Jordan's Commercial Oil Shale Exploitation Strategy

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Abstract

This paper explains Jordan's Oil Shale Development Strategy and discuses the mechanisms to put Jordan on the road to greater energy independence and make it a pioneer country in commercial applications. The future beneficial use of the oil shale resources depends on the following facts:

1. Suitable oil shale technologies that have already been developed to use oil shale economically and cleanly can be employed successfully in Jordan.
2. Oil shale is Jordan's most extensive domestic fossil-fuel source throughout the 21st century and beyond.
3. Jordan ranks third in the world of oil shale reserves. The identified reserves are more than 70 billion metric tones.

Jordan has signed five Memoranda of Understanding (MOUs) with international companies to undertake viability studies for the use of well-known surface mining and retorting technologies such as: Petrosix, Kiviter, Galoter and ATP, and with Shell to undertake a full comprehensive assessment of employing the deep In Situ Conversion Process. During the coming months, a pilot and a demonstration phase will be established to be followed by commercial production of shale oil and/or electricity substituting for imported crude oil and petroleum products. Oil shale is seen as a viable option at today's oil prices so that oil shale use will result in significant savings in foreign exchange, improve Jordan's energy supply and security and create new jobs. The Government's position is now clear as to what should be done to use this strategic energy resource wisely. Comprehensive scientific research, feasibility studies, legislation and best practices codes are the main parts of the national oil shale plan that will be addressed. The expected outputs are to determine new processes, to improve the feasibility of production and to evaluate technology needed to reach to a commercial phase.

Introduction

Conventional hydrocarbon resources are finite and will run out one day. However, the general belief is that we have at least two or three decades before this event happens. The growth of the world economy needs energy, and if oil is depleting then the energy to grow can no longer come from oil. Therefore alternatives to oil must be developed now.

As oil production falls and global consumption continues to climb, oil prices will rise. Everything that depends on oil will also go up in price. As oil prices escalate and technology drives the development and production costs for unconventional resources down, these secure resources are looking more and more attractive and viable.

When crude oil is first pumped from a well, it can take the energy of one barrel of oil to get 100 barrels of oil from the ground. This is called the Energy Profit Ratio (EPR). Today on average it takes the energy of one barrel of oil to get ten barrels of oil from the ground. When it takes the energy of one barrel of oil to get one barrel of oil from the ground then the Energy Profit is zero and there ceases to be any energy benefit from the activity.

The situation in the global energy horizon gives enough reasons to believe that in the near future, conventional fossil fuel will no

longer be available as a source of sustainable energy in the quantities known today. Therefore, oil shale is considered as one of the promising options to substitute for conventional fuels in the coming future. If the technology can be developed to economically recover oil from oil shale, the potential is enormous. If the contained organic material could be converted to oil, the quantities would be beyond all known conventional oil reserves.

Oil shale contains about 25 % solid organic material, mostly kerogen and some bitumen. Kerogen, from the Greek word meaning "oil generator", is a complex collection of hydrocarbon molecules, ancestor to the alkanes in petroleum. It was discovered that the linking steps from oil shale to oil could be speeded up by heating in the absence of air, a process known as pyrolysis (or destructive distillation), with temperatures in the range of 500 °C. When the kerogen is converted to oil and separated, the process is called retorting.

Oil shale can still be considered as Jordan's most extensive domestic fossil-fuel source throughout the 21st century and beyond, as Jordan ranks third in the world of oil shale reserves. The identified resources of this oil shale are huge (50 - 70 billion metric tones) sufficient to satisfy the national energy needs for hundreds of years.

One ton of shale rock will typically produce one barrel of shale oil compound. The resulting spent shale has a large heat value that can be used as a source for heating new shale rock entering the retort. The spent shale also can be used for cement and building materials.

There are other places that have utilized oil shale. Estonia's economy is dependent on oil shale - over 90% of its electricity is powered by oil shale, and it is one of that country's chief exports. Permanent mining began in 1918 and has continued until the present day. By 1955 oil shale output had reached 7 million tonnes, mainly used as power station/chemical plant fuel and in the production of cement. The opening of power plants in 1965 and 1973 again boosted production and by 1980 (the year of maximum output) the figure had risen to 31.35 million tonnes.

China has been using oil shale since 1929. China's production from its Fushun shale oil plant in 2002 was about 90,000 tons of shale oil, from 3 million tons of rock, most of which is sold as fuel oil. There are plans in China to at least double its current oil shale production. A new oil shale plant is under construction, comprising two sets with 40 new retorts that are identical to the existing ones and are planned for startup sometime this year.

