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POTENTIALITY OF SHALE GAS IN GHADAMIS BASIN AS FUTURE ENERGY RESOURCE, LIBYA

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الملخص

في السنوات العشر الأولى من القرن الحادي والعشرين، شهد بوادر على تغير نوعي في مجال مصادر الطاقة العالمية ، حيث توجد دلائل على حدوث تغيير نسبي في مصادر الطاقة المفضلة عالميًا. فالغاز الصخري بظهوره هو ظهور استراتيجيات جديدة لسوق الغاز العالمية ، ذلك للخصائص المرتبطة به مثل العرض والطلب في السوق والتكاليف واسعاره.

من الواضح أن الاكتشافات العالمية لاحتياطيات الغاز الصخري ستعيد صياغة الخريطة الجيوسياسية للطاقة ، وستكون أحد المصادر الرئيسية في المستقبل. فبعد الدراسات والبحوث في العديد من البلدان ، قدرت الوكالة الفيدرالية الأمريكية لمعلومات الطاقة أن موارد الغاز الصخري يمكن أن تزيد الغاز القابل للاستخراج بأكثر من 40٪ ، وكذلك يشير هذا إلى إمكانية تحول العديد من الدول المستوردة للغاز إلى دول منتجة ، و قد تصبح بعض الدول مُصدرة للغاز في المستقبل. كل هذه الحقائق تمهد الطريق لمرحلة جديدة تصبح ثروة الغاز الصخري التي قد تؤدي إلى تغييرات كبيرة في مسار تجارة الغاز في العقد المقبل ، مما قد يؤثر على الأسواق وأسعار النفط والغاز العالمية.

من ناحية أخرى ، يواجه التنقيب عن الغاز الصخري وإنتاجه العديد من التحديات مثل التطبيقات التقنية المستخدمة والآثار البيئية ومخاوف من استخدام المياه في التكسير الهيدروليكي والتي لا تتوافق مع اللوائح الدولية.

تشير الاحتياطيات المقدرة من قبل إدارة معلومات الطاقة إلى أن الاحتياطي القابل للاسترداد تقنيًا من الغاز الصخري في حوض غدامس يتراوح بين 80-120 تريليون قدم مكعب. في حين قدرت دراسة(ARI) أن الغاز في ليبيا في هو 1147 تريليون قدم مكعب ، في حين أن الاحتياطيات القابلة للاستخراج 290 تريليون قدم مكعب. هذا الأخير أكبر بخمس مرات من الاحتياطيات التقليدية المؤكدة في البلاد، حيث أن الغاز الصخري الموجود في حوض غدامس 57 تريليون قدم مكعب و 1090 تريليون قدم مكعب في حوض سرت.

الهدف الرئيسي من هذه الدراسة هو تسليط الضوء على تقييم الغاز الصخري المكتشف في حوض غدامس في ليبيا باستخدام مصفوفة تحليل(SWOT :القوة والضعف والفرصة والتهديد) ومقارنة معايير التقييم مثل مساحة الحوض وسمك الدفع والعمق واجمالي الهيدروكربون العضوي ، والاحتياطي القابل للاسترداد تقنيًا مع أحواض أخرى في العالم ، كغاز صخري يكون مصدر جديد للطاقة.

الكلمات المفتاحية: غاز صخري ، مورد ، قابل للاستخراج ، نموذج ، تحليل ، حوض غدامس.

Abstract

In the first ten years of the atheist and the twentieth century has seen signs of a qualitative change in the field of global energy sources, where there are signs of a relative change in the global favorite sources for energy. However, shale gas is the emergence of the global gas *market strategies, including associated characteristics as market supply and demand, costs and prices.*

It is clear that global discoveries of shale gas reserves will re-formulate the geopolitical map of the energy, and will be one of the main sources in the future. After studies and research in many countries U.S. Federal Agency estimates for the Energy Information that shale gas resources could increase recoverable gas by more than 40%, as well as this suggests the possibility of the transformation of many gas-importing countries to producer countries, and some countries may become gas exporter in the future. All these facts pave the way for a new phase become the shale gas wealth that may lead to significant changes in the path of gas trade in the next decade, which may affect the markets and the prices of international oil and gas.

On the other hand, shale gas exploration and production facing many challenges such as technical applications, environmental impacts and scares of water for hydraulic fracturing and that don't comply with the international regulations.

The reserves estimated by EIA indicate that the technically recoverable reserve (TRR) of shale gas in Ghadamis basin ranging from 80-120 tcf. While the ARI study estimated that for Libya the gas-in-place is 1,147 tcf, while the recoverable reserves are 290 tcf. The latter is more than five times longer than the country's proven conventional reserves. Of the gas-in-place, 57 tcf are in the Ghadamis basin and 1,090 tcf in the Sirte basin.

The main objective of this study is to highlight on the assessment of shale gas discovered in Ghadamis basin in Libya using SWOT (strength, weakness, opportunity and threat) analysis matrix, and comparing evaluation parameters such as basin area, pay thickness, depth, total organic hydrocarbon, and technically recoverable reserve with other basins in the world, as shale gas a new source of energy.

Index Terms*: Shale gas, resource, recoverable, model, analysis, Ghadamis basin.*

1. Introduction

Shale gas is the same fuel as that produced from conventional onshore and offshore gas fields, but is found in different geologic formations. The formations require new techniques of extraction, which bring environmental problems not found with conventional gas. Shale gas reserves are usually found in different geographical locations from conventional gas reserves, which means that certain countries without conventional gas may be able to produce shale gas.

One of the most exciting developments in recent energy history has to be the dramatic increase in the production of natural gas from shale formations,[1] or shale gas as it is commonly known amongst lovers and haters alike. Although experts have been aware of the vast deposits of shale gas around the globe, technological difficulties and the excessive financial costs associated with extraction have previously made shale no more than an impractical dream[2]. Increasing demand and lagging supply mean high prices for both oil and gas allowing more lucrative gas plays to penetrate the market[3].

