ASSESSING CLIMATE CHANGE RISKS AND OPPORTUNITIES FOR INVESTORS

Oil and Gas Sector

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Oil and Gas Processing Sector

Introduction

The oil and gas extraction and processing (oil and gas) sector is already financially vulnerable to extreme weather events such as cyclones. Climate change is forecast to increase the exposure of oil and gas companies to climate, energy and carbon price risks. Few oil and gas companies publically report having a comprehensive, corporate-wide climate change mitigation or adaptation strategy. As this guide will show, oil and gas companies have available to them many adaptation measures and opportunities to mitigate energy cost, carbon and carbon related regulatory risks.

Purpose

This guide provides information to help investors assess and integrate climate risk and opportunity in the oil and gas sector into investment analysis.

How to use this guide

Identify the risk factors: Recognise key climate change, energy and carbon risks faced now by investors in the oil and gas sector in Australia.
(Table 1 and Table 2 provide a checklist of issues for investors)

Indentify how risks will increase: Unmitigated climate change will increase risks related to extreme weather events, energy cost and carbon liability. Increasing risks and potential for negative impacts are explained.

Identify the adaptation strategies and mitigation measures: The most cost effective measures companies can take to adapt to physical risks (to build resilience for climate changes which can no longer be avoided) and mitigate energy costs and carbon risks (reduce exposure) are then described based on observations of leading practices. These measures should not be considered in isolation but within the capital planning cycle of companies.

Assess materiality: Not all climate change risks affect all sectors equally. Tables identifying risks, adaptation strategies and mitigation measures in this guide include the most significant issues for the oil and gas sector.

Integrate the information into investment processes: The diagram below indicates how investors can integrate the information in the guide into investment practices.

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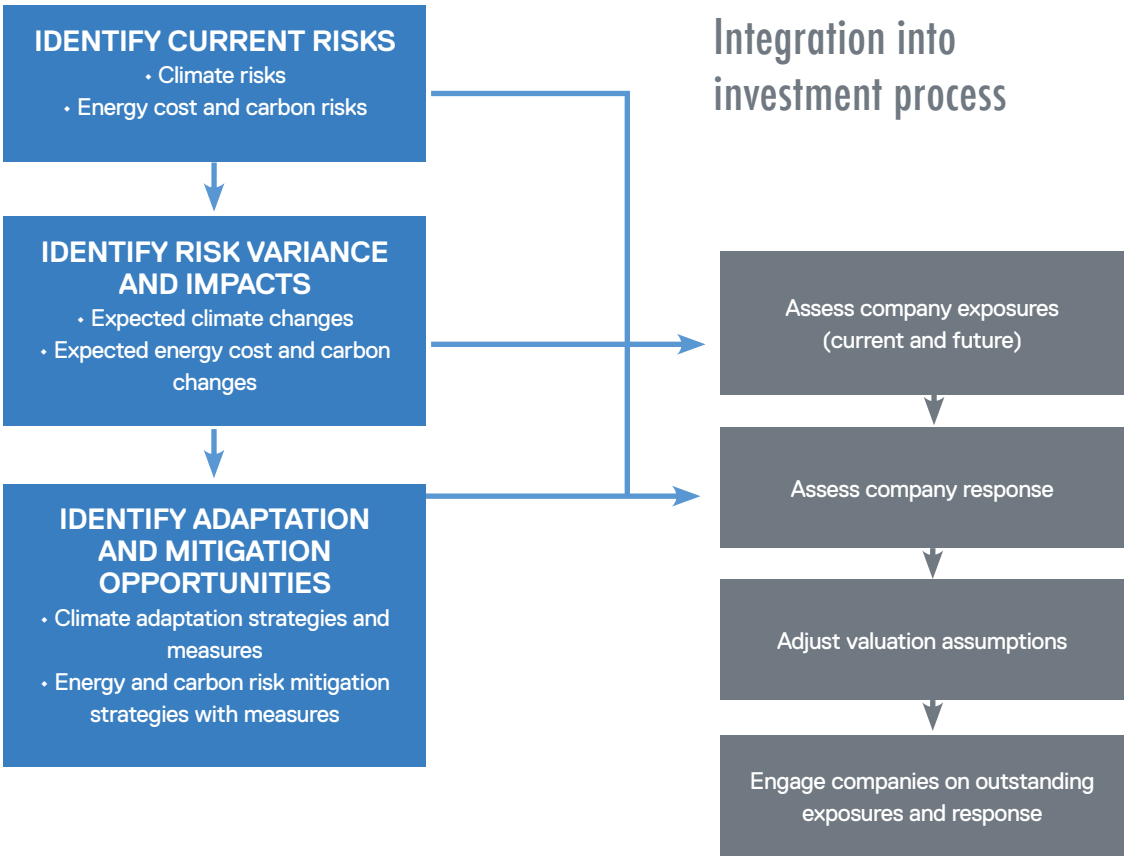

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SUMMARY OF CLIMATE RISK IN THE OIL AND GAS SECTOR

Climate related risks

The oil and gas sector is a capital intensive sector with many long life fixed assets, long supply chains and significant water requirements to enable operations. The sector also operates often in remote 'high temperature' or sub-zero temperature locations, many of which are exposed to risks of cyclones and flooding. Therefore oil and gas companies are already exposed to many extreme weather and water supply related risks that have historically resulted in either sudden production downgrades, costly delays to projects or greater risks of costly liabilities as evidenced by the following high profile examples.

Cyclones - construction cost blow outs	The Gorgon LNG project has experienced construction cost blow outs of US$15 billion or 40% to $US52bn, up from an original estimate of $US37bn when the project was approved in 2009.[2] Gorgon has cited a range of factors causing this, stating 'We were impacted by weather as we were constructing the beds, other facilities and infrastructure in the early days of Gorgon. There were a number of cyclones that went through the area, and that (negatively) impacted us.[3]
Cyclones - asset damage and loss production	Oil and gas extraction in the North-West Shelf was adversely affected by cyclones and severe weather, with 13 per cent of annual production lost in 2005-6,[4] and considerable lost revenue.
Lack of water availability and droughts	The oil and gas sector is a water intensive sector. It is, therefore, vulnerable to declines in water availability to maintain operations and proceed with new projects. For instance, the coal seam gas industry's growth projections over the next few decades are dependent on having access to 7600 gigalitres of groundwater over the next two decades according to the National Water Commission – equivalent to about a third of the average annual flow of the Murray-Darling river system. [5]
Intense flooding	Flooding events pose risks to the oil and gas industry such as damage to facilities, loss of production and risks of dispersal of salt from coal seam gas mines onto farming land. For instance, the January 2011 Brisbane floods caused a ''steam outage'' at the Caltex Lytton refinery on 5 January, prompting an unscheduled shutdown resulting in a decline in share price.[6] According to Arrow Energy 'Floods have the potential to disrupt coal seam gas field infrastructure and services. In the event of flooding, access to the well sites is limited particularly in the Bowen Basin (central Queensland); this reduces the efficiency of the fields and limits any drilling activity during those events.' [7]
Storm surges and sea level rises	The storm surge from Hurricane Katrina caused the closure of nine refineries, resulting in the total shutdown of oil production in the Gulf of Mexico from the six-month period following Katrina cutting US annual oil production by over 20%. Up to 50% of Australia's refineries are positioned on the coast not far above sea level. Caltex Australia reported to CDP 'Some Caltex facilities could be impacted by sea level rise (in the long term).
Bushfires - gas leaks or pipeline explosions	Gas vented from leaks in compressors or pipelines can be ignited by sparks or embers from bush fires and contribute to bushfire damage to local areas. There is another risk of corroded gas pipelines exploding and causing fires, such as in 2008, when the explosion of a corroded gas pipeline on Varanus Island, off Western Australia, caused a fire which burned out of control and caused $60 million in damage to the refinery. The plant was shut down for several months, cutting gas supplies to the state and industry by a third, leading to economic losses in Western Australia of up to $3 billion.[9]
High temperatures	High temperatures will add to operational oil and gas industry costs in numerous subtle ways. For example, the LNG manufacturing process requires natural gas to be chilled to less than minus 160°C in order to liquefy it for efficient transport. High temperatures add to the amount of energy and costs needed to liquefy natural gas.

Climate change risks, forecast change, potential impacts and adaptation strategies

The latest climate science shows, over the last century, the average intensity of these extreme weather events has increased due to climate change[10] and, if current greenhouse gas emission trends continue, will continue to increase over the coming decades. Given this, it is reasonable for investors to expect companies to plan for such scenarios now, including implementing cost effective adaptation strategies open to oil and gas companies summarised in Table 1 and described in further detail below in Table 4. 75% of oil and gas companies reporting to CDP identify physical climate change risks as having the potential for substantive negative effects on their business, yet only 5% mentioned adaptation as a consideration in their response.[11] Only three oil and gas companies report developing a specific ''Climate Change Adaptation'' plan or strategy.

