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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. Along with the growth of these funds, methodologies to evaluate corporate sustainability have also burgeoned. 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 (BOTELHO and MAGRINI, 2011).

In addition to discrediting the rating agencies, the Deepwater Horizon reinforced the thesis that environmental risks can translate into significant financial losses (NEUHAUSER, 2016). Investors have traditionally used historical data analyses to determine future environmental risks, a strategy which has proven generally effective in identifying trends and future performance (CHATTERJI *et al.,* 2009; DELMAS and BLASS, 2010). Nevertheless, we argue that the rapidly evolving exploration scenario, an exclusive feature of the Oil and Gas (O&G) industry, suggests that past performance will most likely not resemble future risk.

This present study points out an issue that has been overlooked when evaluating O&G E&P activities: the relationship between reserve characteristics and environmental risk. We use these relationships to propose an increased disclosure of reserves, which can be used to complement historical performance in the valuation of O&G corporations.

The U.S. Securities Exchange Commission (SEC) does not require companies to report certain characteristics of their reserves that could aid investors and other market players to determine the exposure of stocks to environmental risks. This paper compares the information on reserves extracted from regulated reports issued by companies with information originated from a specialized O&G reserves database, Rystad Energy's global database Cube Browser. Using Cube Browser, we identified companies more vulnerable to climate change, accidents, and water risks based on their reserves characteristics. The ultimate purpose of this present study is to show how a greater transparency on reserves could empower market players to make better decisions.

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 and E&P Forum, 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.

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 and E&P Forum, 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 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.

Table 1 - Main environmental risks of oil production stages

Stage of Production	Environmental Aspects	Environmental Risks
Survey	Noise Emissions Air emission, effluents and waste generation and release Temporary area occupation Accidents	-Local air pollution -Climate change -Erosion -Behavioral impacts of the fauna -Temporary habitat depletion/deforestation and fragmentation -Access to previously inaccessible land/ Interference with protected areas
Drilling and Appraisal	Area occupation Air emissions (GHG, methane venting, and local pollutants) Effluents (fracturing fluids, produced water) Waste (muds and cuttings) Water consumption Energy consumption Accidents	-Use of resources (such as water and energy) -Water and soil contamination -Flora and fauna impacts -Contribution to local air pollution -Contribution to climate change -Spills, blowouts and fire -Access to previously inaccessible land/ Interference with protected areas -Temporary habitat depletion fragmentation and degradation
Production	Area occupation Air emissions (GHG, methane venting, and local pollutants) Effluents (completion fluids, well cleaning solvents, fracturing fluids, produced water, pit/pond storage) Waste (muds and cuttings) Water consumption Energy consumption Accidents	-Use of resources (such as freshwater withdrawal and energy) -Water and soil contamination -Flora and fauna impacts -Permanent habitat depletion fragmentation and degradation -Contribution to local air pollution -Contribution to climate change -Spills, blowouts and fire -Access to previously inaccessible land/ -Interference with protected areas
Decommissioning	Waste Accidents Leakage	-Possible wrecks -Blowout and spill -Seepage from cutting piles -Destruction of marine habitat -Waste to landfill

(Source: Developed by the author, based on UNEP and E&P Forum, 1997; EPA, 2000; UNEPFI, 2006; MAGRINI and BOTELHO, 2012, REIG *et al.*, 2014.)
Note: "VOCs" are volatile organic compounds.

2.1 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 1, we have grouped them into seven main categories being: sensitive areas/access; climate change; water; waste; accidents; air pollution and noise. 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.

2.1.1. 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, which in turn also effects ecosystems. 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 and E&P Forum, 1997; O'ROURKE and CONNOLLY, 2003; 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 (FREUDENBURG AND GRAMLING, 2011; 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).

Moreover, 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 (RODRIGUEZ, 2008).

2.1.2 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, and others as presented in Table 1 (EPA, 2000; IFC, 2007a; IFC,2007b).

Associated gas brought to the surface with crude oil during 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 situation changes when oil sands are introduced, increasing from an average of 20 kg CO2e/MJ for gasoline from crude oil to 45 kg CO2e/MJ for gasoline from oil sands (BURNHAM et al. ,2011, Ingraffea, 2013). 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 extracted using mining are 8-37% greater than traditional crude oil, using in-situ mining this number increases from 23 to 73%.

Canadian and Venezuelan bitumen has higher CO2 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 Pipeline1 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).