The growing interest in unconventional gas, namely shale, has been spurred on by recent experience in the United States where shale production has increased ten-fold between2006 and 2010[4]. This remarkable development overturned expectations of a continuing decline in US gas production, reduced US gas prices, led to an oversupply of liquefied natural gas on world markets and stimulated business and policy interest in shale gas around the globe[5].

The paper focuses on shale gas as the most promising ‘unconventional’ gas, and can be regarded as alternative energy source in the future for sustainable development.

2. Study Area

This study has been conducted on the shale gas in Ghadamis basin which lie between longitudes 10° 15 00 and 14° 00 E and Latitudes 28° and 32° N (Figure 1).

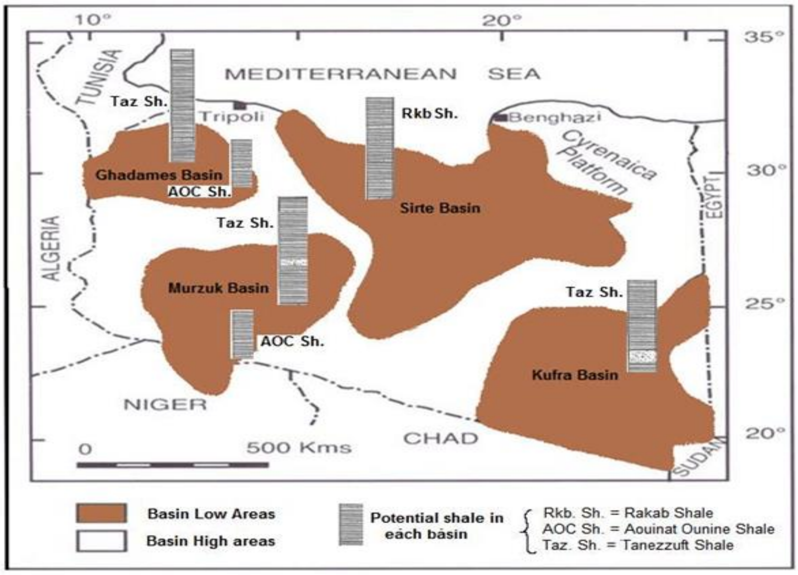

Fig. 1 A map showing the location of Ghadamis basin (USEIA)[6]

Figure 2 a map showing the expected areas to be rich in hydrocarbons and shale gas of Ghadamis, Sirte and Murzuq basins.

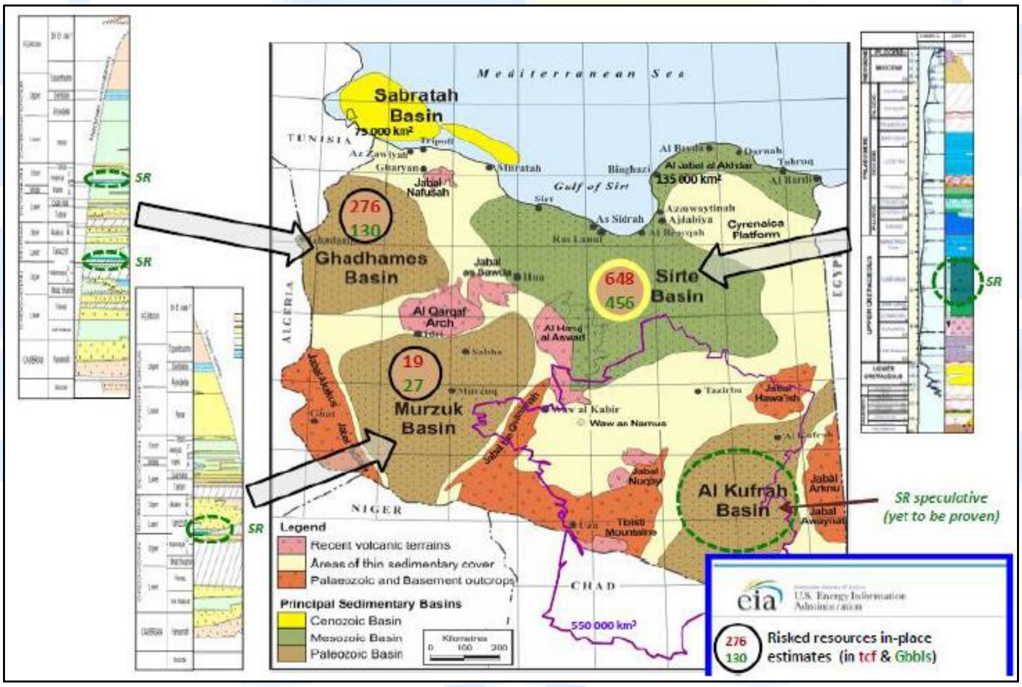

Fig. 2 Shale gas probability in Libyan basins[7]

The shale gas in Ghadamis basin occurs in the basal Tanezzuft formation. Figure 3 a map depicts the shale formation thickness of Tanezzuft shale in both Ghadamis and Murzeq basins.

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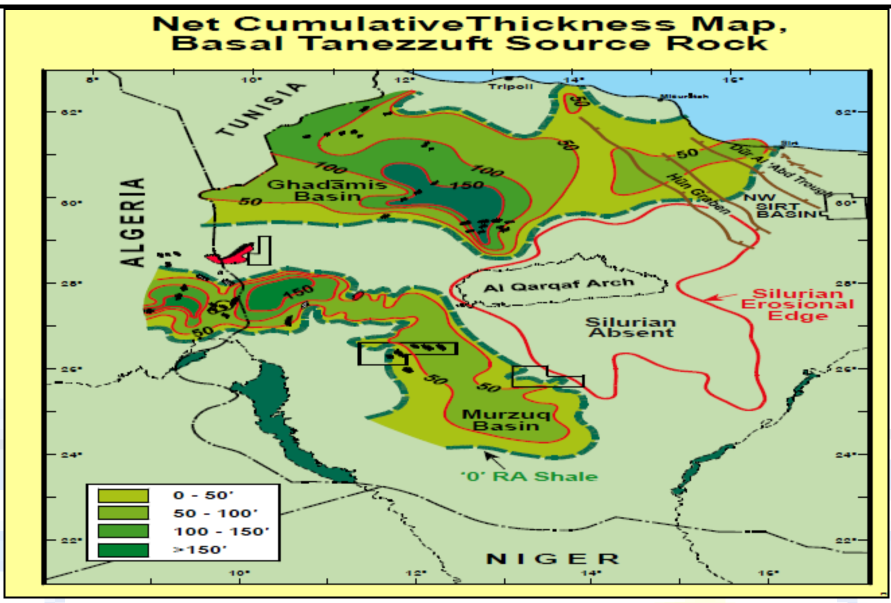

