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A Critical Evaluation of Climate-Related Risks Associated with Oil and Gas Industry in Libya

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Abstract
Risk is something found almost everywhere, and not managing risks can be extremely costly. This study focuses on climate-based risks associated with the oil and gas industry in Libya. The primary data was acquired through a survey study, where a total of 150 questionnaires were distributed to a targeted population. 71 of the questionnaires returned indicating 47.3% involvement of the survey population. The water related issues are common climate risks, and most of the companies spread climate risks among insurance companies, while others retain and manage these risks. Based on the ranked results, this study illustrates various critical climate risk factors. The top ten of these factors are extremely critical. These include temperatures, lack of water availability and droughts, loss of access to water, loss of peak cooling capacity, air pollution, gas leaks or pipeline explosions, burning of fossil fuels early season delays, damage to coastal facilities, and changes in land use. However, the majority of firms adopt a risk transfer strategy followed by risk response and risk acceptance strategies for treating climate risks. Therefore, there is an urgent need to adopt possible ways to avoid the harmful impacts of climate risks for the improvement of the efficiency of projects.

Keywords
Climate Risks, Oil and Gas, Risk Management, Risk-Avoidance Strategies, Risk Mitigation Strategies

1. Introduction
As the oil and gas industry of the world is currently operating in places with an extreme range of environment for example deep water, arctic, regions and hot and arid areas, it is of key importance for the companies to identify and evaluate the risks of climate changes in these environments. The climate variables have a significant impact on the oil and gas industry and the potential variables that have been identified by the world industry include the rise of sea level, floods; migratory shifts of different species, availability of water, extreme events and permafrost thawing just to name a few. These variables present a risk for not only the operations of the oil and gas sector but also to its supporting infrastructure and the value chain involved. In this study, the climate risk factors associated with oil and gas industry in the Libyan perspective were discovered by integrating the questionnaires approach and literature review approach. Afterword, the identified risks were analyzed and evaluated based on the opinion of the survey respondents.

However, in 2013 International Petroleum Industry Environmental Conservation Association (IPIECA) reported that the coastal barriers are under degradation as a result of increased erosion. The enhanced permafrost thawing is causing a reduced time. The change in the precipitation patterns of the particular regions and their frequency is affecting the water resource availability which would ultimately affect the operations by flood susceptibility. In the northern latitude, the increased lightning strikes have a potential to damage the infrastructure and also have a strong impact on the communities of particular importance are the ones that lack the electrical grounding and are wildfire susceptible. Nevertheless, it is important to understand the risks of these climate changes for neighbors and other communities that

are essentially outside the boundaries of the company's operations and facilities. Not only on the regional but also at the urban scale, the oil and gas sector is dependent on the infrastructure of the community such as electricity, water supply, communication system and transportation. The non-flexibility of the communities and infrastructure that reside outside the fence of the companies may limit the value of investment. Of high value is the operations with the local government to identify the surrounding communities' vulnerability and it is of key importance from the perspective of recruitment. Thus, the various climate projections indicate the potential threshold, such as temperatures, that exceed more regularly than now and, for this reason, will place communities at greater risk of going through numerous events (IPIECA 2012, NOAA, 2012). Of importance is the need to develop adaptation planning according to local needs and operational actions and designs should be established accordingly, since the projects would be unique and would be based on the local level, and so would the impacts. In this evaluation of climatic risks, some important parameters to consider include the location where the operations would be carried out, the type of installation that would be developed in that location, be it a refinery or a pipeline, etc., the design of the installation to develop and current and previous climate variability data. Some additional parameters to add to this include the anticipated life time of the project and project changes in environmental conditions and climate and the rate of these changes (IPIECA 2013). A good example of this could be the precipitation frequency evaluation of the local climate which would change the water availability in future for the region and also the flooding potential. However, for projects with a shorter lifetime, this risk would be lower than for the ones with longer life. These climate risk assessments would enable the firms to categories the environmental business interruption along with other risks which are innate to the sector of oil and gas. A rather integrated approach may be established to cope with all these risks, whether associated with climate or business, in case a potential is found for overlap among them. The advent of new technologies would lead to upgrading of these risk assessments associated with climate changes on a regular basis.

2. Climate Risks and its Impacts

2.1 Climate Risks

The sector of oil and gas is one with a huge number of assets which are fixed and also long life, substantial requirements for water supply and long supply chains making it the most capital-intensive sectors. Further, the operations in this business are expanded to areas with extreme environmental risks such as high or even sub-zero temperatures, areas with risks of cyclones and flooding. Here is some examples of the weather extremities and water supply issues and these has resulted in project delays that were catastrophic for the companies in terms of the cost, production downgrades and cost liabilities.