Brazil began its oil shale industry in 1950s with the establishment of the Oil Shale Industrialization Commission (CIXB). It was set up to study the construction of a plant in the town of Tremembé. In 1954, when Brazil's national oil company, Petrobras, was established, a division of that company, SIX, oversaw oil shale development. A prototype oil shale retort plant, built near Sao Mateus do Sul, began operations in 1972. It had a design capacity of 1,600 tons of oil shale per day. Using a proprietary PetroSix process, a larger version was built in 1991 that was 35 ft in diameter. It produced about 550 tons of shale oil per day. More than 1.5 million tons of shale oil products had been produced through 1998.

Table 1 shows recent oil shale resource estimates from the U.S. Department of Energy.

Table1: Oil Shale Resources estimates as percentage of world total

Rank	*Country*	*Percentage*
1)	U.S.	72.0%
2)	Brazil	5.4%
3)	Jordan	4.2%
4)	Morocco	3.5%
5)	Australia	2.1%
6)	China	1.5%
7)	Estonia	1.1%

The Energy Situation in Jordan

Jordan is strategically located at the heart of the Middle East region. As a result, the country has a diverse and rich archaeologi-

cal and historical heritage. While Jordan experiences a lack of petroleum reserves, it has been able, through numerous programs to develop extensively the infrastructure needed for both a high standard of living and industrialization. Jordan's wealth has always been the political stability and the encouragement of liberal economics. Liberalized investment law has encouraged foreign and local investors, a situation which created a climate favorable to private enterprise.

Jordan is favorably situated between the Precambrian outcrop belt and the rich oil-producing area of the Gulf coast geo-syncline, making it a prime prospective frontier area for oil and gas deposits. There are numerous oil and gas shows throughout Jordan, even in wells that are not located on recognizable structures. There is also an abundance of surface indications of hydrocarbons in the form of seeps, asphalt impregnation and near surface deposits of rich oil shale.

Jordan is interested in exploiting all the available sources of energy. A comprehensive plan for renewable energy is prepared. Renewable energy utilization includes solar water heater panels, solar photovoltaic, wind farms of 1.5 MW, small hydropower of 5 MW, biogas of 3.5 MW and passive solar. The total contribution of renewable energy in Jordan is about 1% of the total energy mix.

The most important domestic sources of indigenous energy are oil shale, natural gas and renewable energy. Domestic natural gas covers only 3-4% of the Kingdom's energy need.

At present, Jordan meets its oil need from Saudi Arabia, Kuwait and the United Arab Emirates. Jordan has only one small oil field "Hamza" in the East near the Iraqi border. The Jordanian and the Iraqi government are negotiating to build a pipeline to Zarqa refinery to accommodate Jordan's future oil requirements. The Jordan Petroleum Refining Company was established in 1956 and has a current capacity of 107,000 b/d. Its monopoly concession is due to expire in 2008.

Risha gas field is the only field that produces gas in Jordan, its located in the Eastern parts of Jordan also near the Iraqi borders. The proven reserve of natural gas is about 288 million cubic meters that can be extracted and utilized. The gas field produces 35 million cubic feet per day. Al-Risha Power Station supplies Jordan with 10% of its electricity by using this natural gas.

The electricity sector preserved a sustainable growth with 8% average, covering 99% of the country. Currently the total installed capacity stands at 1,636 MW generated by eight plants. These plants are fired by a combination of natural gas that is imported from Egypt, heavy fuel oil and diesel.

A regional natural gas pipeline project is underway. This pipeline started from Egypt's gas fields in Al-Arish and it goes all the way into Jordan, Syria, Lebanon and Turkey. Another regional electrical interconnection project is under way called The Seventh Electric Interconnection Project (EIJLLST) that aims to connect the electrical network of Libya, Egypt, Iraq, Jordan, Lebanon, Syria and Turkey.

Apart from oil and gas possibilities, Jordan has a number of energy potential resources which could act as an energy base in the next decade and beyond. Table 2 provides a summary of the potential new and renewable energy resources in Jordan.

Jordan has been implementing an ambitious privatization program since 1996. Early power sector reform efforts started in 1994 when the Jordan Electricity Authority was converted from a statutory body into a public company owned by the government.

In 1997, as part of the government privatization program, a comprehensive reform program for the power sector was initiated aiming at achieving an adequate and reliable electric power supply under the most efficient conditions in terms of quality and cost; and creation of an operating and regulatory environment conductive to attract private capital and expertise.