Fig. 3 Formation thickness of Tanezzuft shale[8]

3. Methodology

The methodology of this study based on the following:

1. The statistical analysis for the data and information's that obtain from different sources such as research papers, scientific analysis reports, institutional reports, journals and international publications. The majority of these sources refer to institutional and international agency e. g. Energy Information Administration (EIA) and Advanced Resources International (ARI).
2. The inputs of shale gas activities in the different countries in the world, the strength, weakness, opportunity and threats (SOWT) are identified for shale gas activities in Libya.
3. The strategy on the impact of strength and weakness on opportunity and threats using the TOWS (threat, opportunity, weakness and strength) matrix.

4. Shale Gas Activities Worldwide

The shale gas success story in the US has resulted in heightened speculation over the potential for shale gas to transform energy markets in other regions.

According to the latest estimates by the EIA, Poland (187 tcf) has the largest technically recoverable shale resources in Europe, while China (1,275 tcf), South Africa (485 tcf) and Argentina (774 tcf) lead the resource base in Asia, Africa and South America, respectively[7]. The US, which given its experience of shale gas production, probably has the most accurately estimated resources

and accounts for 13% of the global total. Shale gas exploration is currently underway across the globe, with Argentina, Poland and the UK leading the way. Although there is immense potential for developing shale gas reserves worldwide, environmental and social concerns could impact growth prospects.

China has the world's largest shale reserves, accounting for almost 20% of the global reserves and approximately 92% of the reserves in Asia. The Chinese Government has been taking concrete steps in harnessing its huge shale gas potential. It plans to produce between 164 million standard cubic meter per day (mmscmd) and 274 mmscmd of shale gas annually by the end of 2020[9].

Exploration is currently in progress in several countries in Europe, including Austria, Germany, Hungary, Ireland, Poland, Sweden and the UK[10]. Nearly57% of the estimated shale reserves in Europe are concentrated in two countries — Poland and France. The need to reduce the region's dependence on Russian gas supplies and meeting carbon emission targets are the main drivers contributing to shale gas development in the region. However, environmental concerns over hydraulic fracturing have led some European countries to rethink their strategy on developing shale gas reserves. While countries such as France and Bulgaria have banned hydraulic fracturing, others such as the Czech Republic have imposed a temporary moratorium until new legislations are put in place[11].

Argentina accounts for 63% of the reserves in South America. The Argentinean Government is encouraging investments in the shale gas industry to offset the declining conventional oil and gas production in the country and reduce its dependence on imported gas from Bolivia. Figure 4 shows the global shale gas reserves distribution.

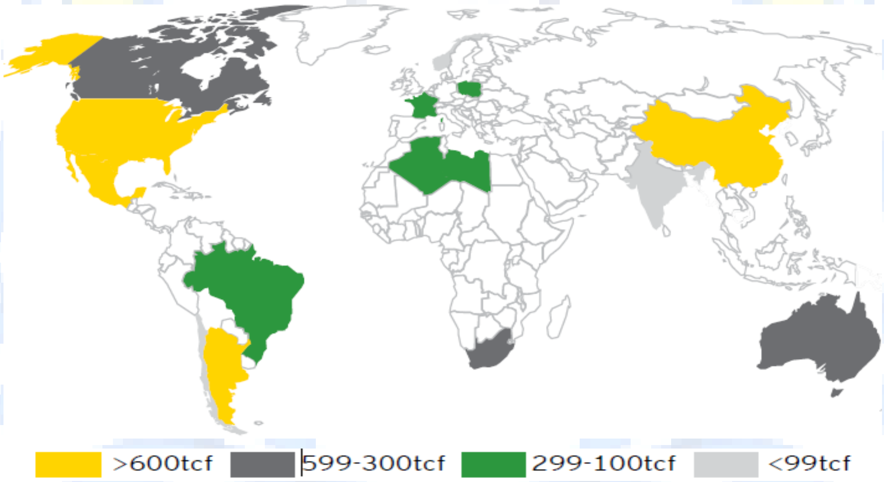

Fig. 4 Global shale gas reserves distribution[7]

5. Extraction of Shale Resources

Shale can, in places, be hydraulically fractured to produce large quantities of natural gas, NGLs, and tight oil. Hydraulic fracturing entails pumping fluid composed of water, proppants, and chemicals into the ground at very high pressure. The pressurized water and chemicals create and enlarge cracks in the shale formation, which increases its permeability by 100- to 1,000-fold, allowing the hydrocarbons to flow more easily to the wellbore[12].

6. Shale Gas in Africa

The US Energy Information Administration (EIA) produced a study in 2011 estimating global technically recoverable shale gas reserves[12]. Technically recoverable reserves are those that can, with a high degree of certainty, be expected to be able to be extracted with current technology and under current economic conditions[13]. To make such an estimate extensive geological data is needed, and it was available for 32 countries.

The EIA study estimated that the technically recoverable global shale gas reserves are almost50% of technically recoverable conventional gas reserves, indicating the very large impact that the technological breakthrough has had on potential global gas production. For Africa, the technically to the technically recoverable shale reserves, of the countries for which estimates could be made, are almost equal to the technically recoverable conventional gas reserves of the continent.

Several organic-rich shale are located in basins in northern Africa from the western Sahara and Morocco, across Algeria, Tunisia and Libya, but most exploration companies are concentrating on discovering and developing conventional reservoirs in these regions (Figure 5). However, unlike Algeria, Tunisia and Libya, Morocco has few natural gas reserves and depends heavily on imports to meet its internal consumption needs. For this reason, exploration activity in shale deposits is ongoing there.