Further, Méjean and Hope (2008) estimate the social cost of all CO2 emissions from the Canadian oil sands industry, including emissions from land-use change, and conclude that the social cost of CO2 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 CO2 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, 2008).

When defending the exploitation of shale gas, a lower carbon emission

[1] 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.

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 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 (2013), 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, 2013). To the Canadian government, Ingraffea (2013) 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." Furthermore, Schneising et al. (2014) concluded that at the current methane loss rates, a net climate benefit over coal on all time frames owing to tapping shale gas and tight oil resources in the analyzed tight formations is unlikely.

2.1.3 Water

2.1.3.1 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). After extraction and separation, the produced water is treated and discarded, in offshore production it goes most of the time to the sea. 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 and E&P Forum, 1997; 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). According to Ingraffea (2013), shale gas wells are fractured with 50 to 100 times the volume of fluid used conventional gas production, increasing significantly the amount of effluents. 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.

2.1.3.2. 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.

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)

2.1.4. 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.

2.1.5 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, 2011)

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).

2.1.6 Air pollution

As seen in Table 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).

2.1.7 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 albeit 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."

3. Socially Responsible Investors

The roots of socially responsible investment (SRI), also called ethical or sustainable investment, are religious and date back many centuries (STATMAN, 2010). The SRI movement, however, has gained momentum over the past decade: more than 1.300 institutions, representing around US$ 45 trillion in assets, have now agreed to follow the United Nations-supported Principles for Responsible Investment (UN PRI, 2015). The concept of SRI is therefore growing in popularity, and in recent years has attracted increasing interest from academia (O´ROURKE, 2003; VAN DEN BRINK and VAN DER WOERD, 2004; FOWLER and HOPE, 2007; ZIEGLER and SCHRÖDER, 2010; FERRARO and BEUNZA, 2014.).

A general definition for SRI 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 investment strategies available consist mainly of ethical exclusions,[2] best-in-class,[3] thematic funds,[4] norm-based screening,[5] engagement and integration,[6] and impact investing,[7] often in combination with one another (EUROSIF, 2014).

Pension funds, universities, and a large number of individuals who invest in ethical financial market instruments seek to identify the stocks that they want to own or avoid through labels, indexes or ratings (CHATTERJI and LEVINE, 2007; CHATTERJI et al., 2009).

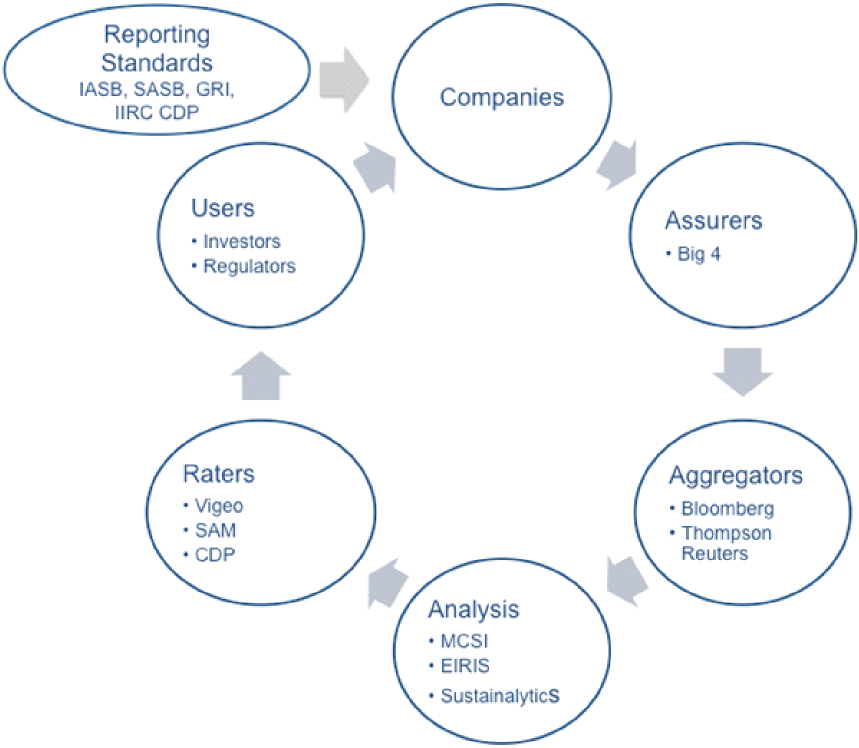

Figure 1 The Sustainability Information Landscape (Adapted from WHITE, 2012)

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[2] An approach that excludes specific investments or classes of investment from the investible universe such as companies, sectors, or countries (EUROSIF, 2014).