Cyclones –Construction Cost Blow Outs

The cost blow out of a leading LNG project is a leading example of destruction as a result of cyclones. For this project the company suffered 40% of cost blow out (US$ 15 billion) from the initial estimate of $US 37 billion in 2009 when the project was approved for actual $US52 billion (Chambers, 2012). The company spokesperson has provided with a number of causes that had this drastic impact on the project cost and the key culprit was the weather as it has affected the construction in initial phases including construction of beds, project facilities and other related infrastructure. The area has suffered a number of cyclones in that period which impacted the project in the most negative ways.

Cyclones - Asset Damage and Loss Production

In the year 2005-2006, a 13% production loss was observed as a result of cyclones and severe weather in the undergoing oil and gas extraction in the North West Shelf and it caused a considerable loss in the revenues generated (Topp et al. 2008).

Lack of Water Availability and Droughts

The water requirements for the oil and gas sector are intensive and thus they are prone to considerable damage when this valuable resource become inadequate or the availability has declined. This would not only affect the on-going operations but also the initiation of the new projects. A good example of this could be demonstrated by the coal seam gas industry, whose growth projections for the coming decades are highly dependent, as per the National Water Commission, on the access of 7600 giga liters of water that should be available for the coming two decades. This amount of water is equivalent to the one third of the Murray-Darling river system's annual flow (Walker and Packham, 2011).

Intense Flooding

A significant risk is posed by the event of flooding for the oil and gas sector and it could affect the operations by damaging the operational facilities, production loss and dispersal of salt on the farming land of the coal seam gas mines. Floods could potentially damage the services and infrastructure of the coal seam gas fields as described by the Arrow Energy and this could be demonstrated by the limited access to the well sites in the event of flooding. This limited access is particularly for the Bowen Basin (Central Queensland); which could significantly reduce the site efficiency and limit the drilling activities during floods (Arrow Energy, 2012).

Storm Surges and Sea Level Rises

Nine refineries were closed by the storm surge of the Katrina (The Hurricane) which resulted in the complete production closure of oil in the Gulf of Mexico. This closure extended for six months after Katrina and a total of twenty per cent cutting in the production of oil in the US was observed. Another example of this could be found in the country where more than half of refineries are located on the coast, Australia which means that they are not far from the sea level and an increase in the sea level could be detrimental to the operations (Smith, 2010).

Bushfires - Gas Leaks or Pipeline Explosions

Another potential risk for not only the industry but also to the local areas is the explosion of the pipelines which may be caused by the gas pipeline leakage which may ignite by sparks or could get on fire by the bush fires. This would not only damage the infrastructure but could be harmful to the area. Another way the pipelines could get fired is when they got corroded and explode causing site damage and may be a cessation of operations for significant amounts of time which would affect the overall operations by decreasing the production and increasing the cost. One example that worth mentioning here is of a corroded pipeline explosion in Varanus Island which caused the closure of operations for several months leading to a loss of $3 billion (Bills and Agostini, 2009).

High Temperatures

Another major risk for the increased operational cost is posed by the higher temperatures which could affect the operations in many elusive ways. This could be demonstrated by the high energy and thus cost requirements for the LNG cooling for its effective transportation which is required it to be cool down to minus 160^{o} C (Smith, 2010).

2.2 Impacts of Climate Risks

The potential impacts of the different climate risks along with the forecast for the future have been described in this section. Beginning with the intensity of the cyclone the forecast for which indicate it to rise by 60% by 2030 and 140% by 2070 and the impacts of this rise would be significant in many ways for the oil and gas sector. This could result in construction delays and decommissioning and to add to the potential could even cause damage to the infrastructure. Further, the disruption of operations and the supply chain could be damaging for the routine operations as a result of increased cyclone intensity and could also cause spills and leaks leading to potential litigation.

As the water is a vital requirement for the oil and gas sector the forecasted shortage of water in 2070 (50% to 60%) would impact the operations by increasing the costs of the water supply and also a risk to cope with the increased competition for water. On the other hand, the rainfalls are anticipated to increase in intensity despite the reduction in overall rainfalls and could pose a risk of increased flooding events. These flooding events would affect the oil and gas sector by delaying the construction and decommissioning activities, damaging the infrastructure and disrupting the supply chains and routine operations.