Table 2: Energy resources of Jordan

1.	Oil Shale	Geological reserves	40 billion tons
2.	Tar Sands	Geological reserves	40 million tons
3.	Uranium	Uranium to phosphate ratio Uranium reserves	80-160 PPM 8-16 thousand tons
4.	Solar	Average 5.5 kWh/m^2/day	Potential 1.3 million MW
5.	Wind	5- 8 m/s average wind speed	More than 1000 MW
6.	Bio gas		More than 50 MW
7.	Hydro	When connecting RSDS canal	600 MW
8.	Geothermal	Under investigation	

As a result of genuine attention to the energy sector from King Abdullah Ibn Al-Hussain II, a Royal Committee was formed headed by His Highness Price Hamzah-Ibn Al-Hussain to overlook and coordinate efforts in the sector. The Committee has initiated a process of revising the Energy Sector's Strategy which aims at securing the country's need for energy and facilitating local and foreign investment in energy related projects.

Jordan's Oil Shale Resources

Oil shale is the most abundant fossil energy resource discovered to date in Jordan. The estimated reserves are more than 50 billion tons capable of yielding some 50 billion barrel of crude oil.

It is believed that the existence of oil shale in Jordan has been known for centuries. British geologists investigated the oil shale of the general region after World War 1, where samples were taken and retorting tests were made. Records from the outcrop of Shallaleh deposit have indicated that villagers have used the shale for many years to heat water and to lime their homes and wells.

Oil shale deposits are widespread and discovered in many areas of the country. Jordan has looked into oil shale potential since the late 1960s. Geologic studies since then have shown that over 60% of the country contains oil shale deposits. There are more than 25 surface and near-surface occurrences of oil shale in Jordan; seven of these deposits have been studied in detail. These major surface deposits of commercial scale interest are located about 100 km south of Amman, are easily accessible from the highway, and are traversed by a high-voltage power transmission line. These deposits are regarded as the richest organic bituminous marl and limestone that occur at shallow depth.

Jordan's oil shale is generally of a good quality, with relatively low ash and moisture content. Gross calorific value (7.5 MJ/kg) and oil yield (8-12%) are similar to those of western Colorado (USA) shale. Jordan's oil shale is kerogen - rich bituminous argillaceous limestone that was deposited in a shallow marine euxinic environment, mostly during the Maastrichtian and Paleocene stages of geological time. The kerogen in this limestone represents the fossil remains of plants and animals that accumulated in prehistoric seas and lakes that covered most of Jordan some 80 million years ago during the Upper Cretaceous period. It is believed that planktonic organisms such as algae are the main source materials.

The geological conditions of Jordanian oil shale *e.g.* its thickness and the structural settings, the chemical and mineralogical compositions are favorable for both open-pit and deep mining. All these factors together with the low mining and infrastructure costs render the deposit quite suitable for industrial utilization.

Table 3: Comparison of properties of world oil shale deposits to Jordanian oil shale

	Moisture content, wt.%	Water	Oil	Residue	Gas + losses
Kvarntrop (Sweden)	2.0		5.7	87.2	5.1
Kukersite (Estonia)	Dry	1.9	22.0	70.5	5.6
Green River (USA)	Dry	1.4	10.4	85.7	2.5
Irati (Brazil)	4.6	1.2	6.9	83.6	3.7
Maoming (China)	5.0	3.2	7.3	80.6	3.9
El Lajjun (Jordan)	4.0	1.4	10.1	80.8	3.7

Table 3 compares various properties of a Jordanian oil shale to oil shale from various other nations. Table 4 tabulates properties of numerous oil shale deposits in Jordan.

Previous Work in Jordan

Since 1980's the Government of Jordan (GOJ) has conducted extensive studies for the exploitation of oil shale reserves which have led to the assessment of this oil shale and the suitability of the state-of-the-art technologies. Detailed surveys were carried out by drilling core holes and performing laboratory work to determine proven geological reserves, quality, oil content and calorific value. These studies have concluded that the Jordanian oil shale, due to its high organic content, is considered as a suitable source of energy

Table 4: Characteristics of oil shale deposits in Jordan

Deposit	*Geologic Reserves (Billion tons)*	*Surface Area (sq.km)*	*Overburden Thickness (m)*	*Oil Shale Thickness (m)*	*Organic Matter (%)*	Average Oil Content (%)
El-Lajjun	1.3	20	31	29	28	10.5
Sultani	0.99	24	69	32	25	9.7
Jurf Ed-Darawish	8.6	150	47	68	18	5.7
Attaraat	11.3	226	47	36	29	11.0
Wadi Maghar	32	29	40	40	20	6.8
El-Thamad	11.4	150	142 - 400	72 - 200	25	10.5
Khan Ezzabib	N.A	N.A	66	39-45	N.A	6.9

	Number of Drilled Wells	*Moisture Content (%)*	*Ash Content (%)*	*Sulfur Content (%)*	*Density (g/cm^3)*	*Calorific Value Kcal/Kg*	*Calorific Value (kj/kg)*
El-Lajjun	135	2.1	54.7	3.1	1.81	16 50	6 906
Sultani	57	5.5	55.5	2.4	1.96	15 26	6 380
Jurf Ed-Edarawish	50	4.5	58.4	2.4	2.1	11 00	4 603
Attaraat Um-Ghudran	41	3.25	53.2	2.6	1.8	1730	7.235
Wadi Maghar	21	2.9	57.5	2.6	2.03	1090	4.773
El-Thamad	12	2.5	54.7	3.2	1.8	1800	6 903

either by direct burning to generate electricity or by retorting for the production of oil and gas.