[3] An approach whereby leading or best-performing investments within a universe, category, or class are selected or weighted based on ESG criteria (EUROSIF, 2014).

[4] Investment in themes or assets linked to the development of sustainability. Thematic funds focus on specific or multiple issues related to ESG (EUROSIF, 2014).

[5] The screening of investments according to their compliance with international standards and norms (EUROSIF, 2014).

[6] Engagement activities and active ownership through voting shares and engagement with companies about ESG issues. This is a long-term process that seeks to influence behavior or increase disclosure (EUROSIF, 2014).

[7] Eurosif (2014) defines impact investments as investments made in companies, organizations, and funds with the intention to generate social and environmental impact alongside a financial return.

The flow of sustainability information between companies and investors passes through several players, as can be seen in Figure 1. Companies report to the market often based in one or more external standards, such as the GRI, CDP or the newly launched Sustainability Accounting Standards Board (SASB). These reports are assured through various verification activities, often the same team of auditors as the ones for the financial statements. Bloomberg and Thomson Reuters serve as aggregators, compiling data from various sources and commercialize to analysts, rating agencies or even directly to investors. Analysts evaluate sustainability trends and potential future performance. Specialized agencies such as SAM, KLD, Oekom and Vigeo, issue rating labels and indexes used by investors applying usually their proprietary “best-in-class” methodology (BOTELHO and MAGRINI, 2011). Best-in-class is considered a more advanced SRI strategy than many others and applies a number of criteria in order to select the best companies from each industrial sector. The inclusion of a stock in such indexes is regarded as an indicator of excellent corporate sustainability performance (ZIEGLER and SCHRÖDER, 2010).

Although a large amount of literature seeks to establish a link between financial returns and social and environmental performance, 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’” (ENTINE, 2006).

3.1. Relevance of the O&G sector to investors

At the end of 2013, proved global oil reserves were 1,668.9 billion barrels, sufficient to meet 52.9 years of global production (BP, 2014). 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, 2015).

The largest companies are state-owned, such as Saudi Aramco and

Petronas, and are not listed in the markets (RUSSEL, 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 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 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 (CTI, 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, 2014).

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). Further, CTI (2013) claim that current valuations are based on the full exploitation of proven reserves and do not include longer-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. In the authors' analysis:

> *If listed fossil fuel companies have a pro-rata allocation of the global carbon budget, this would amount to around 125-275GtCO2, or 20-40% of the 762GtCO2 currently booked as reserves. The scale of this carbon budget deûcit poses a major risk for investors. They need to understand that 60-80% of coal, oil and gas reserves of listed ûrms are unburnable. For these scenarios, even with full investment in CCS [carbon capture and storage], it extends the carbon budget for the 2oC "[to avoid such a rise in global temperature] by only 12-14%.* (CTI, 2013)

Impax (2014) conducts an analysis by substituting fossil stocks with renewable and energy efficiency companies, and concludes that investors should consider reorienting their portfolios toward 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 investors withdraw money from the fossil fuel sector, few if any alternative sectors 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 is too small to absorb money on the scale of the US$4.9 trillion valuation of the quoted oil and gas sector (MCCRONE and BULLARD, 2014).

McCrone and Bullard (2014) go on to argue that rate stock substitution should be determined by the speed of the transition to a cleaner energy system. In the authors' view, the bearish thesis that the world can burn only a small part of the known deposits of fossil fuel will not hold true as quickly as needed in order to avoid a temperature increase of more than two degrees centigrade, as recommended by the IPCC. The authors say that gas will be a short-term winner and coal may be a loser; 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 a significant volume of literature seeks to establish the effects of sustainability on returns for investors and the cost of capital (see WADDOCK, 2003 and HOEPNER, 2007 for a review). A few studies also focus on finding this relationship within the O&G industry, although, as reported in this section, their findings are inconclusive.