Forest fires are yet another potential risk for the oil and gas sector and by the year 2020, the days with extreme forest fire danger index (FFDI) would increase to 4 – 25% whereas the ratings in the year 2050 would be 15 – 70%. This increase would lead to an anticipated cost increase in the infrastructure distribution required to meet the necessary standards and also increase the risks of pipeline explosion and leakage which could ultimately intensify the bushfires and may even cause them. The high temperature rages would affect the oil and gas industry by increasing the cost for many steps in the whole process of extraction, transportation and refining and an estimated increase in temperatures in the year 2020 is from 0.1 – 1.5^{o} C, in 2030 is from 0.3 – 4.0^{o} C and 2080 is by 0.4 – 8.0^{o} C (Smith, 2010). Thus, there is a range of risks that are currently being identified by the oil and gas companies from the current and future changes in the environment which could affect their operations (IPIECA, 2013). The value chain involved and the infrastructure and some of these have been presented in Table 1.

Table 1 – Potential risks

Category	Risks
Exploration	• Delays because of migration of species. • Wave loading. • Subsidence. • Loss of access to surface water.
Pipelines	• Wildfires. • Thaw subsidence and frost jacking.
Production	• Loss of access to surface water. • Pad damage. • Ice road—decreased tundra travel. • Early season delays. • Production interruptions.
Neighboring communities	• Storm impacts on key infrastructure. • Water. • Loss of species and habitat.
Refining and processing	• Loss of peak cooling capacity. • Flooding. • Loss of access to water.
Transport and terminals	• Reduced or improved shipping lanes/seasons. • Shipment interruptions. • Damage to coastal facilities. • Ice-load variation.

3. Climate risk management

There are three vital factors that must be carefully considered while establishing a climate risk management strategy and these include identification and evaluation of the potential climate change projection, the involved uncertainty under these changes and the impact of these projections on current operations. To understand the vulnerabilities involved, risk evaluation and feedback for the proposed plans, a multidisciplinary team, at the level of the company is necessary which comprise of the stakeholders. The decisions for the investments are made in the interim regardless the fact that the uncertainties involved in the climate remain unchanged for the future (Baglee *et al.* 2012). An assessment of the existing vulnerabilities for the operations and the operational business assets can be done by the gas and oil sector firms when they are equipped with appropriate information. This assessment of vulnerabilities would lead to the effective establishment of the adaptation strategies to manage the risks of climate changes. With the increased learning about the risks involved and the affectivity of the action plans, the iteration may exist in real time practice of these steps (Baglee, *et al.* 2012).

According to OECD (2009) no regrets adaptation plans could be established as a result of active identification and assessment of the climate risks that are associated with any particular project. These plans could ultimately describe a way to establish resilience among the existing operations of the firms and their new projects on a relatively lower cost. As a result, for the three to four decades, the climate change projections will be increased significantly and this requires for rather flexible as well as robust designs for the adaptive risk management which could not only manage the risks of the climates but also adopt according to the impact ranges. A successful strategy applied to cope with the climate changes by the oil and gas industry is employment of a myriad of risk management strategies and this could be demonstrated through an example of using a number of alternative transportation means, and personnel to avoid any disruptions caused by these changes. Across the worldwide oil and gas industry, energy supply diversification is observed which is enabling ways to mitigate the energy supply disruptions through a wider range of geographical regions as a result of severe environmental events (IPIECA, 2013).

The strategies which are undertaken or even under development by the companies responding to the Carbon Disclosure Project (CDP) have been disclosed in order to cope with the current and future environmental variability. According to the results published in 2011, 75% of the companies responding to the survey report to recognize physical risks as a result of climate changes. Out of these identified risks, 96% were reported to have significant impact on the operations of the companies. The most commonly identified physical risks by the oil and gas companies in this survey

were cyclones, rise in the sea level and snow. According to the firms of the sector, they incorporate climate risk management into their business strategies (IPIECA, 2013).

4. Climate risks in Libya

Libya has been under the influence of a number of factors, interaction among which determines the climate of the region. Most importantly, its geographical position (20º to 34º N) creates a rather sub-tropical climate. The two climate regions which affect the environment of Libya include that of the Mediterranean and Sahara, which both are contrasting and could contribute either maritime origin or that of continental origin effect on the climate of Libya. Against the huge area which is occupied by the desert, the coastal belt contributes to the precipitation effect efficiently. As the mean angle of the sun from a global perspective is always highest at the equator and gradually lowers towards the poles, so is the case in Libya where the temperature decreases with increasing latitude. To add to the precipitation effect, the mountains play a key role by acting as a strong barrier to the air masses and alter the precipitation pattern on either side of windward and leeward (Domros and Gongbing, 1988).