Table 1. Climate change risks, forecast change, potential impacts and adaptation strategies

	FORECAST CHANGE	IMPACTS	SAMPLE ADAPTION STRATEGIES
MORE INTENSE CYCLONES	Cyclone Intensity + 60% by 2030 +140% by 2070	· Delays to construction and decommissioning · Damage to infrastructure · Operations disrupted · Supply chains disrupted · Increased risk of a spill/gas leak leading to damages and potential litigation	· Plan construction and decommissioning activities to address likely cyclone events · Increase design and construction standards · Improved standards for offshore platforms · Replace semi-subs with drill ships · Reconsider geographic diversification · Diversify sources of material inputs · Insurance
MORE INTENSE EXTREME RAIN-FALL EVENTS	Despite overall decreases in rainfall (see below), rainfall events will become more intense creating a greater risk of flooding.	· Delays to construction and decommissioning · Damage to infrastructure · Operations disrupted · Supply chains disrupted	· Plan construction and decommissioning activities to address the tropical wet season · Flood defense measures · Managed aquifer storage of flooding waters · Pumping equipment and backup generators · Multiple transport routes · Insurance
REDUCED WATER AVAILABILITY	(%) 2030 2050 2070 North: -10 to +5 -20 to +10 -30 to +20 South: -10 to 0 -20 to 0 -30 to +5 No. of months in drought by 2070 South WA : +80% Eastern Australia : +40%	· Reduced amounts of water · Water supply cost increase · Greater competition for water	· Improve efficiency of water usage · Develop alternative water supplies · Desalination and treatment of 'produced water' for re-use by farmers · Managed aquifer storage of flooding waters
AVERAGE HIGHER TEMPERATURES	0.1 - 1.5°C by 2020 0.3 - 4.0°C by 2030 0.4 - 8.0°C by 2080	Higher energy costs (e.g. chilling costs in LNG plants and air-conditioning costs)	· Effective insulation of super-cooled LNG processes · Adding pre-chillers to LNG plants · Energy efficient chillers · Energy efficient air-conditioning · Use of reflective white paint on metal surfaces exposed to sunlight
MORE DAYS OVER 35°C (northern Australia)	7 - 11 days per annum by 2000 69 days er annum by 2030 308 days per annum by 2070		
HIGHER RISK OF BUSHFIRES	Days with very high and extreme Forest Fire Danger Index (FFDI) ratings: 4 - 25% by 2020 15 - 70% by 2050	· Increased costs for distribution infrastructure to meet higher standards · Risk of pipeline leaks or explosions adding to, or causing, intense bushfires.	· Improved pipeline standards to withstand extreme heat from bushfires · Reduce risk of pipeline leaks and explosions · Build appropriate fire breaks · Reduce bushfire fuel loads · Work with Rural Fire Service · Implement best practice OH&S

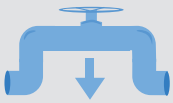
Energy costs and carbon risks and mitigation opportunities

As well as climate change related risks, investors in the oil and gas sector face risks that could lead to higher energy costs and exposure to the price on carbon if not strategically managed. A sample of these is listed below.

Rising energy intensity	Energy intensity in the petroleum sector has risen by approximately one-third since 1980 in OECD countries due to: • The growing maturity of oil and gas fields. In Australia, oil production reached a plateau before eventually peaking in 2000-01, and then declining • Increasing reliance on less accessible conventional fields, which generally require more energy to produce. [14] Recent efforts to invest in energy efficiency have stopped this trend and have seen a reduction in energy intensity. Still greater investment in energy efficiency will be needed to continue to constrain energy costs rising per unit tonne of production.
Changing regulatory landscape	Regulation of oil and gas companies' own activities is intensifying; for instance refineries are amongst the industry groups already included in the EU and Australian carbon price/emissions trading schemes, while an increasing number of governments globally are moving to eliminate gas flaring.
Carbon liability uncertainty	Oil and gas companies currently are rarely reporting fugitive methane emission levels. This leaves investors vulnerable to exposure to potentially higher costs under a carbon price. There is inadequate data on the level of fugitive emissions from unconventional gas-fields. The US Environmental Protection Agency has doubled its own estimate of fugitive emissions to 2.4 per cent.[15] If the US EPA estimate is used, the Australian coal seam gas industry could face hitherto largely ignored future carbon liabilities of up to $2.4 billion a year if fugitive emissions of methane from unconventional gas production turn out to be around 2.4 percent in Australia. [16]
Risk of fugitive emissions	The most recent scientific literature shows that even just a 2% rate of fugitive methane leakage offsets virtually all of climate change mitigation benefits of reduced carbon dioxide emissions from using natural gas. [17]
Market value uncertainty and risk of stranded assets	Approximately half of the value of oil and gas companies in the industry lies in the assets they have yet to exploit – their reserves – the value of which is considerably greater than the value of currently productive assets. As a consequence, analysis of the prospective carbon liabilities associated with those future productive reserves is vital to understanding the extent of value at risk through climate and policy related change in coming years. Projections from the IPCC imply that annual emissions of GHGs must be reduced by at least 80% from 1990 levels if risks of 'abrupt and irreversible' climate change are to be reduced. Barring the development of commercially viable technologies able to significantly reduce the emissions released in the burning of fossil fuels, a transition to a low carbon global economy will require a significant reduction in the use of fossil fuels. [18]
Climate change policies driving down demand for natural gas.	Due to Australian climate change policies, since 2009, domestic demand for fossil fuel electricity has peaked and started to fall. According to the Australian Energy Market Operator, the rate of decline is increasing. This has led to Energy Australia[19] and ACTEWAGL[20] shelving plans for new large scale gas powered electricity plants citing declining domestic electricity demand.

Energy cost and carbon risks are summarised in Table 2 with relevant mitigation strategies for investors to discuss with companies.

Table 2 Energy and carbon cost risks, forecast change, potential impacts and mitigation strategies

RISING ENERGY INTENSITY 	FORECAST CHANGE Energy intensity in the petroleum sector has risen by approximately one-third since 1980 in OECD countries.	IMPACTS • Higher energy costs • Higher construction material costs • Higher transportation costs	ADAPTION STRATEGIES • Reduce flaring, venting and leaks • Reduce fugitive methane emissions • Improve energy efficiency of gas compression equipment • Improve energy efficiency of oil and gas transportation via pipelines • Improve the energy efficiency of oil and gas refining plants • Improve energy efficiency of general technical equipment
CHANGING REGULATORY ENVIRONMENT 	FORECAST CHANGE Exposure to a carbon price 2012-2015: $23+/tonne 2015 onwards: global market price, likely to be between $10-$20 per tonne		
CARBON LIABILITY UNCERTAINTY 	FORECAST CHANGE Oil and gas companies currently tend not to report levels of fugitive methane emissions. This leads to uncertainty regarding carbon liability	IMPACTS Potentially higher carbon cost liabilities	
RISKS FROM FUGITIVE EMISSIONS 	FORECAST CHANGE The most recent scientific literature shows that even just a 2% rate of fugitive methane leakage offsets all of the climate change mitigation benefits of reduced carbon dioxide emissions from using natural gas. [21]	IMPACTS Increased growth in renewable energy markets Potential reduction in community support	ADAPTION STRATEGIES • Diversify into fast growing low carbon renewable energy • Diversify into fast growing markets for gas powered cogeneration systems • Invest in R&D to commercialise carbon capture and sequestration
MARKET VALUE UNCERTAINTY 	FORECAST CHANGE A range of studies suggest that only 20-35% of proven oil and gas reserves can still be burned and stay within 2 degrees of global warming beyond which irreversible 'dangerous' climate change is highly probable to occur	IMPACTS Risk of stranded assets	
REGULATORY RISKS – CLIMATE CHANGE POLICIES DRIVING DOWN DEMAND FOR NATURAL GAS. 	FORECAST CHANGE Climate change policies on energy efficiency and renewable energy have resulted in demand for gas powered electricity in eastern states flattening since 2009 and now falling. Gas demand from offshore markets is expected to grow.	IMPACTS Lack of demand currently for new gas powered electricity power stations	

The oil and gas sector is a highly capital intensive industry with long life assets and long supply chains. This sector is also water intensive. Oil and gas companies are already financially vulnerable to extreme weather events and drought. Climate change is forecast to increase the exposure of these companies to such risks (Table 1). The oil and gas sector is also vulnerable to energy and carbon price shocks from a range of factors. Most of these can be addressed by investing in cost effective and profitable climate change mitigation strategies (Table 2).

Analysis of the climate change risks and impacts

Historically, the oil and gas sector has always been materially vulnerable to extreme weather events such as cyclones. It is also a water intensive industry and thus is vulnerable to drought. Additionally, it has long pipelines across oceans and land. Oil and gas companies are already exposed to many weather related climate change risks that could result in construction delays, production downgrades or blow outs to decommissioning costs, if not managed well.

The probability of these risks, which already exist for this sector, becoming higher due to climate change, is strong. This is acknowledged by Carbon Disclosure Project (CDP) responses by oil and gas companies: as of 2012, 75% of respondents acknowledged physical climate change risks pose the potential for substantive negative impacts on their business. [22] Of these risks, respondents identified 59% as having a medium to high level of risk in terms of magnitude and likelihood of occurring. Climate change risks include the following.

Damage to assets and lost production from extreme weather events. Cyclones can negatively affect all phases of oil and gas projects resulting in either disruption of construction and production, or damage to facilities, or injury to personnel or delays to decommissioning. Over the last thirty years, many major cyclones that have hit northern Australia have stopped production and in some cases resulted in damage to oil and gas infrastructure (Table 3).

Climate change modeling predicts an increase in the intensity of cyclones of 60 percent by 2030 and 140 per cent by 2070. [24] Projections also indicate that tropical cyclones are moving southward as sea surface temperatures increase. Oil and gas industry investors have had a glimpse of the damage inflicted by cyclones of this level of intensity in the impacts of hurricanes on the oil and gas industry in the Gulf of Mexico, USA. For instance, in 2005, hurricanes Katrina and Rita caused extensive damage to oil and gas companies' Gulf of Mexico assets. These hurricanes reduced US oil and gas output significantly in 2005/6.

Table 3: Costs from cyclones to the oil and gas industry of Australia

	DAMAGES/COSTS TO THE OIL AND GAS INDUSTRY
KERRY 1973	Kerry passed close to a number of oil-drilling rigs causing damage and lost productivity time that cost over one million dollars
ORSEN 1989	Substantial cost to offshore oil and gas infrastructure.
OLIVIA 1996	Offshore, cyclone Olivia produced large swells up to 21 m (69 ft). These waves, in combination with record breaking winds exceeded 265 km/h, caused several million dollars in losses to oil platforms. On Barrow Island, a world-record wind gust of 408 km/h (253 mph) was recorded at the local airport.
MONTY 2004	Monty caused substantial economic losses to the offshore Australian oil and gas industry
GLENDA 2006	Offshore, the threat of Glenda prompted officials to close oil production for a time, representing a lack of production of 154,000 barrels of oil. Additionally, natural gas fields were closed, and several ports along the coastline were shut down during the passage of the storm. [23]
GEORGE 2007	Oil and Gas companies had to ultimately close operations in order to deal with the threat of the cyclone.