For some critics, given that oil is not a sustainable energy source and the risks inherent in its exploration, production, and consumption are high, those companies involved with it 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 (HARRIS INTERACTIVE, 2013). Cai et al. (2012) ask: "Can firms in controversial industries be socially responsible while producing products harmful to human beings, society or the environment?" Many in the sustainability field believe SRI has the potential to shift corporate behavior toward more sustainable patterns of production and consumption (O´ROURKE, 2003). According to the World Bank (2004) 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), Bullard (2014), and CTI (2014) are based on reserve profiles and not on traditional environmental performance indicators. However, Schaeffer et al. (2012), Lee et al. (2011), and Cai et al. (2012) test how sustainability performance, using as proxy the Dow Jones Sustainability Index (DJSI), the Pacific Sustainability Index (PSI), and the Kinder, Lydenberg, and Domini (KLD) rating respectively, can have a positive impact on oil companies' market value. Schaeffer et al. (2012) find that only two company's betas8 decreased as a result of entering the DJSI and that this had no effect on market value. On the other hand, Lee et al. (2011) conclude that the PSI and research and development intensity are major determinants of business performance in the O&G industry across countries. Finally, Cai et al. (2012) find that firm value is positively associated to corporate social responsibility (CSR). Schaeffer et al. (2012), Lee et al. (2011), and Cai et al. (2012) use 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. These are used to create a scoring system that yields a single score per company based on information available in corporate disclosures. The DJSI and KLD, however, use questionnaires, corporate reports, and media investigation to rate companies by applying a proprietary methodology (ROBECOSAM, 2014 and MCSI, 2015) with some of the indicators aligned with the CDP and GRI (SOYKA and BATEMAN, 2012). The predictability of these indexes and ratings has been examined by several authors, as discussed in the following section.

3.3. Sustainability ratings

Sustainability ratings are currently one of the signs that the general public considers most relevant about the environmental performance of companies. However, the ratings do not track all the activities of companies and have no access or expertise to analyze the relevant data (SADOWSKI et al., 2010). Investors also have a limited ability to analyze information about the social and environmental performance of companies; therefore, they demand tools that are adapted to their needs. Thus, the indexes are a crucial communication link between companies and investors, especially for those investors who have concerns about the social responsibility of the 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 with accurate information that makes transparent the extent to which companies' behaviors are socially responsible (CHATTERJI et al., 2009; White, 2012).

However, investors and other stakeholders who rely on sustainability ratings to identify target companies could be misallocating resources if the ratings have been unable to identify the best sustainability performance. In addition, when the metrics that are used are invalid, none of the hypothesized benefits of SRI can occur (CHATTERJI and LEVINE, 2007). To shed some light on this issue, six recent studies have attempted to scrutinize the rating process and evaluate its effectiveness. These studies are described below in order of publication.

Fowler and Hope (2007) perform a critical review of sustainability ratings, focusing on the DJSI, and find that the DJSI favors large companies. 48.3% of the companies in the DJSI had a market cap of more than US$50 billion, whereas the Dow Jones Global Index (DJGI), which is the pool used to extract the companies that make up the DJSI, had large-cap funds composing 29.6% of the index. In addition, the authors' impact analysis of the Calvert Social Index, Domini 400 Social Index, DJSI, and FTSE4good was considered low in terms of the extent to which fund managers opted to license the indexes. Further, the total amount invested, adding all the indexes together, was found to be below US$8 billion in a market in which the assets were more than $20 trillion (FOWLER and HOPE, 2007).

Chatterji and Levine (2007) explore the theoretical perspectives that explain 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 social responsibility indicators are valid measures of corporate sustainability performance and thus corroborate SRI's benefits.

The authors attempt to answer this question with statistical tests to verify the ratings' convergence, in terms of criteria and membership, and 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, Calvert, 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. Further, because 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. They also conclude that the results signify that "most SRI ratings are not measuring 'true' social responsibility." Since the authors do not say 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. For example, both Calvert and KLD analyze U.S.-based companies, whereas the DJSI and Innovest use global indexes (CHATTERJI and LEVINE, 2007).

Chatterji and Levine (2007) also consider the ability of social metrics to predict major scandals in the near future by measuring the involvement of companies in such scandals, including fraud against investors, the death of nearby residents, and the destruction of ecosystems, within a window after being listed in the ratings. KLD's Domini 400 data were selected because they extended over a longer period than any other set since it was important to verify if a member would be involved in a scandal within the next three years. The results showed that social ratings have a low predictive validity, with 35% of scandal-hit companies and 36% of control companies in the Domini 400. Nonetheless, Chatterji and Levine (2007) note that the results do not support Entine's (2006) assertion that companies 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, to determine whether environmental sub-scores can foresee environmental accidents.

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

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

The performance evaluation of 15 companies in the chemical sector vis-à-vis their rating at KLD is analyzed by Delmas and Blass (2010). Environmental performance was measured according to U.S. EPA toxic release inventory (TRI) regulatory compliance and a set of indicators for transparency and reporting defined by the authors. Several statistically significant correlations were found. Unsurprisingly, companies with higher toxic release also tended 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, it was determined that companies with the highest number of environmental concerns also had high scores 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 et al.'s (2009) conclusion that researchers and stakeholders alike still need to find better measures to assess environmental management.