The conditions of temperature and the moisture in Libya are controlled by the Mediterranean Sea distribution. the warmest area of the sea attracts the relatively cooler maritime polar air to the region and sometime from arctic air and continental European air is attracted to the region. The distribution of the pressure of the air is responsible primarily for the wind patterns contributing to the temperature and the precipitation. The differences in the air pressure and the weather systems are responsible for the creation of winds (Martyn, 1992).

The main source of water in Libya is the groundwater with around 88% of the water needs and according to the groundwater basins in Libya water balance is under a severe shortfall (Schliephake, 2004). As the precipitation is responsible for providing the surface water, the absence of the permanent streams in the region contributes to its deficiency. The surface water provides with a total of 3% of consumption. 16 dams have been developed by Libya on Wadis having total water holding capacity of 385 million m^3 and an annual capacity of 60.6 million m^3 on an average (General Environmental Authority, 2001).

5. Impact of Climate Change: Libyan Perspective

Researchers examined and scientists are interested in the city of Benghazi over the impact of climate change on the environment and public health in a symposium organized by government agencies under the auspices of the World Health Organization. A seminar organized on the occasion of World Health Day coincided with the National Day of the environment-experts and Libyan officials, academics and specialists from all around the world participated in this event. They spotted a symposium of environmental degradation due to climate change, as discussed aspects of health and environmental policy in the state.

Deforestation: Participants in the symposium warned that environmental degradation witnessed in Libya represents a decline in the vegetation and the small number of forests, noting that forests easy Ajafarh example receded by 70% in 2007. Attributed by the Libyan expert at the Center for Space Science and Remote Sensing; Mahmoud Faitouri deforestation in arid and semi-arid to poor management of natural resources, resulting in soil erosion to look after the rainy season and frequent sandstorms. Moreover, experts opined that deforestation leads to ecological imbalance, and noted a decrease in vegetation easy Ajafarh and Green Mountain dramatically after the conversion of some forest land to agricultural land. It is reported in the report that forests easy Ajafarh decreased from 23,000 hectares in some places to 5,000 in the past few years (Almher, 2008). Accordingly, the rainfall in the region of Cyrene (225 kilometers east of the city of Benghazi) 600mm, which is equivalent to rainfall in the French capital Paris. However, the difference, according to an expert not only in quantity, but in a period of rain in the former about seventy days, while rainfall over the second 188 days throughout the year.

Climate and Malaria: As specialized in medical statistics a participant linked between climate change and adjust the cases of malaria in Libya, and said that the continuation of climate change may make parts of the south of the Libyan threatened by the disease. In contrast, played safe with good Deputy National Representative of the World Health Organization (WHO) in Libya from the risks of climate change in this country. He said that Libya the best countries in the Middle East in this file, compared with Latin America, Asia and Europe because of the natural factors (Almher, 2008).

6. Data Acquisition and Analysis

A total of 150 questionnaires were distributed to professionals who associated with climate risk management in oil and gas company. Seventy-one questionnaires were returned which shows 47.3% involvement to the survey population. Based on these findings and interpretations, possible ways are recommended to avoid the harmful effects of climate risks for improving the efficiency and efficacy of Libyan oil and gas projects. The critical climate risks are prioritized using the simple average mean weight of each factor. The weighted average is usually used for risk ranking. Weighted average of risk factor scores can be calculated from equation 1.

$$\textit{Risk weighted average} = \textit{sum}\ (\textit{Risk score} \times \textit{Risk weight}) \,/\, \textit{sun}\ (\textit{Risk weight}) \quad (1)$$

As shown in Figure 1 that the greater number of respondents (62%) demonstrated their experience between 11 and 15 years while 24% of respondents their overall experience between 16 and 20 years. Only 5.5% of participants have experience between 5 and 10 years whereas 8.5 of respondents had more than 20 years of relevant oil and gas experience. On the other hand, all the respondents replied that they have enough information on climate related risks associated with oil and gas industry.