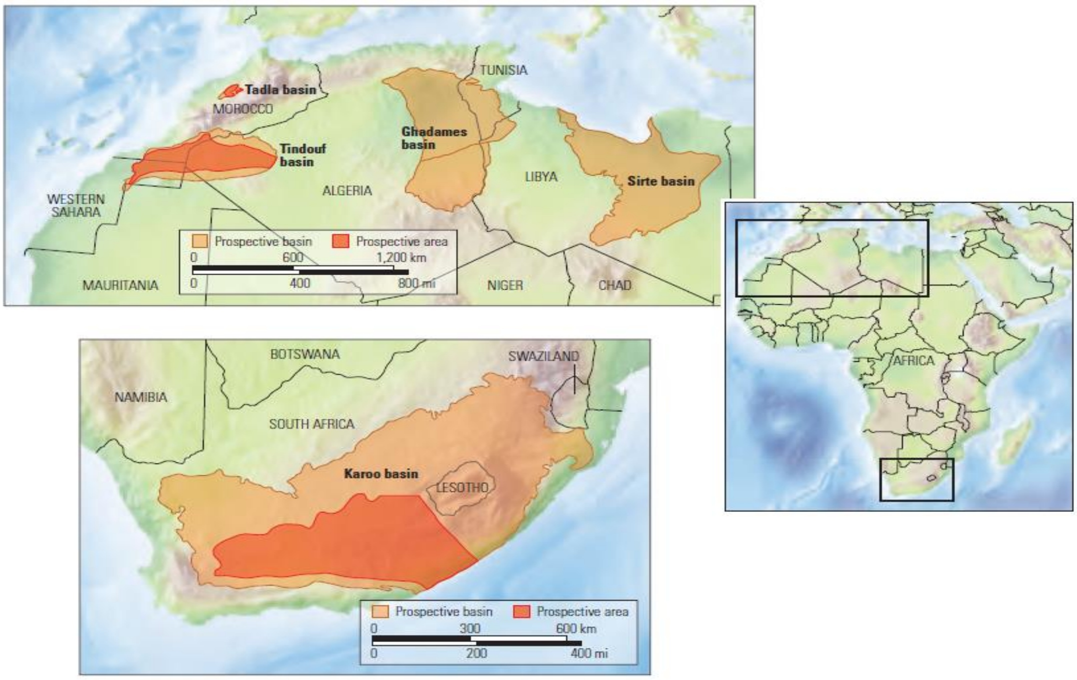

Fig. 5 Shale basins in north and south Africa continent[7]

Table 1 presents the estimates made by ARI for gas-in-place and technically recoverable shale gas reserves for these countries. Each of these is based on detailed information about the shale formations and their geological properties, using field engineering formulae. For comparison, the proven conventional gas reserves and production for each of these countries are included. If the estimates of the reserves are confirmed by exploration and production drilling, they could make very significant contributions to these economics. Figure 6 illustrates a comparison between Africa countries for both shale gas in place and technically recoverable shale gas reserve.

Table 1 ARI estimates of technically recoverable shale gas reserves, proven conventional gas reserves, and current production of gas in trillion cubic feet[12,14]

Country	Shale gas-in-place[1]	Technically recoverable shale gas reserves[1]	Proven conventional 2012[2] gas reserves	Production of conventional 2010[2] gas in
Algeria	812	230	158	2.957
Libya	1147	290	52	0.586
Tunisia	61	18	2.26	0.071
Morocco	68	11	0.035	0.004
Mauritania	2	0.4	0.989	0.000
Western Sahara	37	7	-	-
South Africa	1834	485	0.000	0.035
Total Africa	3962	1042	504	7.313

The estimates for gas-in-place and technically recoverable shale gas reserves provided by EIA[12] specify the countries for which estimates were made. For Africa, these include Algeria, Libya, Tunisia, Morocco, Mauritania, and South Africa, as well as the territory of Western Sahara.

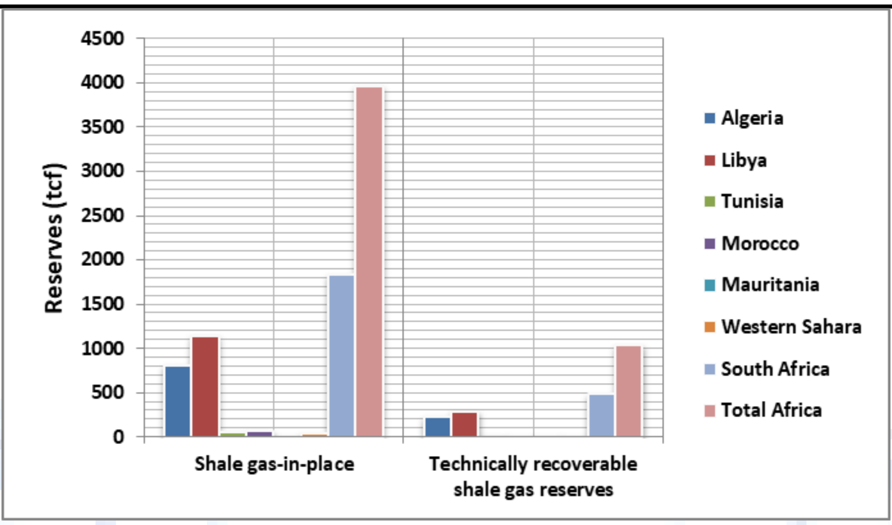

Fig. 6 Comparison between Africa countries of shale gas

The comparison of technically recoverable shale gas and proven conventional gas reserves in Africa indicates just how important the former will be. The data in Table 1 indicates that at the continent level, if shale gas reserves were to be confirmed by exploration they would be double the current proven reserves of conventional gas. For the largest conventional gas producer, Algeria, shale gas reserves if proven would be 50% larger than the conventional reserves. The shale gas reserves in Libya and South Africa would also be larger than the conventional gas reserves for any of the continent's major producers.