Using the Deepwater Horizon accident as a backdrop, Botelho and Magrini (2011) study the differences in methodologies of six sustainability indexes (the DJSI, GS Sustain, Oekom Industry Focus - Oil & Gas, Tomorrow's Value Rating, World's Most Sustainable Oil Companies, and FTSE4Good ESG) and consider how these are reflected in the indexes' rankings of O&G companies. The authors find that the French company Total is the only corporation included in all ratings, followed by Shell, Repsol, Petrobras, and ENI. It is worth mentioning that BP ranked above fifth place before the Gulf accident in all reviewed ratings; however, only one maintained the company's position after the Deepwater Horizon incident. Botelho and Magrini (2011) hypothesize that operational safety may be diluted among the other criteria, which means that a company with a low safety score may still achieve high overall marks.

Botelho (2012) went on to scrutinize the predictability of the DJSI in terms of oil spills. 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 the DJSI spill less than non-members. The author finds a weak negative correlation between DJSI members and non-members in terms of oil spill metrics. However, it was not possible to test whether the DJSI criteria for "releases to the environment," which include oil spills, correctly identify the companies most prone to oil spills. It probably does, as Chatterji and Levine (2007) find in the case of KLD, but other factors included in the overall points offset the poor safety scores.

4. Reporting Standards

PWC (2012) reports that investors are using ESG data and that financial companies are opening ESG research departments. Further, an ACCA and Eurosif (2013) investor survey reveals that the most important sources of nonfinancial information for investors are sustainability reports (91% of investors state that such reports are "high" or "essential" on their lists of sources).

By using the Corporate Register (2015) database, it can be seen that the number of sustainability and similar reports issued yearly by corporations has grown from 26 in 1992 to 7,749 in 2013. The latter figure includes reports published by 222 O&G producers. Similarly, a survey by KPMG (2013) finds that "CR reporting is now undeniably a mainstream business practice worldwide," undertaken by 93% of the world's largest 250 companies. For Lydenberg et al. (2010), this growth in voluntary sustainability reporting means that corporations and their stakeholders value such publications.

However, the quality and completeness of reporting and its voluntary status places in question the reliability of the information that is published (GUNTHER et al., 2006; LYDENBERG et al., 2010). KPMG (2013) finds that sectors with significant social and environmental impacts, such as the O&G sector, average the lowest scores in a quality evaluation (55 out of 100 for O&G). For 93% of the investors responding to the ACCA and Eurosif (2013) survey, the information provided in sustainability reports is not sufficient to quantify the materiality of nonfinancial factors in financial terms. The same percentage also thinks that nonfinancial reporting is currently not sufficiently comparable across companies.

The Global Reporting Initiative (GRI) is the most commonly applied reporting standard (GUNTHER et al., 2007; LYDENBERG et al., 2010; KPMG, 2013). It was created in 1997 by the United Nations Environment

Program (UNEP) and the Coalition for Environmentally Responsible Economics (Ceres) in order to "enhance the quality, rigor and utility of sustainability reporting" (GRI, 2015). Since 2000, when the first guidelines were launched, the GRI has proposed a reporting structure and indicators to corporations, using a hierarchical framework in three focus areas, namely social, economic, and environmental (SINGH et al., 2012). The GRI released an O&G sector supplement in 2012 (GRI, 2012).

In 2000, at the request of an institutional investors' network, the CDP began with the idea of asking companies to share information publicly about their carbon emissions and the actions they are taking to manage them. Since then, 82% of Global 500 companies use this UK-based nonprofit (WINSTON, 2010). Further, CDP currently helps 767 institutional investors that hold US$92 trillion in assets to reveal risk in their investment portfolios (CDP, 2015). It achieves this by implementing and disclosing a questionnaire and creating an investment index.

The CDP started by focusing on climate change, expanded to include water, and later encompassed forests. The O&G module, based on a reporting framework of the 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 O&G refiners, producers, and integrated companies. The CDP has successfully used the principle that shareholder action is likely to encourage companies to adopt practices consistent with the aims of a broader social movement (KOLK et al., 2008).