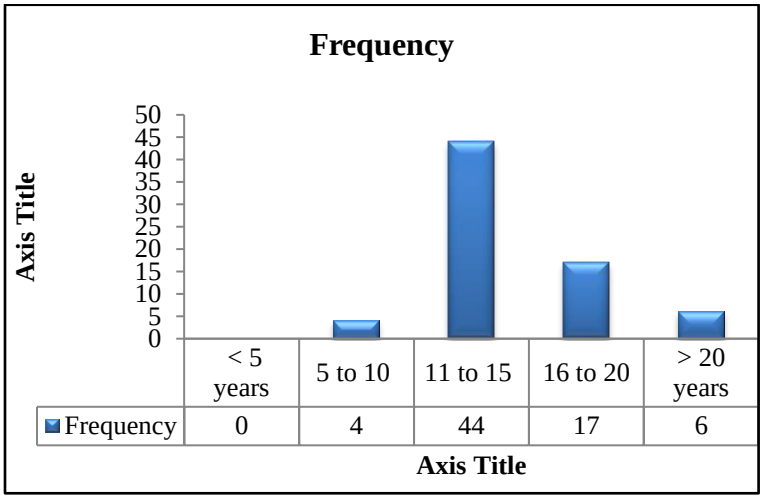

Figure 1 – Respondent's experience

The following points are the results that obtained from the analysis of the questionnaire:

a) Importance of climate risk: it is important to realize that risks of rapid climate changes in neighbouring countries affected the operations of oil and gas companies at the both reginal and urban scales. The survey shows almost 96 % of the respondents are aware of the criticalness of climate risk in oil and gas sector.

b) Effect of human activities: Just 4% of the responders claimed that the human activities affect the climate, however, about 92% of the responders replied that the human activities not affect the climate and 4% replied with 'don't know'. This shows a difference of opinion between the respondent's point of view and what is reported in the literature. Whereas, the Statistics Canada report in 2008 stated that since 1750 human activities are playing a noteworthy role in overloading the atmosphere with CO_2. Likewise, Elmabrouk, et al. (2017) mentioned that CO_2 emission sources are part of human daily activities and include those of power plants, public transport, industrial sources, chemical production, oil production and agricultural practices, whereas many of these sources burn fossil fuels, including coal, oil and natural gas, which are the main cause of CO_2 emissions.

c) Risk responsibility: the responsibilities of overcoming problems emerging from climate risk vary country-to-country. In Libya, National Oil Corporation (NOC) is the major national authority which aims to formulate policies and develop strategies to deal with climate related risks. NOC is supported by its subsidiaries and overseas partners that assist it in various decisions. However, regarding the responsibility of making crucial decisions in order to reduce the impact of climate changes, the results are very hard to analyse because of the diverse nature of answers. a majority of the respondents believe that government followed by national and international environmental agencies are the responsible parties. Many people also perceive that local councils, united nations and even individuals need to be responsible to reduce climate change impacts. In contrast, some professionals believe that the European Union, an

organization itself, and businesses and industry should not be responsible for making decisions to avoid or mitigate the risk of climate changes.

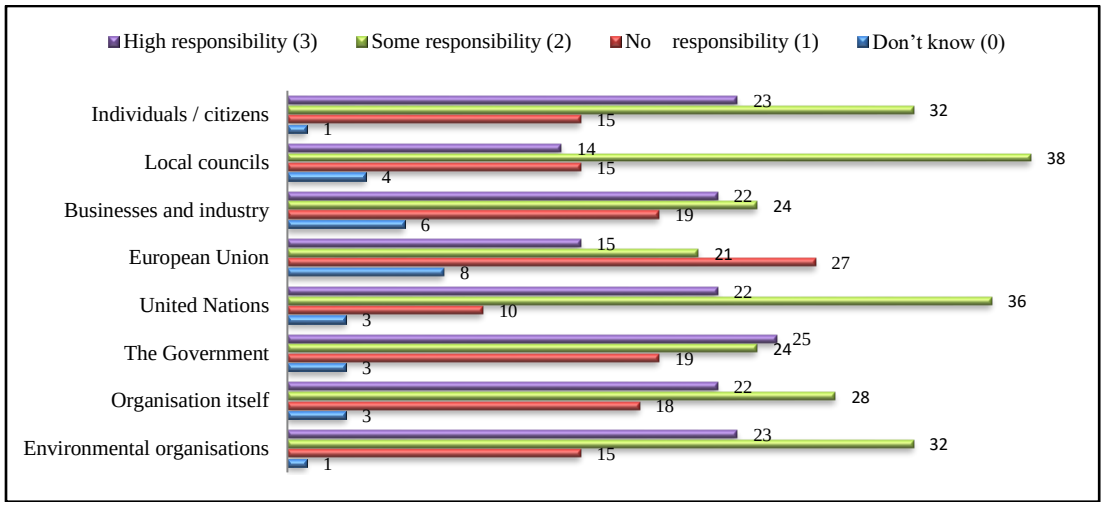

Figure 2 – Responsible authority

d) Climate risk reduction policy: 87% of the participants conformed that the Oil Companies have a formal policy to reduce the impact of climate risks. While 10% responded with 'don't know' and 3% answered that the Companies do not have any formal policy to reduce the impact of climate risks.