Libya has until now concentrated more on oil production, but is looking to place an increasing emphasis on gas production. This would enable it to supply domestic needs for electricity generation and industry as well as exports. Libya also has experience in managing a gas sector, but will face similar challenges to Algeria on the environmental front, especially with respect to the supply of water.

The ARI study estimated that for Libya the gas-in-place is 1,147 tcf, while the recoverable reserves are 290ctf. The latter is more than five times longer than the country's proven conventional reserves. Of the gas-in-place, 57 tcf are in the Ghadames basin and 1,090 tcf in the Sirte basin. The prospective shale gas formations in the Sirte basin lie in deep subsided troughs and so are very lightly explored.

The long-term prospects for shale gas production in Libya seem to be highly promising based on such large reserves. The country has familiarity with the sector, is already producing gas, and has a pipeline structure. About two thirds of its gas production is exported, mainly by pipeline to Europe. However, the country’s recent political instability has reduced its attractiveness for investment in the short term.

If Libya were to see a major increase in gas production from its shale reserves, it is likely that two issues might drive the government to seek outside assistance. First, the increased use of gas revenues for domestic development could present problems for an economy that has previously been run on dirigiste lines. Experience from the domestic economic strategies being developed in other new gas producers might also be applicable to the case of Libya. The second issue would be fracking: water supply and water recycling and treatment are both likely to be important in the Libyan context, and the government would certainly have little relevant experience with the problems, solutions, and monitoring required.

Both ARI and IEA provided data for the shale gas reserves of the rest of the world (selected countries only for ARI), which are summarized in Table 2. These suggest that, on the basis of countries included in both studies, Africa contains about 15% of the shale gas reserves that are likely to be of interest for commercial exploitation.

Table 2 Technically recoverable shale gas reserves (tcf) [12,14]

	ARI	IEA
Africa	1042	1060
Rest of the World	5538	6291

The IEA in 2012 analyzed the longer-term pricing effects of increased output of US and other producers of unconventional gas. The analysis argues that, although the use of long-term contracts indexed to international oil prices will become less prevalent, even by 2035 there will not be full gas-to-gas competition, in which gas prices in various regions differ only by transportation costs. The IEA's assumed prices for a basic reference case and for a low unconventional gas production case are shown in Table 3 The additional unconventional gas production is expected to have substantial effects in reducing global gas prices. In turn, this will have large effects on encouraging the switch towards gas use and away from competing fuels. The difference in gas supply between the IEA's two scenarios is due to the slow development of unconventional gas in the low-gas case.

This difference, caused by various constraints, amounts to 535 bcm in 2035, out of a total of 5.1 tcm in the base case, corresponding to a low gas production scenario of 4.6 tcm. It is important to note that even in the base case, where a considerable volume of unconventional gas comes onto the market, real gas prices are expected to rise substantially by 2020, and even more by 2035. Prices are lower than in the low-gas case, but they are still higher than in2010.

Table 3 Natural gas price scenarios (2010 US$ per MBtu)[14]

		Base case		Low unconventional gas case	
	2010	2020	2035	2020	2035
US	4.40	5.40	7.10	6.70	10.00

Europe	7.50	10.50	10.80	11.60	13.10
Japan	11.00	12.40	12.60	14.30	15.20

MBtu = thousand British thermal unit

7. Results and Discussion

This study based on some factors for shale gas in the study area of Ghadamis basin to assessment the potentiality of natural resource as alternative energy source in the future and sustainable development.

The analysis activities of the shale gas have been carried out in different parts of the world e. g. USA, EU, China, and India. These analyses discussed the shale gas reserves, development and factors affecting on activities of exploration and production (Table 4).

Table 4 Comparison between shale basins in different countries and *Ghadamis* basin

Gas shale basin		Estimated area (sq. miles)	Depth (ft)	Net thickness, (ft)	TOC (%)	TRR (tcf)
USA[15]	Barnet	5000	6500-8500	100-600	4.5	-
	Fayette ville	9000	1000-7000	20-200	4-9.8	-
	Marcellus	9500	4000-8500	50-200	3-12	-
	Woodford	11000	6000-11000	120-220	3-10	-
	Antrim	12000	600-2200	70-120	1-20	-
France[16]	Paris basin	61000	4000-16400	83-160	4.5-9	129.3
Netherlands[16]	*West Netherlands basin*	2750	3300-16400	90-450	2.4-6.5	25.9
Denmark[16] Sweden	*Alum Shale*	90000	3300-15000	200	7.5	41.5
UK[16]	North UK	10200	4000-6000	410	3.0	25.10
	South Uk	3470	5000-13000	149	3.0	0.6
Eastern Europe[16]	Carpathian Foreland	70000	3300-16400	400	4.5	73 (Ukraine 52, Romania 21)
	Dnieper-Donets	23200	3300-16400	350	2.0	Ukraine 76
	Moesian Platform	45000	5000-16400	260-450	3.0	46 (Romania 30, Bulgaria 16)

Poland[16]	Baltic basin	16200	6500-16000	451	3.9	105
	Lublin basin	4980	7000-16000	228	3.0	9
	Podlasie basin	6600	6000-11500	297	3.0	9
China[16]	Sichuan	74500	9700-13200	250-275	-	-
	Tarim	234200	10790-16400	160-240	-	-
	Junggar	62100	5000-16400	410	-	-
	Songliaoi	108000	3300-8200	500	-	-
	Subei	55000	3300-16400	150-300	-	-
India[16]	*Cambay*	7900	6000-16400	500	2.6	29.5
	Krishna-Godvari	7800	4000-16400	100-390	6.0	56.9
	Cauvery	1009	7000-13000	500	2.3	4.5
	Damodar Valley	2270	3300-6600	250	3.5	5.4
Libya[8]	Ghadamis	135,193	760-1340	*20-50*	*15-3*	*80-120*

TRR = Technically recoverable reserve TOC = Total organic carbon

Several parameters are tabulated (Table 4) to compare the geological characteristics for different countries and different shale play. The assessment factors including the estimated basin area, depth of shale formation, net thickness of the play, total organic carbon (TOC) and technically recoverable reserve (TRR).