Another strong reference for reporting in the O&G sector are the IPIECA/API/OGP (2010) guidelines, a first version of which was launched in 2005 with a revision in 2011. Indeed, KPMG (2011) finds an increasing tendency toward the use of sector specific guidelines such as those of the IPIECA/API/OGP (2010) for the O&G sector. GRI and IPIECA have also worked together to create a bridging document in order to align and facilitate the use of the CDP and API/OGP/IPIECA (2010) standards simultaneously.

Two recent reporting standards worth mentioning are the Integrated Reporting (IR) from the International Integrated Reporting Council (IIRC, 2013) and the Sustainability Accounting Standards Board (SASB, 2015). The IR is a framework that seeks to integrate sustainability information with the financial and business data, does not provide indicators, but instead principles for companies to apply while reporting. Unlike the IR that applies to businesses of any sector, SASB is currently developing standards for 80 sectors composed. The O&G E&P was published June 2014 and are considered provisional for at least one year after the initial release, to receive feedback from the public SASB, 2015). Two aspects differentiate SASB from other standards: 1) SASB identifies sustainability topics which may be material to a company within that industry and 2) SASB standards are to be reporting in the existing annual filings (Form 10-K or 20-F) with the U.S. Securities and Exchange Commission (SEC).

4.1 Indicator Analysis

Although the number of companies that are disclosing information about sustainability issues is 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."

The most credible and important sustainability frameworks are the GRI, CDP, and DJSI. GlobeScan and SustainAbility (2014) survey corroborates this finding, placing CDP and the DJSI among the top five sustainability ratings. However, the indicators for the DJSI questionnaire will not be analyzed here because it is not a reporting framework and the questionnaire is proprietary and not publically available.

In this context, the IPIECA and API (2003) surveyed 32 companies from the O&G industry. According to this sample, 63% published a report on one or more sustainability issues. In their reports, companies most often included data on the subjects of oil spills (21 companies); fines paid in relation to environment, health, and safety (EHS) (20); NOx and SOx emissions (19); greenhouse gases (17); total hazardous waste (17); and CO2, methane (CH4), and volatile organic compound (VOC) emissions (16 each). Further, Gunther et al. (2006) analyze 19 companies from the O&G industry, and find the following eight indicators present in more than 50% of reports: "total water use," "air emissions," "noncompliance," "direct energy use," "spills," "greenhouse gas emissions," "total amount of waste," and "initiatives for renewable energy." Further, 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., 2006).

Magrini et al. (2013) analyzed the requirements for O&G companies of the following instruments: GRI, DJSI, CDP (water and climate), IPIECA/API/OGP, Brazilian Stock market Sustainability Index (ISE), and Life Biodiversity Certification (LIFE). The authors found that although the instruments reviewed were of different natures (index, reporting standard and certification standard), the requirements and issues considered were relatively similar, with a few exceptions. CDP is theme specific, IPIECA/API/OGP place a larger emphasis on safety and GRI is the most comprehensive. The result of the themes present in the instruments is summarized in Table 2.

Table 2. Environmental Issues in GRI, CDP, ISE, Life and DJSI (Adapted from MAGRINI *et al.*, 2013)

Management and Strategy	Governance
	Policy
	Strategy
	Compensation
	Legal Compliance
	Communication
	Stakeholder Engagement
Local Pollution	Emissions (Except for GHG)
	Water and Effluents
	Biodiversity
	Waste
Climate Change and Energy	Energy
	GHG Emissions Inventory
	Management
Products and Services	Management System
	Product Safety
	Product Nature
	Packing
	Consumer Information
Health and Safety	Safety
	Emergency
	Health

It is important to understand if and how information on reserves is contemplated in these voluntary sustainability reporting standards and if they are making the connection to environmental risks. Table 3 presents the current indicators from GRI, IPIECA and CDP that can be considered forward-looking; meaning they provide direct insight into potential future performance.

Table 3 - Forward-looking GRI environmental indicators

IPIECA /API/OGP 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 because of climate change.

(Source: Developed by author based on GRI, 2013 and CDP, 2014 a and b)

Reserves are mentioned in the GRI (2012) O&G sector supplement indicator "OG1-volume and type of estimated proven reserves and production" under the Economic Category of the sector specific supplements (GRI, 2012). On the full text explanation of the indicators, item 3 reads as follows: "Report, where this is not constrained by regulatory requirements, estimated proven reserves by resource type (e.g., tar sands/oil sands, coal seam methane, tight gas, shale gas) and operating environment (e.g., onshore, offshore shallow, deepwater, ultra deepwater and Artic), broken down by geographic area or major project (GRI, 2012)." There is no explanation on why this should be reported, or if this information has any link to environmental risks.