e) Litigation on climate change: NOC consult with environmental organizations worldwide and the government to impose laws. At the same time, numerous of lows and regulations exist in Libya on climate risks and changes in climate. Some companies endeavour to follow the litigations and retain and manage the risks while most of them spread it among insurance companies (Schwarte and Byrne, 2010). However, 6% of the participants claimed that the Oil Companies spread climate risk among insurance providers and 15% feel that the company retains and manages liability risk. The rest (4%) feel that not likely concern for the company.

f) Critical climate risks in oil & gas sector

In 2013 IPIECA reported that 96% of the climate risks are associated with sea level, floods, migratory shifts of different species, availability of water, extreme events and permafrost thawing. A total of 25 climate risks were listed in the questionnaire. The respondents provided their opinion by assigning 1 to 4 weights (Very High, High, Medium, Low) to each risk factor. Based on weighted average, the risks are ranked and presented in Table 2. A weighting is a value given to a risk factor according to how important it is perceived to be, or how significant it contribute to the overall risk rating; the larger the value, the more important the risk factor. However, the risk factors are not all equally important. Weighting should be given to each risk factor to reflect its perceived importance. Those more important risks should properly contribute more to the final result than those less important. The risk weighted average was calculated from Equation 1. As a result, the top ten critical factors are: high temperatures, lack of water availability and droughts, loss of access to water, loss of peak cooling capacity, air pollution, gas leaks or pipeline explosions, burning of fossil fuels (coal, oil, and gas), early season delays, damage to coastal facilities, and changes in land use.

g) Climate risk management: the awareness of risk management shows that professionals know how to deal with unexpected events by adopting critical procedures and protocols that enable them to periodically evaluate the risks of climate changes (Filed, 2012). The lack of risk management implementation shows existing weaknesses of operations in the oil and gas sector and lead to disastrous events. In addition, if a company evaluates climate risks and other weaknesses through a risk management approach, it will lead an effective development of strategies in order to manage risks of rapid climate changes (Baglee *et al.* 2012). The survey shows the following points regarding the climate risk management:

- 65% of the participants are not aware with climate risk management, whereas, only 44% of the respondents showed their awareness.
- surprisingly, nobody confirmed that the company adopts any climate risk management strategy, while 85% claimed that the company does not officially adopts any climate risk management strategy and 15% are unaware of the presence of any risk management strategy to mitigate climate risks.

- 77.5% of the respondents do not implement risk management to address climate risks and 17% implement risk management to some extent.
- 45% of respondents claimed that senior management undertakes the responsibility of climate risk management, while 35% claimed that the operations management takes the responsibility of addressing climate related risks. Figure 3 illustrated the sentiments of the participants regarding undertake the responsibility of risk management. As a result, it can be said that the companies where most of these professionals' work have no risk management strategy to address climate risks.

Table 2 - Climate risk factors

Risks factor	Low (1)	Middle (2)	High (3)	V. high (4)	Total	Risk Weighted Average
High temperatures	5	8	11	47	71	24.2
Lack of water availability and droughts	4	5	29	33	71	23.3
Loss of access to water	3	10	28	30	71	22.7
Loss of peak cooling capacity	4	16	20	31	71	22.0
Air pollution	4	15	23	29	71	21.9
Gas leaks or pipeline explosions	5	15	22	29	71	21.7
Burning of fossil fuels (coal, oil, gas)	5	14	27	25	71	21.4
Early season delays	3	18	27	23	71	21.2
Damage to coastal facilities	6	15	26	24	71	21.0
Changes in land use	8	16	19	28	71	20.9
Reduced or improved shipping lanes/seasons	8	11	33	19	71	20.5
Shipment interruptions	5	24	25	17	71	19.6
Extreme events	4	25	27	15	71	19.5
Wildfires	26	19	20	6	71	14.8
Subsidence	38	27	6	0	71	11.0
Delays because of migration of species	38	29	3	1	71	10.9
Loss of species and habitat	44	19	5	3	71	10.9
Intense flooding	51	20	0	0	71	9.1
Ice road—decreased tundra travel	62	9	0	0	71	8.0
Storm impacts on key infrastructure	65	6	0	0	71	7.7
Thaw subsidence and frost jacking	68	3	0	0	71	7.4