The comparison between Ghadamis basin geological factors and other shale plays in different countries revealed that there is a great variation between them. Whereas Ghadamis play characterized by the large estimated area (about 135,193 sq. mile) after Tarim basin in China as shown in Figure 7, the lower depth (2,500 – 4,000 ft) (Figure 8) and the technically recoverable reserve which ranging from 80 to 120 tcf (Figure 9).

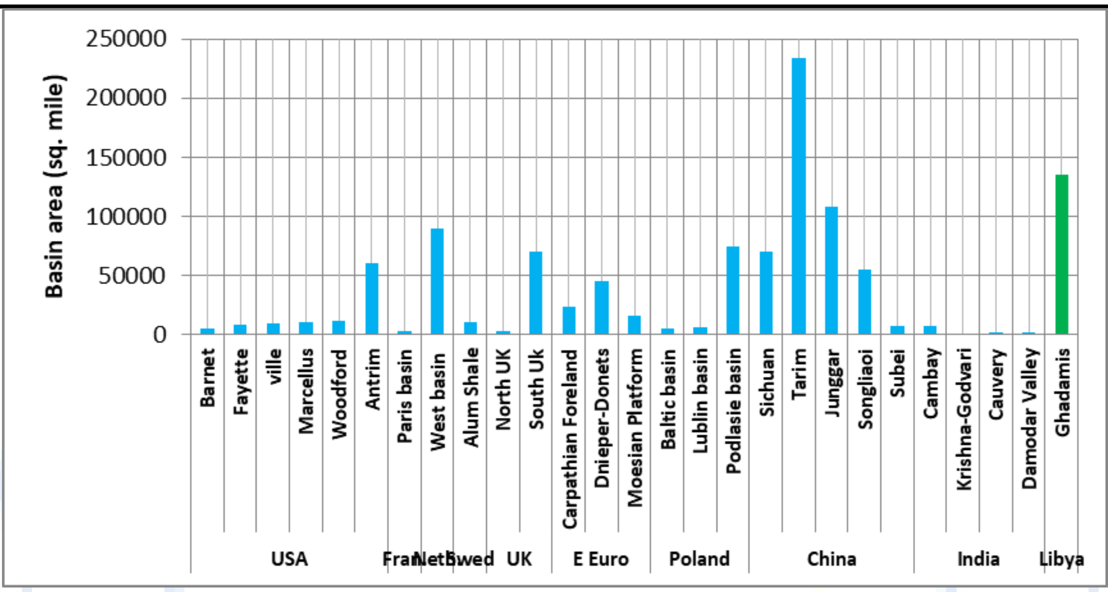

Fig. 7 Comparison between Ghadamis basin area and other shale basin areas

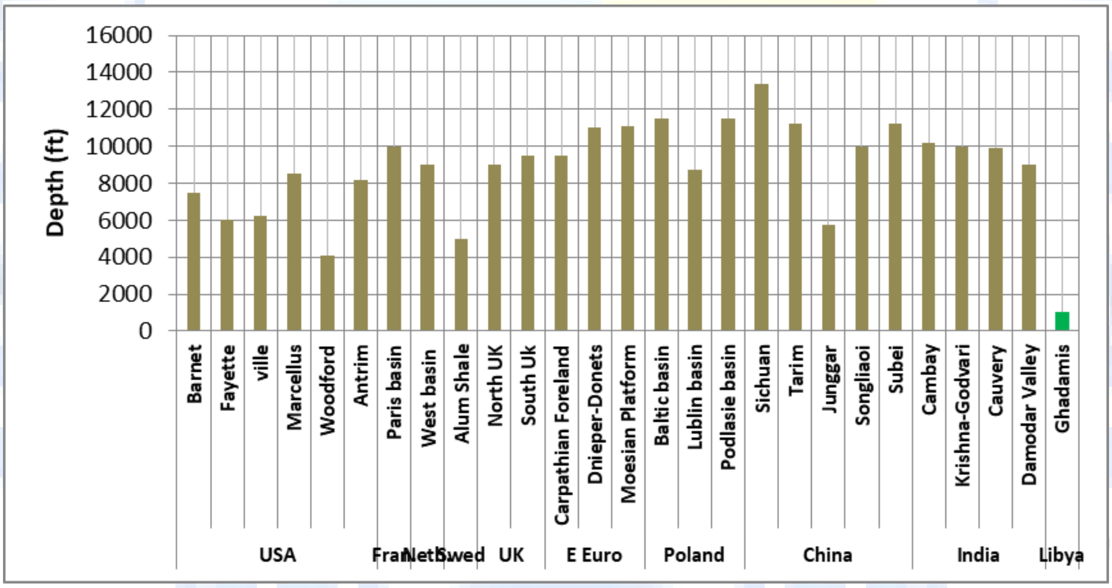

Fig. 8 Comparison between Ghadamis basin depth and other shale depths

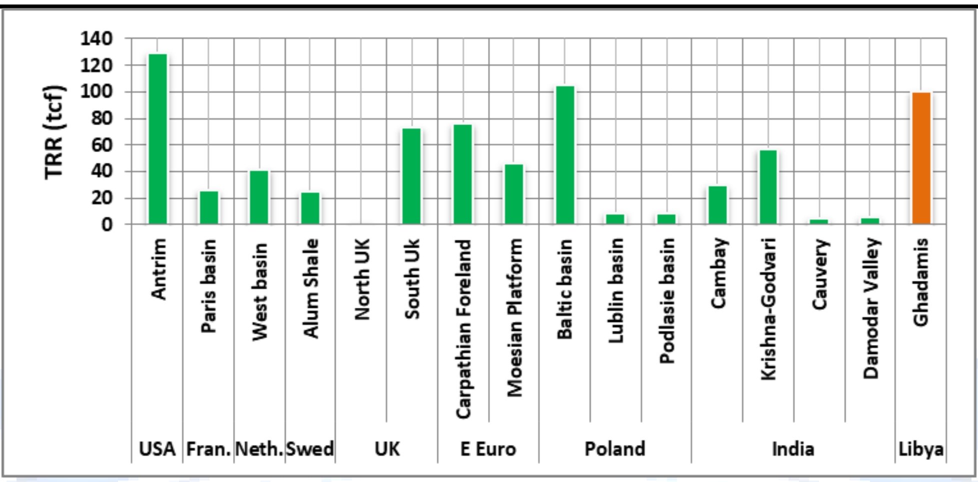

Fig. 9 Comparison between Ghadamis TRR and other shale gas basins

The thickness of the shale play of Ghadamis regards as small comparing with the other plays as depicted in Figure 10, while the total organic carbon regards as the second one after Woodford basin in USA (Figure 11).