Reduced water availability. The oil, gas and refining sector is a water intensive sector. Due to climate change, average annual rainfall is expected to decrease in southern, western coast and subtropical Australia (Table 1). [25] This is likely to lead to greater competition between oil and gas, other mining, manufacturing, farming, towns and cities for the remaining water resources. Likely changes to water availability in northern Australia will make it harder to predict water resource levels. This is because the majority of water used for oil and gas extraction in the Pilbara is sourced from groundwater, the recharge of which depends on cyclonic rainfall events occurring between November and March each year. Whilst the intensity of cyclones is forecast to increase, the frequency of cyclones is forecast to decrease in northern Australia due to climate change. This makes it more difficult to predict whether oil and gas companies' groundwater supplies will be adequately recharged or not. This will require additional expenditure to ensure adequate water supply.

Higher temperatures will add to operational oil and gas industry energy costs in numerous subtle ways. For instance:

- more energy is needed to liquefy natural gas
- the thermal efficiency of gas fired power stations declines in hotter weather
- higher air-conditioning loads in facilities and refineries
- increased 'peakiness' to electricity demand due to higher air-conditioning demand. A peakier electricity load provides both potentially upside and downside risks for oil and gas companies. On the upside, greater demand means higher prices and revenue. Conversely, larger gas companies could also be financially exposed to high electricity costs if hedge contracts for supply do not match customer demand. [26]

In addition to these, there are numerous other physical risks from climate change. Table 4 summarises the main climate change related physical risks to the oil and gas sector and outlines the range of potential negative impacts.

Given the extent of the potential physical risk (Table 4), analysts should ask oil and gas companies to provide investors with a description of the risks climate change may pose to operations, with specific reference to the regions of current or future operation considered to be most exposed.

Table 4: Climate Change Risks and Potential Impacts

MORE INTENSE CYCLONES OR STORMS  COMPANIES* RECOGNISING CLIMATE RISKS Shell[27], Santos, , ROC Oil Company,	DAMAGE TO ASSETS AND LOST PRODUCTION More intense cyclones or storms can negatively affect the construction, offshore production, onshore processing and decommission phases of oil and gas projects resulting in either disruption of construction and production, or damage to facilities, or injury to personnel. These extreme events add to risk of major spills/leaks resulting in clean-up costs, regulatory response and litigation. Intense storm induced wave action from cyclones also means · increased capital cost, as oil and gas offshore rig design requirements have to be more robust in cyclone prone regions · increased operating costs through loss of efficiency following start up after shutdowns · decreased revenue from refinery shutdowns and reduced production.	REDUCED WATER AVAILABILITY - DROUGHT  COMPANIES* RECOGNISING CLIMATE RISKS Shell [29], Santos, Oil Search, Origin energy, Caltex, AGL Energy	RISK OF INCREASED WATER COSTS Due to climate change, average annual rainfall is expected to decrease in southern, western coast and subtropical Australia (Table 1). [28] This may lead to greater competition between oil and gas, other mining, manufacturing, farming, towns and cities for water resources. It will also likely lead to an expectation of increased environmental regulation focusing on protecting water supplies and quality. Both changes would add to costs for water using industries.
MORE INTENSE RAINFALL EVENTS - FLOODING  COMPANIES* RECOGNISING CLIMATE RISKS Shell [31], ROC, Caltex	DAMAGE TO ASSETS AND LOSS OF PRODUCTION Flooding events pose risks to the oil and gas industry such as damage to facilities, refineries, loss of production and increasing risks of dispersal of salt and chemicals from coal seam gas mines onto farming land. For instance, the January 2011 Brisbane floods caused a 'steam outage' at the Caltex Lytton refinery on 5 January, prompting an unscheduled shutdown resulting in a decline in share price. [30]	SEA LEVEL RISE AND STORM SURGE  COMPANIES* RECOGNISING CLIMATE RISKS Shell[33], ROC, Caltex	FLOODING AND DAMAGES TO PORTS AND FACILITIES The storm surge from Hurricane Katrina caused the closure of nine refineries, resulting in the total shutdown of oil production in the Gulf of Mexico for the six-month period following Katrina, cutting US annual oil production by over 20%. Up to 50% of Australia's refineries are positioned on the coast not far above sea level. Caltex Australia advised in their CDP report 'Some Caltex facilities could be impacted by sea level rise (in the long term).' [32]
MORE INTENSE EXTREME WEATHER EVENTS – GENERAL  COMPANIES* RECOGNISING CLIMATE RISKS ROC, Oil Search	RISKS OF REDUCED ASSET OPERATION, PERFORMANCE AND HIGHER COSTS OF DECOMMISSIONING More intense extreme weather may damage oil and gas infrastructure, pipelines, equipment, and staff accommodation which, in turn, can disrupt operations, performance and also add to decommissioning costs.	MORE INTENSE EXTREME WEATHER EVENTS – GENERAL  COMPANIES* RECOGNISING CLIMATE RISKS Arrow Energy	RISKS OF AND COSTS OF DISRUPTIONS TO SUPPLY CHAINS More intense rainfall and extreme weather events risk disrupting supply chains and transportation services of critical materials, personnel, energy fuels.
MORE INTENSE EXTREME WEATHER EVENTS – GENERAL  COMPANIES* RECOGNISING CLIMATE RISKS AWE, Arrow Energy, Origin Energy,	RISK OF HIGHER INSURANCE PREMIUMS Greater intensity and damage from extreme weather events has led to a considerable increase in weather related insurance and re-insurance costs over the last 10 years.[34] Unmitigated climate change is forecast to contribute to continuing this trend leading to ongoing increases in insurance costs.	MORE INTENSE BUSHFIRES  COMPANIES* RECOGNISING CLIMATE RISKS Arrow Energy, Origin Energy acknowledge (1)	RISKS FROM BUSHFIRES 1. Bushfires potentially threaten energy distribution and transmission infrastructure. 2. As methane is highly flammable, gas vented from leaks in compressors or pipelines can be ignited by sparks or embers from bush fires and contribute to bushfire damage to local areas.[36] 3. Older corroded gas pipelines can explode and cause fires.
HIGHER TEMPERATURES  COMPANIES* RECOGNISING CLIMATE RISKS Santos, Woodside Petroleum, ROC, Arrow energy, Origin Energy, AGL Energy	RISK OF HIGHER ENERGY COSTS This will add to operational oil and gas industry energy costs in numerous subtle ways. For instance, the process of manufacturing LNG requires natural gas to be chilled to less than minus 160°C in order to liquefy it for efficient transport. Any increase in the severity or frequency of extreme temperatures will impact the ability of processing equipment to operate efficiently. Pre-chillers may also have to be added to existing LNG plants.		

(Source: Smith, M. Stasinopoulos, P)
* Companies listed are a sample of those reporting through CDP or other publically available reports their recognition of these risks.

Oil and gas companies should be doing the above, as part of normal risk management assessments, as BP Australia[35] and Rio Tinto [36] do, or through additional climate change risk assessments by specialists, as Shell does. [37] This involves identifying and quantifying local risks and opportunities with modeling at regional and site-level.

Carbon Disclosure Project reporting from the majority of oil and gas companies acknowledges they are exposed to physical risks from extreme weather events. The intensity of these extreme weather events has already increased over the last century and is forecast to increase further through the coming decades unless substantial mitigation measures are undertaken. Investors should seek companies demonstrating risk management processes with embedded climate change risk assessments. Analysts should also seek companies implementing company-wide climate change adaptation strategies to reduce the risks of extreme weather events negatively impacting on profitability. The next section provides a checklist of adaptation responses for investors to use to assess comprehensiveness and likely effectiveness of oil and gas company adaptation responses.

ANALYSIS OF CLIMATE CHANGE ADAPTATION OPPORTUNITIES

There is a growing recognition that current regulatory frameworks and government standards are insufficient to protect company assets and operations from more intense extreme weather events. Compounding this, the oil and gas sector's peak industry bodies offered little evidence of climate change adaptation as a high priority until recently, when IPIECA, the global oil and gas industry association for environmental and social issues, hosted its first workshop on climate change adaptation in October 2012.

CDP responses from 2009-2012 provide little demonstration of most oil and gas companies taking action to integrate climate change adaptation into risk management processes and decision making.[38]

A detailed analysis of all CDP oil and gas company reports in 2009 raised concerns regarding physical risks related to their direct assets and operations, for instance:

- 76% of the major oil and gas companies globally reported their physical assets would be compromised by extreme weather events and

- whilst 83% of oil and gas companies reported assigning responsibility for climate change to an executive body, it is unclear if the responsibility includes climate change adaptation.

As at 2012, 75% of oil and gas company CDP respondents identify physical climate change risks as having potentially substantive negative effects on their business.[39] Oil and gas companies assessed 96% of these physical risks as relating to their direct assets and operations, with just 4% relating to supply chains. Given the oil and gas industry's long supply chains, 4% may be an underestimate.

Notwithstanding, oil and gas companies acknowledge direct capacity to manage 96% of the risks. Despite this, only 5% of CDP respondents even mention 'adaptation' or 'adaptation strategies/measures/initiatives' to manage risks from extreme weather and climate change in their reports. Only three oil and gas companies mentioned having developed a specific 'Climate Change Adaptation' plan or strategy. Prudently, leading oil and gas companies are starting to manage their climate change related risks through adaptation strategies which exceed present compliance requirements, to reduce risks of negative shocks to operational performance, revenues and business continuity.