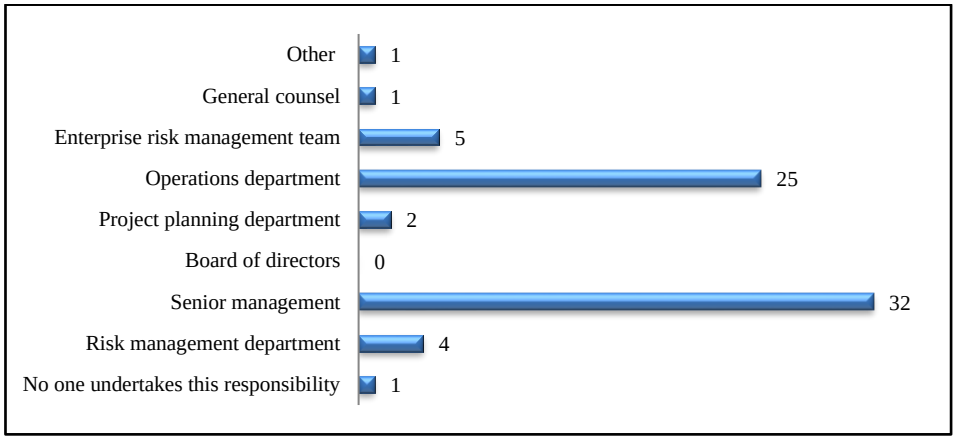

Figure 2 – Responsibility of risk management

h) Mitigation strategy: risk mitigation strategy can be established as a result of active identification and evaluation of climate risks associated with the oil and gas industry. This strategy consequently explains a way to develop a framework through which existing operations within the firm can be accomplished with a relatively low cost. Some possible treatments were identified from the literature and loaded into the questionnaire. Table 3 shows the responses of the survey participants that are ranked through weighted average (Equation 1). The results show that the transfer strategy ranked first with 14.5 weighted average and response strategy ranked second with 13.46 weighted average.

Table 3 – Expected treatments of climate risks

Expected strategy Responses	1 = least expectation; 7 = most expectation							Weighted Average
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Transfer strategy	5	4	3	5	5	4	45	14.50
Response strategy	2	3	2	3	25	27	9	13.43
Acceptance strategy	3	6	8	4	13	29	8	12.50
Increase oil prices to recover damages	6	5	16	27	9	5	3	9.57
Not sure	6	19	18	16	6	3	3	8.25
Climatic changes don't have any affect	8	20	18	13	10	1	1	7.75
Other	41	14	6	3	3	2	2	5.00

7. Summary and Conclusions

Climate risks and changes have a devastating impact on oil and gas sector worldwide regardless of any specific country. Among many stern climatic risks, water related issues like lack of water, leakages, poor water quality and floods have deep impact on oil and gas operations and consequently raises time and cost of the entire project. Similarly, high temperature has overwhelming impact and result in cost increases during oil exploration, extraction, transportation and refining operations. The climate risks also result in failure of physical assets, risks to the health and safety of the workers, intensified pressure on the available water resources; financial assets value drop and a significant damage to the reputation of the company. A rapid increase in climate risks placed a greater risk for the communities through a number of incidents. It is concluded that Libyan professionals today are familiar with the importance of climate risks and their impact on various projects in oil and gas context. It is also important to know that climate changes in neighboring countries can also influence the operations to a great extent in terms of disturbance in the transportation system, weather effects, water supply, and communication etc. The impact of human activities on climate changes due to overloading the atmosphere with CO_2 is the point raised by many international organizations, but it is perceived as a low impacting factor in Libya.

The geographical position and weather changes in Libya have upsetting impact. Many water related issues are the common climate risks in Libya. Although, the NOC along with the government has taken many steps to bring improvement in the availability of water resources but still it is not standardized. From the survey results, it can be concluded that professionals are confused about the responsible authority or body for minimizing or eliminating the impacts of climate risks. Thus, the major reason for this confusion is the lack of knowledge of the respondents. It is also found that oil and gas companies in Libya do have adequate climate risk reduction policy to stay away from the devastating impacts of climate risks. Most of the companies also spread climate risks among insurance companies while others retain and manage these risks.

