891	2110
Noble Energy	2009	126	0	0	90	312	605	953
	2010	126	0	0	97	333	629	984
	2011	126	0	0	166	342	650	1066
	2012	124	0	0	235	343	673	1149
	2013	130	0	0	308	362	716	1265
Natural Resourc	2009	866	2935	0	14	646	671	4492
	2010	835	2990	0	17	621	656	4509
	2011	803	3061	0	23	594	639	4540
	2012	768	3089	0	31	570	616	4522
	2013	732	3116	0	37	549	596	4500
Sinopec	2009	3491	0	8	1	705	1009	4562
	2010	3440	0	8	1	760	1074	4579
	2011	3365	0	8	1	822	1152	4586
	2012	3292	0	7	3	830	1166	4532
	2013	3209	0	6	5	847	1208	4500
CNOOC	2009	2266	395	0	7	971	1055	3724
	2010	2237	405	0	41	957	1064	3748
	2011	2179	419	0	115	928	1054	3768
	2012	2146	433	0	193	894	1037	3810
	2013	2061	446	0	265	866	1021	3794
Cenovus Energy	2009	204	599	64	0	238	238	1106
	2010	193	674	62	1	209	209	1139
	2011	182	774	60	1	182	182	1199
	2012	172	844	59	1	161	161	1237
	2013	161	902	56	1	140	140	1261
PetroChina	2009	11316	9	930	5	6035	8398	20674
	2010	11384	30	918	10	6098	8705	21066
	2011	11408	43	905	11	6124	8947	21334
	2012	11443	56	891	47	6222	9343	21802
	2013	11326	65	877	83	6268	9605	21979

Table D.2 Reserves Split by Water Depth (in Mbbl)

Company	Year	Ultra deepwater (1500+ meter)	Deep water (125-1500 meter)	Shelf (to 125 meter)	Land	Sum
ExxonMobil	2009	141	2291	8996	10383	21811
	2010	177	2234	9029	10300	21739
	2011	204	2167	8977	10287	21635
	2012	213	2110	8924	10217	21464
	2013	222	2040	8774	10184	21221
BP	2009	717	1776	3133	4377	10002
	2010	739	1721	3026	4338	9824
	2011	769	1695	2913	4254	9631
	2012	765	1677	2782	4146	9369
	2013	765	1613	2650	4064	9092
Shell	2009	159	2981	3481	9160	15780
	2010	183	2949	3442	9167	15741
	2011	190	2934	3390	9153	15667
	2012	196	2903	3344	9105	15547
	2013	197	2873	3309	9029	15408
Chevron	2009	156	2716	2780	5829	11482
	2010	175	2753	2656	5732	11316
	2011	184	2766	2522	5684	11155
	2012	187	2776	2375	5651	10989
	2013	190	2795	2227	5666	10879
Total	2009	53	1580	4550	3430	9613
	2010	62	1591	4422	3425	9499
	2011	73	1590	4303	3384	9349
	2012	82	1567	4171	3494	9313
	2013	89	1549	4037	3541	9216
ConocoPhillips	2009		649	1556	5725	7931
	2010		631	1527	5691	7850
	2011		608	1512	5865	7985
	2012		593	1479	6000	8072
	2013		582	1451	6018	8051
Eni	2009	47	1794	2635	2558	7034
	2010	58	1771	2571	2525	6925
	2011	61	1753	2528	2475	6817
	2012	64	1729	2443	2442	6678
	2013	65	1678	2372	2378	6494
Petrobras	2009	2825	5192	434	1406	9857
	2010	3373	5189	405	1328	10295
	2011	3755	5085	377	1251	10468
	2012	4339	4937	356	1178	10809
	2013	4659	4753	331	1104	10847
Statoil	2009	61	4501	900	828	6289
	2010	73	4410	858	894	6235
	2011	81	4294	819	1003	6198
	2012	90	4164	784	1136	6174
	2013	98	4025	762	1245	6129
Suncor Energy	2009		1	313	2146	2460
	2010		2	297	2140	2439
	2011		3	284	2194	2480
	2012		4	269	2296	2568
	2013		4	254	2349	2606
Hess	2009		211	348	694	1253
	2010		211	339	702	1253
	2011		198	330	723	1251
	2012		185	332	737	1254
	2013		170	327	764	1261
Marathon Oil	2009	2	72	301	1226	1601
	2010	3	67	275	1265	1610
	2011	3	62	252	1284	1602
	2012	3	56	228	1412	1699
	2013	5	52	201	1554	1812

Table D.2 Reserves Split by Water Depth (in Mbbl)

Company	Year	Ultra deepwater (1500+ meter)	Deep water (125-1500 meter)	Shelf (to 125 meter)	Land	Sum
Imperial	2009			1	1030	1031
	2010			1	1031	1032
	2011			1	1055	1056
	2012			0	1069	1070
	2013			0	1105	1105
Anadarko	2009	108	211	0	1846	2165
	2010	119	222	0	2014	2354
	2011	127	230	0	2146	2503
	2012	129	229	0	2392	2750
	2013	132	230	0	2481	2844
Devon Energy	2009				2372	2372
	2010				2425	2425
	2011				2647	2647
	2012				2811	2811
	2013				2887	2887
Oxy	2009			863	2469	3331
	2010			853	2472	3325
	2011			839	2481	3320
	2012			824	2480	3305
	2013			806	2483	3289
Apache	2009	9	46	495	1431	1981
	2010	9	51	460	1478	1997
	2011	7	50	430	1500	1987
	2012	7	49	394	1657	2107
	2013	7	51	360	1881	2299
EOG Resources	2009	2		115	1201	1317
	2010	2		115	1378	1494
	2011	1		107	1600	1709
	2012	1		102	1849	1953
	2013	1		95	2014	2110
Noble Energy	2009	100	72	168	613	953
	2010	137	67	162	619	984
	2011	161	62	154	688	1066
	2012	181	54	145	769	1149
	2013	224	48	134	858	1265
Canadian Natural Resources (CNRL)	2009		117	58	4317	4492
	2010		104	55	4350	4509
	2011		93	52	4395	4540
	2012		82	46	4395	4522
	2013		73	44	4383	4500
Sinopec	2009	46	101	271	4145	4562
	2010	71	94	260	4155	4579
	2011	80	87	247	4172	4586
	2012	87	84	238	4123	4532
	2013	93	80	224	4103	4500
CNOOC	2009	69	453	2341	861	3724
	2010	78	459	2298	912	3748
	2011	88	456	2223	1002	3768
	2012	97	451	2131	1132	3810
	2013	106	446	2030	1211	3794
Cenovus Energy	2009				1106	1106
	2010				1139	1139
	2011				1199	1199
	2012				1237	1237
	2013				1261	1261
PetroChina	2009			35	20639	20674
	2010			34	21032	21066
	2011			31	21303	21334
	2012			28	21774	21802
	2013			25	21954	21979