Proactive management: beyond compliance

Some examples of oil and gas companies going beyond compliance to better manage and adapt to climate change related risks include:

- **Cyclones - reducing risk of damage to assets and operations**. Shell is investing in more robust offshore rig and well equipment to be able to withstand more intense cyclones. In 2005, Hurricane Katrina in the Gulf of Mexico devastated Shell's massive Mars platform. In May 2006, it returned to production. Shell has used the knowledge gained from the Mars recovery to improve the capability of its offshore equipment to withstand hurricanes and to reduce disruptions when equipment is damaged. Above water, most of the damage to the Mars platform occurred when massive clamps holding part of the rig's structure failed under sustained winds of 270 km per hour. Under water, the anchor of another company's adrift mobile drilling unit cracked a pipeline. In 2006, Shell installed re-designed clamp systems four-fold stronger, not only at Mars but, as a precaution, at all their platforms in the Gulf of Mexico. [40]

- **Addressing water security risks from drought.** Water is critical to the petroleum refining industry. On average, the petroleum refining sector uses as much as 2.5 litres of water for every 1 litre of production unit. To insulate themselves from risks of water licence reductions during the last drought, the following oil and gas companies have shown it is possible to reduce freshwater usage in refineries by at least 80%.

  - British Petroleum's Brisbane based refinery at Bulwer Island has reduced freshwater use by 80% from 2005-2009 through water efficiency measures such as reducing consumption, treating and reusing water onsite in numerous industrial processes. [41]
  - The Shell petroleum refinery in Geelong, Victoria is in the process of shifting to near 100% use of recycled water for its industrial processes.[42]
  - The BP Kwinana Petroleum Refinery in Western Australia has implemented best practice water management since 1997 leading to 70% less drinking water being used and wastewater flows being reduced by 40%. This has saved over US$1 million a year.[43]

Table 5 provides a summary of the material risks to the oil and gas sector from unmitigated climate change as well as potential adaptation responses.

Table 5: Climate change adaptation strategies to manage risk

MORE INTENSE CYCLONES AND SEVERE WEATHER  COMPANIES* RECOGNISING CLIMATE RISKS Shell[42], Santos, Woodside Petroleum, ROC, AGL Energy, Duet Group	**REDUCE DAMAGE TO ASSETS AND INFRASTRUCTURE** · More robust design and construction standards · Retrofit oil and gas offshore platforms to be able to withstand Category 5 cyclones · Insurance	**REDUCED WATER AVAILABILITY - DROUGHT**  COMPANIES* RECOGNISING CLIMATE RISKS Shell[47], Santos, Oil Search, Origin Energy, Caltex, AGL Energy	**ACKNOWLEDGE GREATER COMPETITION FOR LOCAL WATER ASSETS** · Weigh costs and benefits of exploring oil and gas options on non-arable land and at sea · Explore and develop alternative water supplies including, where appropriate, treating 'produced water', harvesting stormwater and flood waters, more efficient use of water, water treatment and recycling · Enable 'produced water' to be reused by farmers or to supplement environmental flows [45] · Using produced water for managed aquifer recharge[46]
MORE INTENSE RAINFALL EVENTS - FLOODING  COMPANIES* RECOGNISING CLIMATE RISKS Shell[44], ROC, Caltex	**REDUCE RISKS AND COSTS FROM DAMAGE TO ASSETS AND INFRASTRUCTURE** · Position new facilities considering climate change and risks of flooding · Flood and coastal erosion management strategies for existing facilities · Flood defense measures · Improve drainage systems to increase capacity to cope with greater rainfall intensity	**FLOODING – SALT DISPERSION**  COMPANIES* RECOGNISING CLIMATE RISKS Arrow Energy, Origin Energy	**RISKS OF REDUCED ASSET OPERATION, PERFORMANCE AND HIGHER COSTS OF DECOMMISSIONING** There are several potential adaptation strategies oil and gas companies are investigating: · Removal of solid salt to approved land fill · Brine injection · Ocean outfall · Treatment of salt to enable it to be used as table salt or other commercial uses. This option is still to be commercially tested.
EXTREME WEATHER EVENTS – GENERAL  COMPANIES* RECOGNISING CLIMATE RISKS ROC, Oil Search	**REDUCE RISKS OF DIMINISHED ASSET OPERATION AND PERFORMANCE** · Reconsider geographic diversification to manage potentially severe regional climate impacts · Emergency power and water supplies, pumping and wastewater treatment · Develop robust climate-proof business continuity plans · Use insurance mechanisms to cover risks	**EXTREME WEATHER EVENTS – GENERAL**  COMPANIES* RECOGNISING CLIMATE RISKS Arrow Energy	**REDUCE RISKS OF AND COSTS OF DISRUPTIONS TO SUPPLY CHAINS** · Diversify supplier base · Increase storage capacity for essential materials, fuel and products used · Review and increase insurance policies covering extreme weather events, business continuity and business disruption
MORE INTENSE BUSHFIRES  COMPANIES* RECOGNISING CLIMATE RISKS Arrow Energy	**REDUCE RISKS OF BUSHFIRES** · Reduce risk of pipeline explosions · Build appropriate fire breaks · Reduce bushfire fuel loads · Work with Rural Fire Service · Implement best practice OH&S	**HIGHER TEMPERATURES**  COMPANIES* RECOGNISING CLIMATE RISKS Santos, Woodside Petroleum, ROC, Oil Search, Arrow energy, Origin Energy, AGL Energy, Duet Group	**RISK OF HIGHER ENERGY COSTS** · More energy efficient chillers and air-conditioning systems · Greater investment in energy efficient air-conditioning and management of staff comfort levels · Health and safety policies to address implications of higher temperatures
SEA LEVEL RISE AND STORM SURGE  COMPANIES* RECOGNISING CLIMATE RISKS Shell[50], ROC, Caltex	**REDUCE RISKS OF FLOODING AND DAMAGES TO PORTS AND FACILITIES** The IPCC recommends the following strategies to reduce the risks of damage from sea level rises.[49] · Protect: Protect oil and gas assets and infrastructure from the combined effect of storm surges and sea level rises so existing sites can be maintained by constructing hard structures (such as seawalls and levees) and using soft measures (such as wetlands to protect from storm surges) · Accommodate: The land is still occupied but some modifications are made		

(Source: Adapted and updated from Acclimatise [2009][51])

*Companies listed are a sample of those reporting through the CDP their implementation of mitigation measures.

ANALYSIS OF CLIMATE CHANGE MITIGATION OPPORTUNITIES TO ADDRESS ENERGY COST & CARBON RISKS

Overview of main energy cost and carbon risks

In addition to extreme weather related risks, there are also material energy and carbon related risks to investors in oil and gas companies including:

Rising energy intensity and energy costs reducing profitability. The energy intensity in the petroleum sector has risen by approximately one-third since 1980 in OECD countries due to both the maturing of current oil and gas fields and the trend to exploit new but more remote and energy intensive oil and gas fields. This direction of industry is forecast to continue.

Changing regulatory environments adding to business costs. Over 50 national or sub-national carbon price schemes are in place around the world. Some countries are legislating to disallow any flaring. Other governments are considering joining Norway in making carbon sequestration a condition of exploiting resources.

Uncertain carbon liability exposing investors to higher carbon costs. As noted in previous reports by the Investor Group on Climate Change, there is a lack of sufficient data on the fugitive emissions by unconventional gas companies. Until such time as credible fugitive emissions data can be disclosed, investors are vulnerable to potentially higher carbon price risks.

Risk of fugitive emissions cancelling natural gas CO^2 reductions. Peer reviewed scientific literature shows that even just a 2% rate of fugitive methane leakage offsets virtually all benefit of reduced carbon dioxide emissions from using natural gas.[52] Currently, due to lack of data, actual proportions of fugitive emissions are unknown. Should unmitigated fugitive emissions be shown to be above 1-2% then regulatory and reputational risks may follow.

Uncertainty over oil and gas company market value and risks of stranded assets. Approximately half of the value of companies in the industry lies in the assets they are yet to exploit – their reserves – the value of which is significantly greater than the value of currently productive assets

As a consequence, analysis of the prospective carbon liabilities associated with those future productive reserves is vital to understanding the extent of value at risk through climate and policy related change in coming years.

Barring the development of commercially viable technologies able to appreciably reduce the emissions released in the burning of fossil fuels, a transition to a low carbon global economy will require a meaningful reduction in the use of fossil fuels. [53]

A range of studies suggest only 20-35% of remaining known oil and gas reserves can be used to stay within 2 degrees of warming. [54] This has profound implications on the value of oil and gas companies and raises the risks of stranded assets. Investors are ultimately concerned with the value of companies, most of which lies in upstream operations derived from the future potential to exploit company oil and gas reserve assets, as shown in Figure 1.

Without commercially viable carbon capture and storage, the asset value of oil and gas reserves is overstated if, under a future global climate change agreement and/or national policies, carbon budgets to avoid the 2 degree guardrail are introduced. This may lead to stranded assets..

Since 2009, domestic demand for fossil fuel electricity has flattened and begun to fall in the eastern states of Australia, due to Australian climate change policies. According to the Australian Energy Market Operator, the rate of decline is increasing. This has led to Energy Australia and AGL shelving plans for new large-scale gas powered electricity plants citing declining domestic electricity demand.