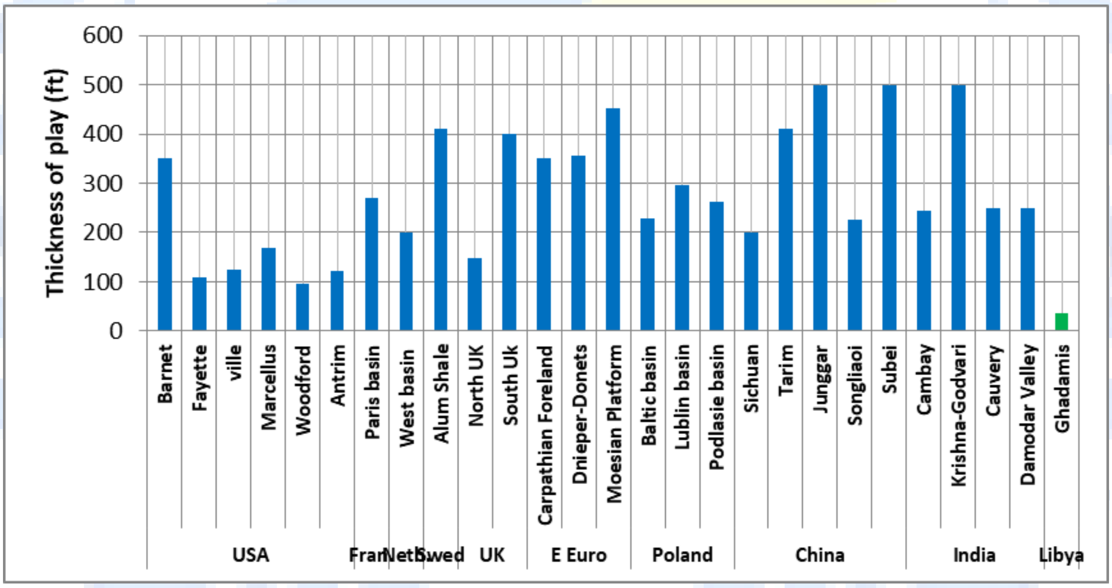

Fig. 10 Comparison between Ghadamis play thickness and other shale plays

On the other hand, the comparison between the petrophysical properties of Tanezzuft formation and the shale play in other sedimentary basins presented in Table 5.

It is obviously that the total organic carbon of Tanezzuft formation higher than the other formations, while the thermal maturity (R_o) ranging from 0.7-2.2% and the saturation by gas (%) is high1.0-6.0%, kerogen type is II. The geologic age of Tanezzuft formation is belonging *to Silurian of Plaeozoic Era, while the other formations are belonging to Middle Devonian and Middle-Late Ordovician*

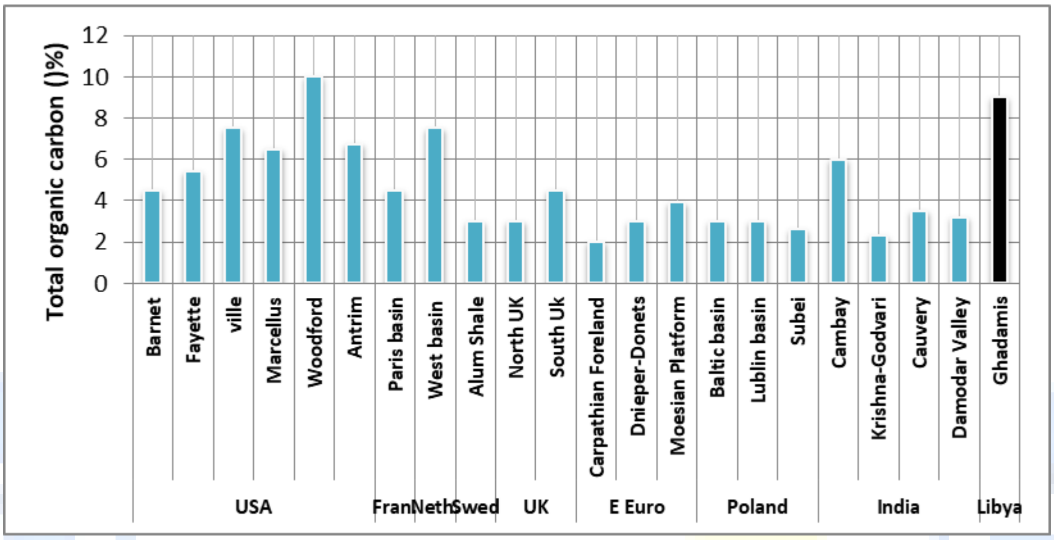

Fig. 11 Comparison between Ghadamis TOC and other shale gas

Table 5 Petrophysical characterizations of some shale gas plays[12]