IPIECA/ API/OGP (2010) considers reserve reporting as part of the statutory annual reports for publicly owned companies and recommends that it should be incorporated in sustainability reports if material (GRI and IPIECA, 2012).

CDP has a more risk-based approach with several qualitative questions on risks; opportunities for the business, including the supply chain; targets; and strategic outlook (CDP, 2014a). Further, in the O&G module, a section is dedicated to development strategy (OG6), requesting information on capital-intensive development areas, financial disclosures, capex, and research and development (R&D). Another section is dedicated to production and reserves according to hydrocarbons (OG1) and includes annual production values and reserves, breakeven cost of production, and lower-demand scenario analysis (CDP, 2014b).

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 and undeveloped reserves?" (CDP, 2014b). However, this question is still qualitative and provides room for interpretation; thus, it is not an easy metric for investor assessment.

4.2 Legal Reporting Requirements

The U.S. Securities and Exchange Commission (SEC) most recent O&G reporting guidelines became effective for accounting periods ending on or after December 31, 2009. In this document, reserves are defined as *estimated remaining quantities of oil and gas and related substances anticipated to be economically producible, as of a given date, by application of development projects to known accumulations. In addition, there must exist, or there must be a reasonable expectation that there will exist, the legal right to produce or a revenue interest in the production, installed means of delivering oil and gas or related substances to market, and all permits and financing required to implement the project (SEC, 2009).*

Oil and gas producing activities includes *the extraction of saleable hydrocar-*

bons, 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 there is a provision for companies to optionally disclosure of oil and gas reserves' sensitivity to price.

Under current SEC reserve reporting guidelines, it is possible to distinguish bitumen and synthetic oil (oil sands) from conventional oil production, but extra-heavy, tight oil, ultra-deepwater and shale gas are not identifiable quantitatively (SEC, 2009). It is required for companies to disclose their risk factors and describe their operations, both in qualitative terms.

Furthermore, in 2010 the SEC issued guidance that requires companies to report on information related to climate change when this is deemed material to an assessment of the companies' 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 their performance (SEC, 2010). However, some critics argue that the SEC has failed to reinforce this guidance (REPETTO, 2016).

5. Materiality evaluation of environmental aspects and their relationship to reserves

5.1 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). 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, the IASB definition of materiality is used because the 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 and b)), investors (represented by Ceres (COBURN et al., 2012)), accounting (represented by BDO, an accountancy and consultancy company, (BDO, 2014) and SASB Industry Brief (SASB, 2014), which provides the results for the materiality analysis performed to select the indicators.

The issues presented in Table 1 were used as a starting point. Table 4 summarizes the main environmental issues identified by each one of the authors. There are three environmental issues that are cited most frequently that O&G corporations with upstream activities must address: climate change, accidents and water.

Table 4 - Material environmental risks of the upstream O&G sector

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

(Source: Developed by author)

The following sections provide a description of the relationship between each of the three environmental issues, which were deemed most material, and reserves.

5.2 Climate change

Oil sands have higher GHG emissions during the production of fuel (MÉJEAN and HOPE, 2008; ETSAP, 2010, BURNHAM et al., 2011; GILES, 2013). 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. 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.

Moreover, other unconventional oils such as extra-heavy have also shown greater GHG emissions compared with conventional oil. Thus, it is expected that companies with more heavy oil reserves are more likely to suffer from climate change restrictions and thus report relatively more climate change risks (CTI, 2013). However, it is not possible to differentiate extra-heavy oil from conventional oil in the current reporting guidelines.

The opposite effect is true with gas, 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) and McCrone and Bullard (2014) anticipate that natural gas businesses could be less affected by a low-carbon world. However, shale gas lifecycle analysis highlights a controversy because upstream methane emissions counteract reduced combustion GHG emissions as discussed in Chapter 2 (WEBER and CLAVIN, 2012 and INGRAFFEA, 2013). However, it is not possible under current reporting guidelines to separate shale gas from conventional natural gas.

5.3 Accidents

Accidents were also identified as a relevant environmental issue for the O&G E&P industry (see Table 4). 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%.

There is discussion among some authors to whether an oil spill can decrease a company's market value, but 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 (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. However, SEC does not require the disclosure of reserve depth.

5.4 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.

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, 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 resources 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 for each liter of oil extracted, 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."

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 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.

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 (EVANS, 2014).

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.