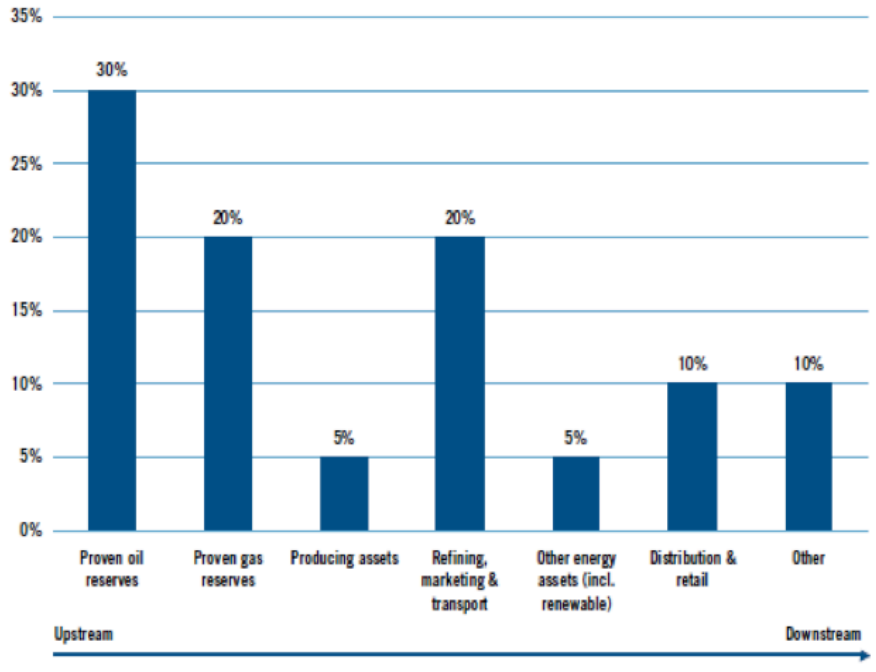


Figure 1: Distribution of value through oil and gas industry value chain (Source: Goldman Sachs Research Estimates)

The final section of this guide will discuss how climate change mitigation strategies offer profitable ways to address energy and carbon risks, including how oil and gas companies are already implementing these strategies.

Reducing energy intensity through energy efficiency

Most oil and gas extraction sub-sector energy efficiency opportunities are profitable.

The oil and gas sector has recognised publically the need to invest in energy efficiency since at least the 1990s to address the rising energy intensity trend driven by an increasing need to

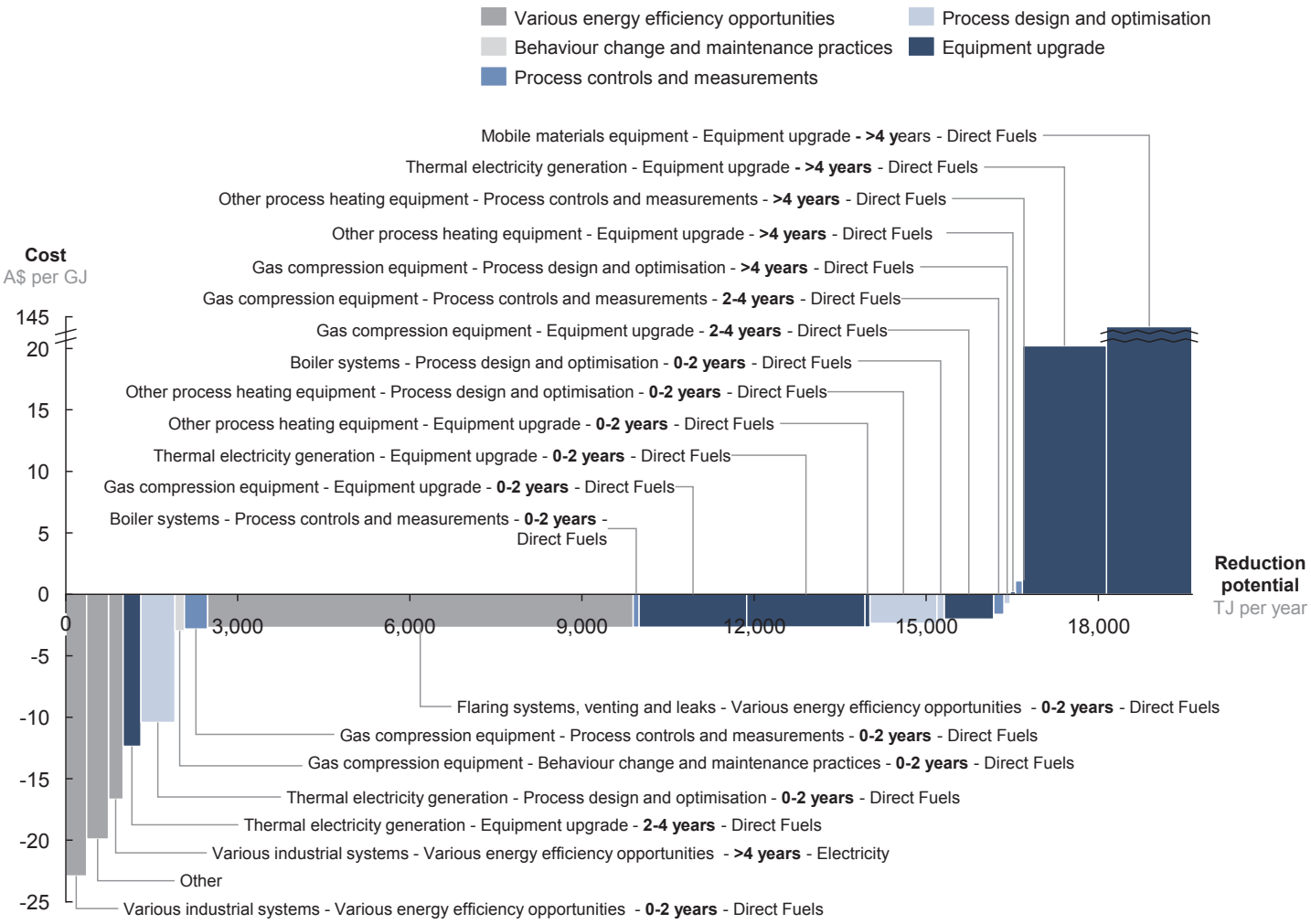
- drill deeper and further out to sea to find and produce oil and gas
- use secondary and enhanced oil and gas recovery techniques
- exploit heavier oil deposits and older reservoirs.

Investment in more energy efficient strategies since 2007 has reduced the energy intensity in extraction in the industry back to below late 1990s' levels. [55]The business case for energy efficiency is strong. For instance, ExxonMobil launched in 2000 its Global Energy Management System (GEMS), which has since identified ways to improve energy efficiency by 15% - 20%, saving close to US$750 million and reducing its CO^2 emissions by about 8 million tonnes. [56]

Despite this progress on energy efficiency, the latest study analysing energy efficiency potential for the Australian oil and gas extraction sector by ClimateWorks Australia [57] has identified over 30 energy efficiency opportunities, many of which are illustrated in Figure 2 below. Most of these opportunities have less than a two year payback period.

Numerous petroleum and natural gas refining energy efficiency measures are also profitable. The business case for investing in energy efficiency[59] is also strong in the petroleum and natural gas refining sectors. Increased demand has created the need to process greater volumes of crude oil and natural gas and at the same time convert most of it into end products, using energy intensive methods to reduce environmental impact (e.g.

Figure 2: Energy efficiency opportunity cost curve – oil and gas extraction subsector'.



(Source: ClimateWorks Australia and DRET)[58]

desulphurisation). Energy costs have been rising in response and this has prompted greater investment in energy efficiency. Studies show there are over 100 potential energy efficiency opportunities in petroleum refineries alone. [60] According to the IPCC:

> *'Key items (for petroleum refining) included: use of cogeneration for heat and power recovery, improved heat integration, combustion optimization, control of compressed air and steam leaks and use of efficient electrical devices. The petroleum industry has had long-standing energy efficiency programmes for refineries and the chemical plants with which they are often integrated. These efforts have yielded significant results. Exxon Mobil reported over 35% reduction in energy use in its refineries and chemical plants from 1974 to 1999, and in 2000 instituted a programme whose goal was a further 15% reduction, which would reduce emissions by an additional 12 MtCO2/ yr. Chevron reported, in 2005, a 24% reduction in its index of energy use between 1992 and 2004. Shell, in 2005, reported energy efficiency improvements of 3 to 7% at its refineries and chemical plants.'* [61]

According to McKinsey Consulting, energy efficiency is the most cost effective way to reduce greenhouse gas emissions in the oil and gas sector. [62]

Reducing exposure to greenhouse gas emission related costs and regulatory shifts by reducing flaring, venting and fugitive methane emissions.

Oil and gas extraction companies' main exposure to greenhouse gas emission costs arises from the practices of flaring, venting and from the problem of fugitive methane emissions from leaks. The oil and gas sector can exploit a key resource, namely natural gas, and improve financial outcomes through reducing flaring, venting and fugitive emissions,[63] because technologies exist now to virtually eliminate these practices.[64] Using these technologies, efforts to reduce fugitive emissions are expected to pay for themselves within a few months or years.

Reduce flaring and venting of natural gas. Gas flaring and venting occurs sometimes for safety reasons or where there is neither a local market nor any infrastructure to sell/use natural gas. [65] There is now a strong investor case for a range of technologies, such as flash gas compressors, which process gas (which would have been otherwise flared) into a resource. Eliminating (or at least reducing) flaring and venting turns waste into valuable resources to increase revenue.