Formation Parameters	Tanezzuft	Wood Ford	Barnet	Fayette ville	Marcellus	Utica
Total organic carbon, TOC (%)	3-15	3-10	3-8	3-8	2.5-5.5	0.5-3.0
Thermal maturity, R_o (%)	0.7-2.2	1.1-3.0	1.2-2.0	1.2-4.0	0.6-3.0	0.3- >1.0
Quartz content, Qz (%)	> 35	60-80	40-60	40-60	-	-
Gas saturation ratio, ∅ (%)	1-6	3-6.5	3-5.5	3-5.5	-	-
Thickness (m)	20-50	30-65	60-150	15-100	-	-
Depth (m)	2500-4000	1800-3600	1800-2700	450-2000	-	-
Pressure gradient (psi/ft)	-	0.52	0.52	0.43	-	-
BCF/Section	-	40-120	50-200	55-65		
Age	Silurian	-	-	-	Middle Devonian	Middle Devonian
Kerogen type	II	-	-	-	II	II

Based on the inputs of shale gas activities in the different countries in the world, the strength, weakness, opportunity and threats (SOWT) are identified for shale gas activities in Libya. The threats, challenges and opportunities are part of the SWOT analysis. Finally, this paper brings out the strategy recommendations based on the impact of strength and weakness on opportunity and threats using the TOWS (threat, opportunity, weakness and strength) matrix. These recommendations can be used as the guidelines to take Libya towards the path of successful exploration and production of shale gas.

8. SWOT Analysis of Shale Gas in Libya

Libya will have many challenges and opportunities in the process of exploration, development and production of shale gas. The concept of SWOT analysis is applied in finding out the strategic factors such as strength, weakness, opportunity and threats of shale gas exploration and production activities in Libya. Table 6 gives the factors of SWOT analysis for shale gas in Libya.

Table 6 SWOT analysis factors of shale gas in Libya

	Strength		Weakness
S1	Libya has a great reserve of technically recoverable resource of shale gas.	W1	Libya does not have indigenous technology on hydraulic fracturing, chemicals and wastewater management that are need for shale gas.
S2	There is a possibility that as shale gas activity progresses more shale gas reserve discovered.	W2	Hydraulic fracturing technologies used in US and other countries may require improvement based on conditions/geology, depth and thickness of shales in Libya.
S3	The USEIA had identified the Ghadamis basin having a promising reserve of shale gas ranging from 80-120 tcf of technically recoverable.	W3	Lack of infrastructure/access roads and pipelines. As the sites of exploration will be new, there is less possibility of an approach road to the new sites, this will be a challenge facing the development of shale gas project.
S4	ARI study estimated that for Libya the gas-in-place is 1,147 tcf, while the recoverable reserves are 290ctf. Of the gas-in-place, 57 tcf are in the Ghadamis basin and 1,090 tcf in the Sirte basin.	W4	Lack of technology in water management and treatment. Libya was suffering from water scares, and there is a shortage of water for usage for shale gas activities. The groundwater is the only source and will depleted, whereas drilling operation usually requires great quantities estimated millions gallons of fresh water for hydraulic fracturing process.
S5	With the substantial reserve, there is a tremendous optional	W5	The requirement of water will be huge to explore thousands of wells for shale gas

	for exploration and production of shale gas in Libya.		production. The volume of flow-back water and produced water is also large to handle.
S6	Shale gas can serve the country for longer period.	W6	Shale gas projects require longer lead-time than conventional oil and gas drilling activity due to the complicated activities.
S7	Libya has a sound history of oil and gas development and more than 95% of the economic depend on the hydrocarbons.		
S8	Many Libyan companies have considerable experience in the shale gas exploration and production.		
S9	Libya has a qualified technical manpower in the field of petroleum engineering.		
S10	Libya has many ports, that facilitate transportation of equipment required for gas shale horizontal drilling and fracturing operations.		
S11	Many big global service companies of oil and gas such as Schlumberger, Eni and others for different oil and gas activities in Libya including shale gas.		
S12	Libya has the fund for the investment in this field to drill numerous wells and hydraulically fractured for the development of shale gas in Libyan basins. Therefore financing the shale gas activities will not be a challenging task.		
	Opportunity		**Threats**
O1	Shale gas production will reduce the gap between energy demand and domestic supply. More natural gas will benefit industries, manufactures and will help Libyan economy to grow.	T1	At present, the reserves are yet to produce shale gas in Libya. The reserves estimated by the USEIA are not certain in all cases, and it can be confirmed by carrying out proper tests in the shale gas all over the basins
O2	The exploration and production of shale gas started around 80 years back in the US. Since then, there were a lot of development and innovations in the technology to explore and produce shale gas.	T2	Shale gas reserve connected to drilled well may be depleted faster because of low porosity of the shale rock.
O3	Libya has some infrastructures and national oil companies to invest and explore in shale gas.	T3	The depletion of water aquifer due to the large quantities of water required for drilling and hydraulic fracturing.
O4	National Oil Corporation, can	T4	The contamination of groundwater owing to

	be cooperating with the other foreign companies for shale gas exploration and development activities.		drilling and exploration activities.
O5	The increased in gas-based power generation will make the environment cleaner.	T5	The opposite of environmental protection organization for shale gas production because of its environmental impacts.
O6	The renewable energy is yet to pick up, shale gas can bridge the gap between conventional non-renewable and renewable energy supply.		
O7	Along with shale gas exploration and production, many job opportunities are created and many supporting ancillary industries are expected to emerge and grow, this will help economic growth.		

9. Conclusion

From the previous study of shale gas it could be conclude the following:

- Shale gas is definitely going to be a useful additional energy resource in the future for several countries particularly Libya because of it has a significant technically recoverable reserve. But the challenge lies in making it sustainable and safe.
- Efficient techniques of exploration in near future can produce good results and will balance the energy demand with the use of shale gas.
- The assessment parameters e.g. the estimated basin area, shale play thickness, depth and technically recoverable reserve (TRR) as well as other factors such as total organic carbon, gas saturation, kerogen type, in addition to the SWOT analysis matrix of Ghadamis basin that comparing with the other shale gas basins in the world revealed a good results that indicate the potentiality of this resource as a sustainable development in the future.
- The main limitation is that the process requires a great volumes of fresh water which Libya cannot afford in a water scarce condition.
- Also the environmental impacts caused due to exploration of shale gas has gained opposition from environmental activists.
- Along with the shale gas, many toxic chemicals are also released which cannot be disposed at once.

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