6. Disclosing Environmental risks of Reserves

As discussed above, each type of oil, either because of the extraction technique being applied or because of the physical characteristics of such oil, may impose varied threat to the environment, which could result in financial losses. Hence, to adequately evaluate climate change, accidents and water pollution and consumption risks which a company is exposed to, investors need to know what oil the company is exploring and extracting.

The NASDAQ was used to select our study sample and the search was filtered for two industries: integrated oil companies and O&G production (NASDAQ, 2013). Companies that did not engage in E&P activities were excluded. Only companies with a market cap above US$20 billion were considered. The result was the selection of twenty-four companies.

Since companies are not legally required to disclose many of the characteristics identified in chapter 5, the legal reports were not a good source to gather information. Thus, reserve data were collected for the fiscal year of 2012 from Cube Browser, an integrated field-by-field database for the global upstream oil and gas industry developed by Rystad Energy (Rystad Energy AS, 2014).

Given the possible methane emissions of shale gas extraction, markets should be able to distinguish between conventional and unconventional gas reserves. In addition, as discussed in section 5.4, shale gas has also been associated with water capture and pollution issues. With current SEC reporting requirements, this distinction is not mandatory. Chapter 5 also suggests that other unconventional oil (extra heavy oil and oil sands) may face restrictions from water issues, whether from the perspective of consumption or pollution, accidents (ultra-deepwater) and climate change (extra heavy oil and oil sands).

Hence, Table 5 presents the percentage unconventional oil and gas reserves gathered in Cube Browser of the twenty-four companies in the study sample.

Table 5. Unconventional and deepwater O&G reserves (%) (year: 2012)

	Oil sands	Extra heavy oil	Tight oil	Shale gas	Ultra deepwater	Deep water	Sum
Anadarko	0	0	15	50	5	8	93
Apache	0	0	16	12	0	2	40
BP	1	0	0	8	8	18	37
Canadian Natural Resources (CNRL)	68	0	0	1	0	2	72
Cenovus Energy	68	5	0	0	0	0	73
Chevron	6	8	2	4	2	25	47
CNOOC	11	0	4	4	3	12	35
ConocoPhillips	12	0	5	26	0	7	56
Devon Energy	19	0	7	44	0	0	95
Eni	0	1	0	0	1	26	28
EOG Resources	0	0	42	35	0	0	85
ExxonMobil	13	1	2	9	1	10	38
Hess	0	0	34	0	0	15	52
Imperial Oil (Public traded part)	85	0	0	1	0	0	86
Marathon Oil	38	0	17	4	0	3	65
Noble Energy	0	0	16	29	16	5	80
Oxy	0	0	8	4	0	0	14
Petrobras	0	1	0	0	40	46	87
PetroChina	0	4	0	14	0	0	19
Shell	13	2	1	4	1	19	41
Sinopec	0	0	0	7	2	2	13
Statoil	1	3	2	9	1	67	86
Suncor Energy	86	0	0	0	0	0	87
Total	3	2	0	3	1	17	27

(Source: developed by authors from Cube Browser data.)

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 environmental risks companies disclose unconventional oil reserves that total 15% or more of their proven total of global oil and gas reserves.

Highlighted in grey in Table 5 are the reserves held above the 15% threshold. Five of the twenty-four companies analyzed did not hold in 2012 above the threshold any particular type of unconventional oil and gas or deepwater reserves (Oxy, Sinopec, CNOOC, Exxon and Petrochina). On average, 56% of the sampled companies reserves are unconventional. Nine companies have reserves above the 15% threshold when adding ultra-deepwater to deepwater reserves, and two companies have ultra-deepwater reserves above the threshold: Petrobras (40%) and Noble (16%).

It is easy to see that some companies are more exposed to one type of unconventional hydrocarbon, such as Suncor to oil sands and Petrobras to deepwater. Others have chosen to diversify their assets such as ExxonMobil, that although does not hold any particular type of reserve above the threshold, when summing all of unconventional reserves of the corporation they amount to 38% of the overall assets.

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

Thus, we propose that companies should report the volume of unconventional oil and gas reserves disaggregating liquids into conventional oil[9], oil sands[10], extra heavy oil[11] and tight oil,[12] and gas into conventional gas and unconventional gas. Furthermore, reserves should also be disaggregated for on-land, offshore shelf (0-125 m depth), deepwater (125 m - 1500 m depth) and ultradeepwater (deeper than 1500 m).

7. Concluding Remarks

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. Nonetheless, 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.

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.

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[9] 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)

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

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

[12] Tight oil in Cube Browser includes development that requires fracturing of the reservoir.

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