Numerous oil and gas companies report reducing gas flaring by as much as 80% from oil and gas fields around the world. For instance, in Australia, Woodside Petroleum has publically reported that its Cossack Pioneer Floating Production Storage and Off-Loading (FPSO) vessel on the North West Shelf, which produces both oil and gas, compresses this gas and exports it to the Karratha Gas Plant for production of LNG, Domestic Gas and LPG (rather than flaring, or re-injecting the produced gas as other Woodside facilities do). [66] There is still enormous potential globally for the industry to reduce flaring as noted in oil and gas companies' sustainability reports. For instance, Chevron has stated 'We identified additional activities that, if successful, will eliminate 80 percent of our pre-existing flares and will create facilities to enable other operators to reduce flaring and control future levels.' [67]

Reducing fugitive methane emissions. Through a variety of technologies (Figure 3), oil and gas companies can cut fugitive methane (natural gas) emissions by as much as 80 percent.[68] Again, efforts to reduce fugitive methane emissions pay for themselves within a few months or years. [69]

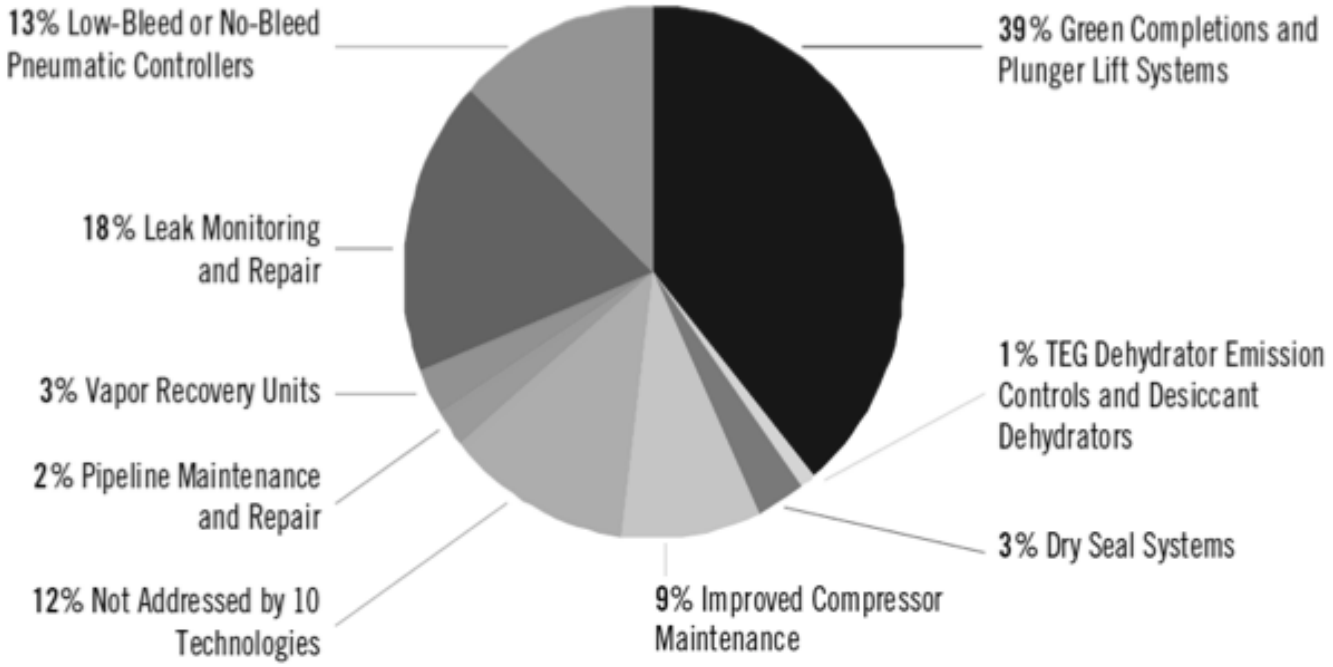


Figure 3: Strategies and technologies to reduce fugitive methane emissions and energy waste (Source: Harvey, S, (2012) [70])

Declining east coast electricity demand – shifting investment into renewables

Energy companies in Australia, like AGL[72] recognise (Figure 4) climate change policies are starting to drive down east coast demand for electricity and have chosen to shelve plans for new gas powered power stations. Recent public reports by AGL show in 2009, there was expected demand for about 8300MW of new combined cycle and open cycle gas turbines. Expectations are now reduced to little more than 1000MW of required gas fired generation. AGL is now almost solely focusing on investing in renewable energy capacity instead of gas powered power stations to meet Australia's renewable energy target (RET).

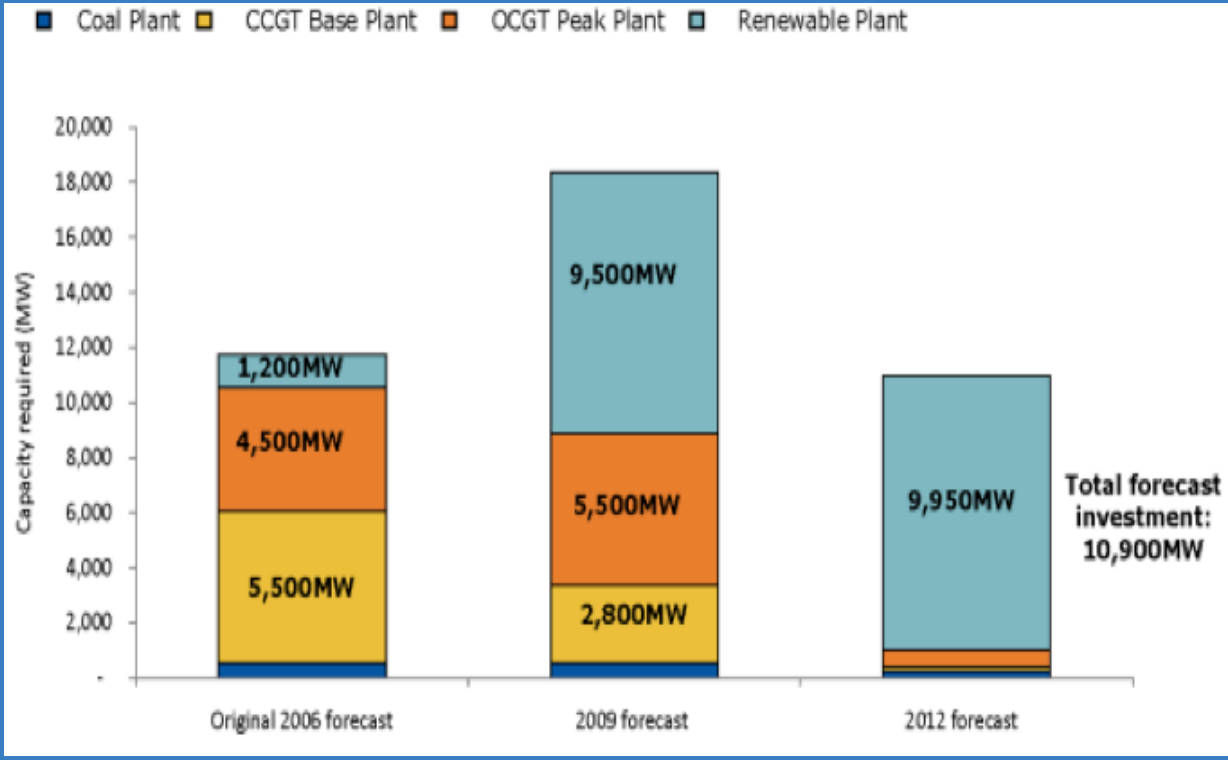


Figure 4: AGL Current and past forecasts of required domestic power capacity to 2020 (Source: AGL)[73]

Addressing additional carbon and energy risks - through diversifying into low carbon energy markets and investing in carbon capture and storage

Other risks faced by oil and gas companies include

- Uncertainty over oil and gas company market value and risk of stranded assets
- Climate change policies driving down demand for electricity from natural gas whilst increasing demand for electricity from renewable energy.

Oil and gas companies are addressing these risks by diversifying into other low carbon energy supply markets and by commercialising carbon capture and storage.

Diversifying into low carbon energy supply markets Many large oil and gas companies have collectively invested billions, to date, in R&D and commercialisation of alternative biofuels, geothermal, wind and solar energy, battery and gas powered co-generation technologies.

Low carbon energy markets are amongst the fastest growing in the world. Since 2008 global investment in new power capacity in renewable energy exceeded that for fossil fuels in almost every year. [71]

Investing in Carbon Capture and Storage

Carbon dioxide may be captured as a pure by-product in processes related to petroleum refining or from flue gases from gas powered generation. The theory is to sequester it, amongst other options, into aging oil and gas fields. Storage of CO^2 in deep, onshore or offshore geological formations uses many of the same technologies developed by the oil and gas industry and has proven to be economically feasible under specific conditions for oil and gas fields and saline formations. Reinjection of carbon dioxide in the Norwegian Sleipner gas field saves the operators 1 million Norwegian Kroners per day in reduced national carbon taxes. A recent article by Worley Parsons concurs that capture of emissions at source of extraction for the oil and gas sector 'can be economic and sustainable at relatively low carbon prices'.[74] The progress of the Gorgon gas project, in Western Australia, which will reinject CO^2 into underground reservoirs, will be a key indicator of how commercially viable carbon capture and storage is in Australia for this sector in the short term .[75]

CONCLUSION

Climate change is forecast to dramatically increase the exposure of oil and gas companies to climate, energy and carbon price risks. There are, however, many opportunities open to oil and gas companies to adapt to physical climate change and cost effectively mitigate emissions. Investors should not expect companies to mitigate every conceivable risk in isolation from other business decisions.

As per the diagram in the How to use this guide section at the front of this report, investors can use this guide to understand the risks and opportunities faced by oil and gas companies. The steps investors may wish to follow to incorporate climate risk and opportunity into investment processes include:

- assess company specific exposures for their severity and timeframe, current and future
- assess the company's response to these exposures and opportunities
- adjust company valuation assumptions based on materiality
- engage the company on outstanding exposures and their response.

In order to perform these steps, investors may gather information on the following issues regarding oil and gas company practice:

- How does the company assess the changing risk to their assets from climate change?
- Does the company consider it is exposed to the risks identified in this report?
- What level of exposure does the company consider it faces?
- What are the upstream and downstream risks to company operations from climate and energy cost risks?
- Is the company building resilience into its assets to adapt to climate risks? If so, how and when?
- Does the company benchmark its energy performance? If so how?
- Which of the energy risk and carbon mitigation measures has the company already implemented?
- What management systems does the company have in place to address the risks identified?
- What does the company see as the priority energy cost and carbon mitigation opportunities for the future?
- How do the opportunities align with future capital expenditure plans?
- What does the company believe are the barriers to implementing adaptation and mitigation measures?
- Considering the risks in this report, what is the disaster response plan for business interruption and what does it mean to investability?
- What is the company's preferred channel for reporting progress on these matters to investors?