Climate risks are always critical to oil and gas companies, but not all risks have the same impact. In this study, several climate risks are identified and ranked on the basis of experienced professionals and matched the results with previous studies. Based on the ranking results, this study concludes various critical climate risk factors where top ten are extremely critical such as: high temperatures, lack of water availability and droughts, loss of access to water, loss of peak cooling capacity, air pollution, gas leaks or pipeline explosions, burning of fossil fuels (coal, oil, and gas), early season delays, damage to coastal facilities, and changes in land use. The full list is available in Table 2. It is evident in the list that a majority of top factors are related to air and water pollution and leakages.

The climate risk management is a part of risk management strategy and has become an integral part of the organization strategy of oil and gas companies worldwide. The multinational companies usually manage various climate risks with

high and low impacts during their routine operations. Therefore, the adoption plans are developed as a vital part of the climate risk management to organize and minimize the identified risks for the operations. In most of the oil and gas companies in Libya, the responsibility of managing climate risks is given to either operations department or senior management. Hence due to lack of separate risk management department or experts, only few companies adopt risk management strategies in either formal or informal ways. However, it is a good sign that survey respondents showed their understanding about the importance of climate risk management. It is also concluded that a majority of firms in oil and gas sector in Libya adopt a risk transfer strategy followed by risk response and risk acceptance strategies for treating climate risks. Therefore, there is an urgent need to adopt possible ways to avoid the harmful impacts of climate risks for the improvement of efficiency of Libyan oil and gas projects.

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References

Almher, K. (2008). Experts monitoring the impact of climate change on health in Libya (Translated). *Al-Jazeera News*, 11 April 2008

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

Baglee, A., Haworth, A. and Anastasi, S. (2012). Climate Change Risk Assessment for the Business, Industry and Services Sector. UK: Crown

Bills, K. and Agostini, D. (2009). Offshore petroleum safety regulation. *Department of Industry*, Australia

Chambers, M. (2012). *Chevron ups cost estimate on Gorgon LNG project to $52bn*. The Australian

Domros, M. and Gongbing, P. (1988). *The climate of China*. Berlin: Springer-Verlag, Berlin

Elmabrouk, S. Kh. Bader, H. E. and Mahmud, W. M. (2017) An Overview of Power Plant CCS and CO2-EOR Projects International Conference on Industrial Engineering and Operations Management, Rabat, Morocco, April 11-13.

General Environmental Authority (2001). *The first environmental report*. Tripoli, Libya

IPIECA (2012). Addressing adaptation in the oil and gas industry: An IPIECA workshop. [online]. Available from: www.ipieca.org/event/20120621/addressing-adaptation-oil-and-gas-industry [Accessed: 20 June 2014]

IPIECA (2013). Addressing adaptation in the oil and gas industry: Climate change. *International Petroleum Industry Environmental Conservation Association*, United Kingdom

Martyn, D. (1992). *Climates of the world*. Warszawa: PWN-Polish Scientific Publishers,

NOAA (2012). National Oceanic and Atmospheric Administration (NOAA), U.S. Climate ExtremesIndex 2012, *National Climatic Data Center*. Retrieved from: www.ncdc.noaa.gov/extremes/cei/graph/1/01-12 [Accessed: 20 June 2014]

OECD (2009). *Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance*. OECD Publishing

Schliephake, K. (2004). The Great Manmade River in Libya, in: MEYER, G., (ed.), The Arab World: in the mirror of Cultural Geography, *Centre for Research on the Arab World, Department of Geography*, University of Mainz, Germany

Schwarte, C. and Byrne, R. (2010). International climate change litigation and the negotiation process. Foundation for International Environmental Law and Development [online]. Available from: http://www.climnet.org/resources/doc_view/1942-field-international-climate-change-litigation-and-the-negotiation-process-oct-2010 [Accessed: 23 August 2014]

Smith, M.H. (2010). Assessing climate change risks and opportunities for investors: Oil and gas sector. Investor Group on Climate Change, Australia

Topp, V., Soames, L. Parham, D. and Bloch, H. (2008). Chapter 5 - Productivity in the mining industry: measurement and interpretation, productivity commission staff. *Productivity Commission Staff Working Paper*, Australia, ISBN 978-1-74037-271-8

Walker, J. and Packham, B. (2011). MPs demand controls on coal-seam gas rush. The Australian