A discussion with a company incorporating these questions and the analysis in this report should provide the basis for a constructive and relevant dialogue.

Investors should be mindful of existing disclosures by companies on climate risk. A similar, but generic list of questions can be found in the CDP annual questionnaire. Investors should refer to the CDP responses of companies to identify answers already provided. Many companies will have disclosed at least some climate risk and opportunity information. CDP company responses can be found at the following link, or investors can contact IGCC for assistance.

https://www.cdproject.net/en-US/Results/Pages/responses.aspx

IGCC will continue its work with members and company engagement partners to support the implementation of this analysis on the oil and gas sector in investment processes. Users of this document are encouraged to provide feedback to improve the quality and relevance of the guide for investors.

KEY RESOURCES

Risks to Climate - Global Climate Modeling of Fugitive Emissions

Wigley, T (2011) Coal to gas: the influence of methane leakage. Climatic Change.DOI 10.1007/s10584-011-0217-3 http://www.usclimatenetwork.org/resource-database/report-coal-to-gas-the-influence-of-methane-leakage

Hayhoe K, Kheshgi HS, Jain AK, Wuebbles DJ (2002) Substitution of natural gas for coal: Climatic effects of utility sector emissions. Climatic Change 54:107–139.

Howarth RW, Santoro R, Ingraffea A (2011) Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change. doi:10.1007/s10584-011-0061-5

Hultman, N., D. Rebois, M. Scholten, and C. Ramig. 'The Greenhouse Impact of Unconventional Gas for Electricity Generation'. Environmental Research Letters 6 (2011): 044008;

Alvarez, Ramón A, Stephen W Pacala, James J Winebrake, William L Chameides, and Steven P Hamburg. 'Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure'. Proceedings of the National Academy of Sciences (April 9, 2012);

Investors call for improved disclosure

IIGCC, IGCC, Ceres (2012) Global Climate Disclosure Framework for Oil and Gas Companies. IIGCC. IGCC. Ceres.

Identifying Cost Effective Adaptation Strategies

IPIECA (2012) Addressing Climate Change Adaptation. IPIECA http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry

Acclimatise, (2009) ''Understanding the Investment Implications of Adapting to Climate Change - Oil and Gas,'' 2009, http://unfccc.int/files/adaptation/adverse_effects/application/pdf/acclimatise_uss_oil_and_gas_final_report_oct09.pdf

AGO, (2006) Climate Change Impacts & Risk Management: A Guide for Business and Government, Department of the Environment and Heritage, Australian Greenhouse Office. http://www.climatechange.gov.au/community/~/media/publications/local-govt/risk-management.ashx

Identifying Cost Effective Mitigation Strategies

IPIECA (2012) Energy Efficiency: Improving Energy Use from Production to Consumer. IPIECA http://rio20.ipieca.org/sites/default/files/fact-sheets/pdfs/ipiecaogpfactsheetenergyefficiency.pdf

IPIECA - Saving Energy in the Oil and Gas Industry. IPIECA http://www.ipieca.org/sites/default/files/publications/Saving_Energy.pdf

ClimateWorks Australia and Department of Resources, Energy and Tourism (2012) Industrial Energy Efficiency Data Analysis – The Mining and Oil and Gas Extraction Sectors. Forthcoming at http://www.climateworksaustralia.com/publications.html

Worrell, E. et al (2005) Energy Efficiency Savings in the Petroleum Refining. US EPA and the LBNL at http://ies.lbl.gov/iespubs/energystar/petroleumrefineries.pdf

Worrell, E. Galitsky, C (2011) Energy Efficiency Improvement and Cost Saving Opportunities For Petroleum Refineries An ENERGY STAR® Guide for Energy and Plant Managers. LBNL. Environmental Energy Technologies Division. Sponsored by the U.S. Environmental Protection Agency.

Havey, Susan (2012) Leaking Profits. NRDC at www.nrdc.org/energy/files/Leaking-Profits-Report.pdf

DRET (2011) Oil and Gas Energy Efficiency Opportunities Register. DRET at http://www.ret.gov.au/energy/efficiency/eeo/resmaterial/Pages/default.aspx

World Bank Global Gas Flaring Reduction Initiative (undated) Flash Gas Compressor Operation Plant. World Bank Global Gas Flaring Reduction Initiative at http://siteresources.worldbank.org/INTGGFR/Resources/12-03-27_TEPB-REX-02_FLASH_GAS_COMPRESSOR.pdf

REFERENCES

1. Researched and Written by Dr Michael H Smith, ANU https://researchers.anu.edu.au/researchers/smith-mh

2. Chambers, M (2012) Chevron ups cost estimate on Gorgon LNG project to $52bn. The Australian http://www.theaustralian.com.au/business/mining-energy/chevron-ups-cost-estimate-on-gorgon-lng-project-to-52bn/story-e6frg9df-1226530997643

3. Butler, B (2013) Gorgon monstered by dollar but Chevron escapes damage. The Canberra Times at http://www.canberratimes.com.au/business/gorgon-monstered-by-dollar-but-chevron-escapes-damage-20130203-2dslm.html

4. Topp, V., Soames, L., Parham, D. and Bloch, H. (2008) Productivity in the Mining Industry: Measurement and Interpretation, Productivity Commission Staff Working Paper, December See Chapter 5 – Other Factors Influencing Multi-Factor Productivity at http://www.pc.gov.au/__data/assets/pdf_file/0003/84918/07-chapter5.pdf

5. Walker, J and Packham, B. (2011) *MPs demand controls on coal-seam gas rush.* The Australian http://www.theaustralian.com.au/national-affairs/mps-demand-controls-on-coal-seam-gas-rush/story-fnaxx2sv-1226210700952

6. Bloomberg (2011) Caltex Australia Shares Fall After Floods in Queensland Shut Oil Refinery. Bloomberg at http://www.bloomberg.com/news/2011-01-12/caltex-australia-shares-fall-after-floods-in-queensland-shut-oil-refinery.html Brisbane Prepares for Floods, Caltex shuts refinery - http://australia.123jump.com/australia/market-update/Brisbane-Prepares-for-Peak-Floods,-Caltex-Shuts-Refinery/42336/

7. Arrow Energy (2012) Carbon Disclosure Report. Arrow Energy

8. Caltex Australia (2012) Carbon Disclosure Project Report. Caltex Australia

9. Kym Bills and David Agostini, (June 2009); *Offshore Petroleum Safety Regulation; Varanus Island Incident Investigation.* http://www.parliament.wa.gov.au/WebCMS/WebCMS.nsf/resources/file-varanus-report/$file/varanusinquiry2.pdf

10. The Climate Commission (2013) The Angry Summer. The Climate Commission at http://climatecommission.gov.au/wp-content/uploads/Angry-Summer-amended-040313-web.pdf accessed March 5 2013

11. Adaptation in the Oil & Gas Industry Michelle O'Keeffe (2012) http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

12. Humayun, T (2012) McKinsey and Company - Increasing resilience to natural hazards: framework for utility and societal impacts (for the oil and gas sector). McKinsey and Company at http://www.hks.harvard.edu/hepg/Papers/2012/Tai_Humayun.pdf

13. Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R. and Ricketts, J. (2006) *Climate Change Impacts on Fire-Weather in South-East Australia, Consultancy Report for the New South Wales Greenhouse Office, Victorian Department of Sustainability and Environment, Tasmanian Department of Primary Industries, Water and Environment, and the Australian Greenhouse Office.* CSIRO Atmospheric Research and Australian Government Bureau of Meteorology.

14. PIECA (2012) Energy Efficiency: Improving Energy Use from Production to Consumer. IPIECA http://rio20.ipieca.org/sites/default/files/fact-sheets/pdfs/ipiecaogpfactsheetenergyefficiency.pdf

15. Paddy Manning, Sydney Morning Herald, (November 19, 2012) '' Coal seam gas faces Tax Bill of Billions'' http://www.smh.com.au/business/coal-seam-gas-faces-tax-bill-of-billions-20121118-29k6t.html

16. Op. Cit.; http://www.smh.com.au/business/coal-seam-gas-faces-tax-bill-of-billions-20121118-29k6t.html

17. Wigley, T (2011) Coal to gas: the influence of methane leakage. Climatic Change.DOI 10.1007/s10584-011-0217-3 http://www.usclimatenetwork.org/resource-database/report-coal-to-gas-the-influence-of-methane-leakage Hayhoe K, Kheshgi HS, Jain AK, Wuebbles DJ (2002) Substitution of natural gas for coal: Climatic effects of utility sector emissions. Climatic Change 54:107–139. Howarth RW, Santoro R, Ingraffea A (2011) Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change. doi:10.1007/s10584-011-0061-5

18. IIGCC, IGCC, Ceres (2012) Global Climate Disclosure Framework for Oil and Gas Companies. IIGCC. IGCC. Ceres.

19. Matt Chambers, The Australian, (December 28, 2012); *EnergyAustralia puts gas-fired plant on hold.* http://www.theaustralian.com.au/business/mining-energy/energyaustralia-puts-gas-fired-plant-on-hold/story-e6frg9df-1226544313381

20. Energy Australia's group executive manager, energy markets, Mark Collette, as reported in the Age, said that suppressed wholesale electricity prices and continued falling demand for energy had led to the decision. http://indymedia.org.au/2012/12/28/gas-fired-power-stations-for-nsw-and-victoria-placed-on-hold-as-demand-slumps

21. Wigley, T (2011) Coal to gas: the influence of methane leakage. Climatic Change.DOI 10.1007/s10584-011-0217-3 http://www.usclimatenetwork.org/resource-database/report-coal-to-gas-the-influence-of-methane-leakage Hayhoe K, Kheshgi HS, Jain AK, Wuebbles DJ (2002) Substitution of natural gas for coal: Climatic effects of utility sector emissions. Climatic Change 54:107–139. Howarth RW, Santoro R, Ingraffea A (2011) Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change. doi:10.1007/s10584-011-0061-5

22. Adaptation in the Oil & Gas Industry Michelle O'Keeffe (2012) http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

23. Smith (2004) cited in IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability,* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, see 'Australia and New Zealand', p515, www.ipcc.ch/ipccreports/ar4-wg2.htm, accessed 2 November 2008.

24. AGL - See Annual Report for 2011 at http://www.agl.com.au/Downloads/2011%20Annual%20Report%20and%20ASX%20release.pdf)

25. Shell (2012) Climate Change Adaptation: Evaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

26. Smith (2004) cited in IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, see 'Australia and New Zealand', p515, www.ipcc.ch/ipccreports/ar4-wg2.htm, accessed 2 November 2008.

27. Shell (2012) Climate Change Adaptation: Evaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

28. Bloomberg (2011) Caltex Australia Shares Fall After Floods in Queensland Shut Oil Refinery at http://www.bloomberg.com/news/2011-01-12/caltex-australia-shares-fall-after-floods-in-queensland-shut-oil-refinery.html Brisbane Prepares for Floods, Caltex shuts refinery - http://australia.123jump.com/australia/market-update/Brisbane-Prepares-for-Peak-Floods,-Caltex-Shuts-Refinery/42336/

29. Shell (2012) Climate Change AdaptationEvaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

30. Caltex Australia (2012) Carbon Disclosure Project Report. Caltex Australia

31. Shell (2012) Climate Change Adaptation CLIMATE CHANGE ADAPTATION: Evaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

32. ICA (2012) Insurance Council of Australia. Submission. Recent trends in and Preparedness for Extreme Weather. ICA. http://www.insurancecouncil.com.au/assets/submission/2013/011413_Senate%20Inquiry%20Extreme%20Weather%20(FINAL).pdf

33. Carbon Disclosure Project: CDP 2012 Investor; 2012 Information Request,BP

34. http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/sustainability/the_energy_future/STAGING/local_assets/downloads_pdfs/CDP_2012_questionnaire_response.pdf

35. See Rio Tinto – Climate Change Adaptation – Our Approach - http://www.riotinto.com/ourapproach/7212_climate_change_adaptation.asp

36. Carbon Disclosure Project: CDP 2012 Investor; 2012 Information Request , Royal Dutch Shell. http://www-static.shell.com/static/environment_society/downloads/environment/climate_change/2012_cdp.pdf

37. Acclimatise (2009). 'Building Business Resilience to Inevitable Climate Change'.Carbon Disclosure Project Report 2008. Global oil and gas. Oxford

38. Adaptation in the Oil & Gas Industry Michelle O'Keeffe (2012) http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

39. Carbon Disclosure Project: CDP 2012 Investor; 2012 Information Request , Royal Dutch Shell. http://www-static.shell.com/static/environment_society/downloads/environment/climate_change/2012_cdp.pdf

40. British Petroleum Australia (2009) BP-Bulwer Island Refinery Verified Site Report 2008. (Issued September 2009). BP Australia.

41. Both the refinery's waste water and sewage from neighbouring areas will be treated to provide industrial-quality water to meet 100 per cent of the water needs for the refinery. This will free-up 2GL a year of potable water currently used in refinery processes, increasing the region's available drinking water by 5 percent – enough to supply 10,000 homes for a year.

42. Smith, M (2010h) Water Efficiency Opportunities – Best Practice Guide - Petroleum Refining. DSEWPC, ANU FSES. http://www.environment.gov.au/water/publications/urban/weo-petroleum-guide.html

43. Shell (2012) Climate Change Adaptation: Evaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

44. Australia Pacific LNG, Finding of the best use for coal seam gas water, http://www.aplng.com.au/pdf/factsheets/Finding_the_best_use_for_coal_seam_gas_water.pdf

45. Santos – (undated) Coal Seam Gas- Water at http://www.santos.com/coal-seam-gas/coal-seam-gas-water.aspx

46. Shell (2012) Climate Change Adaptation: Evaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

47. Shell (2012) Climate Change Adaptation: Evaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

48. IPCC (2001) Climate Change 2001: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, see 'Coastal Zones and Marine Ecosystems', pp 343-379, www.ipcc.ch/ipccreports/tar/wg2/index.htm, accessed 20 November 2008.

49. Shell (2012) Climate Change Adaptation Evaluating the vulnerability of assets to climate change IPIECA workshop Addressing Adaptation in the Oil and Gas Industry Tuesday 9th October 2012 at http://www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry#event-materials-section

50. Acclimatise (2009). 'Understanding the investment implications of adapting to climate change - oil and gas'. Oxford. at http://unfccc.int/files/adaptation/adverse_effects/application/pdf/acclimatise_uss_oil_and_gas_final_report_oct09.pdf

51. Wigley, T (2011) Coal to gas: the influence of methane leakage. Climatic Change.DOI 10.1007/s10584-011-0217-3 http://www.usclimatenetwork.org/resource-database/report-coal-to-gas-the-influence-of-methane-leakage Hayhoe K, Kheshgi HS, Jain AK, Wuebbles DJ (2002) Substitution of natural gas for coal: Climatic effects of utility sector emissions. Climatic Change 54:107–139. Howarth RW, Santoro R, Ingraffea A (2011) Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change. doi:10.1007/s10584-011-0061-5

52. IIGCC, IGCC, Ceres (2012) Global Climate Disclosure Framework for Oil and Gas Companies. IIGCC, IGCC, Ceres

53. The Carbon Tracker Initiative (2012) Unburnable Carbon – Are the world's financial markets carrying a carbon bubble? At http://www.carbontracker.org/wp-content/uploads/downloads/2012/08/Unburnable-Carbon-Full1.pdf

54. IPIECA (2012) Energy Efficiency: Improving Energy Use from Production to Consumer. IPIECA at

55. www.ipieca.org/system/.../ipieca_ogp_fact_sheet_energy_efficiency and IPIECA (2012) Energy Efficiency: Improving Energy Use from Production to Consumer. IPIECA http://rio20.ipieca.org/sites/default/files/fact-sheets/pdfs/ipiecaogpfactsheetenergyefficiency.pdf

56. Saving Energy in the Oil and Gas Industry - http://www.ipieca.org/sites/default/files/publications/Saving_Energy.pdf

57. The ClimateWorks Australia's detailed analysis of energy efficiency opportunities for the oil and gas extraction sector can be accessed from http://www.climateworksaustralia.com/publications.html

58. ClimateWorks Australia and Department of Resources, Energy and Tourism (2012) Industrial Energy Efficiency Data Analysis – The Mining and Oil and Gas Sector. Forthcoming at http://www.climateworksaustralia.com/publications.html

59. McKinsey Consulting (2009) McKinsey Consulting On Oil and Gas. McKinsey Quarterly Review at http://mkqpreview1.qdweb.net/PDFDownload.aspx?ar=2517

60. Worrell, E. Et al (2005) Energy Efficiency Savings in the Petroleum Refining. US EPA and the LBNL at http://ies.lbl.gov/iespubs/energystar/petroleumrefineries.pdf

61. Bernstein, L., J. Roy, K. C. Delhotal, J. Harnisch, R. Matsuhashi, L. Price, K. Tanaka, E. Worrell, F. Yamba, Z. Fengqi, 2007: Industry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter7.pdf

62. McKinsey Consulting (2009) McKinsey Consulting On Oil and Gas. McKinsey Quarterly Review at http://mkqpreview1.qdweb.net/PDFDownload.aspx?ar=2517

63. Havey, Susan (2012) Leaking Profits, NRDC – www.nrdc.org/energy/files/Leaking-Profits-Report.pdf

64. Global Methane Initiative – http://www.globalmethane.org/documents/oil-gas_fs_eng.pdf

65. IEA (2010) Conventional Oil and Gas Technologies. IEA at http://iea-etsap.org/web/P01-Conv-Oil&Gas-GS-gct-AD.pdf

66. DRET (2011) Oil and Gas Opportunities Register. DRET at http://www.ret.gov.au/energy/efficiency/eeo/resmaterial/Pages/default.aspx

67. Chevron Australia (2009) Corporate Responsibility Report – The Value of Partnership. Chevron Australia. http://www.chevronaustralia.com/Libraries/Publications/2009_Corporate_Responsibility_Report.pdf.sflb.ashx

68. Paula Dittrick, Oil And Gas Journal, 25 June 2005, Investor groups ask industry to cut methane emissions: http://www.ogj.com/articles/print/vol-110/issue-6c/general-interest/investor-groups-ask-industry.html: Ceres, Global Investors Call For Action on Methane Emissions from Shale Gas And Oil Fracking; http:// www.ceres.org/press/press-releases/global-investors-call-for-action-on-methane-emissions-from-shale-gas-and-oil-fracking

69. Ibid

70. Havey, Susan (2012) Leaking Profits, NRDC – www.nrdc.org/energy/files/Leaking-Profits-Report.pdf

71. Edis, T (2012) AGL and Infigen's view of the future. Climate Spectator, 19 November 2012 at http://www.businessspectator.com.au/article/2012/11/19/smart-energy/agl-and-infigens-view-future

72. Cited in Edis, T (2012) AGL and Infigen's view of the future. Climate Spectator, 19 November 2012 at http://www.businessspectator.com.au/article/2012/11/19/smart-energy/agl-and-infigens-view-future

73. Worley Parsons study cited in Carbon and Environment Daily, ''LNG industry overlooking profitable ways to slash emissions'', 13 May 2011

74. Western Australia Department of Mines and Petroleum, Study summary released on Gorgon CO2 injection project 10 September 2009: http://www.dmp.wa.gov.au/7105_8523.asp