Oil shale direct burning test results have shown that the Jordanian oil shale is considered as a good and acceptable fuel to be burned in circulating fluid bed boilers (CFB) with very high combustion efficiency and very low emissions. Retorting tests have also shown promising results and indicated that oil yield is 10% and gas yield is 5% by weight. The tests have also showed that the reaction of calcite in limestone with sulfur results in very low SO_2 emission.

A number of collaborative studies have been conducted. The main outcomes of the previous studies and are summarized in the next paragraphs.

Technopromexport: A prefeasibility study was conducted with a former USSR company named Technopromexport to assess the potential for direct burning in a 300 MW power plant. The study concluded that the Jordanian oil shale is suitable as a fuel for direct burning and recommended the construction of an experimental demonstration plant of 200 MW.

Klockner/Lurgi: Jordan conducted a feasibility study with a German Company called Klockner/Lurgi, including studies and test programs for oil shale retorting to produce syncrude (50,000 b/d) and for CFB for direct combustion in power generation. The study concluded the following: • The geological conditions of Al-Lajjun oil shale are reliably proven for a 50,000 barrel/day oil shale retorting plant for 30 years.

- Open cast mining methods for oil shale are technically and economically viable.
- Al-Lajjun oil shale has a high quantity of sulfur (3.5 %). The hydrogen sulphide produced can be converted to 99% pure elemental sulfur.
- Combustion tests on spent shale proved an almost total burnout of residual carbon at 800 °C; the residual oil shale is a suitable material for building and road construction.
- The economic assessments indicated that oil production cost is in the range of 20-25 $US/barrel and electricity production cost is 19 mills/kWh (1988 prices).

Sinopec: Jordan conducted a feasibility study and retorting test program with Sinopec, a Chinese company, in more than 1000 tons of Al-Lajjun oil shale was shipped to China. The results indicated that Jordanian oil shale can be processed in the Chinese Fushun-type retort. There were no difficulties in connection with ash removal or separation of water from shale oil. The oil yield from the retort reaches 80-84% of Fischer assay; oil viscosity was 0.98 and impurities were 0.06%. The calorific value of the gas produced was 1050 Kcal/m^3. Fushun type retorts are suitable for different kinds of oil shale which makes them economically profitable, and especially suitable for small and medium scale shale oil production. The estimated cost of oil production by using Fushun type is in the range of 15-20 $US/barrel (1987 prices).

Lurgi: Based on the results of combustion of 75 tons of oil shale from Sultani deposit, Lurgi concluded the following:

1. There were no upsets in the fluidizing behavior of the circulating material and/or in plant operation.
2. Combustion of oil shale was self - sustained.
3. With particle size 3-5 mm, combustion of oil shale did not pose any problems. 4. Carbon burn-off reached 98%.
5. In view of $CaCO_3$ content of the oil shale ash, it was not necessary to add limestone for desulfurization according to the following chemical reactions:

$$CaCO3 \longrightarrow CaO + CO_2$$

$$CaO + SO2 + ½\ O2 \longrightarrow CaSO4$$

(Calcium sulfate like paste)

6. In view of the low combustion temperature, the SO_2, NO_X and CO emissions were below international standards. Preliminary R&D concludes that the high-calcium ash of Jordanian oil shale is suitable for a wide range of uses such as:
   - Construction material including

bricks, tiles, light weight aggregate cement mixing for manufacturing of concrete products.
- Construction of road bases, use filler in asphalt mixtures.
- Stabilization of soils conditioner and fertilizer production (liming of acid soils).
- Production of foundry cores.
- Animal supplement in animal food.

Enin: A Russian company called Enin conducted a test program. The preliminary results of the Jordan shale thermal processing tests have shown that the technology developed by ENIN makes it possible to use shale of any fractional composition and quality without preliminary sizing for producing high calorific liquid and gas fuels. The technology called UTT - 3000 has found its commercial application in two plants which process as much as 140 tons per hour oil shale. The study concluded that the Jordan oil shale is fully suited for efficient use in UTT-3000 plants which are efficient and environmentally safe facilities to produce oil and fuel gas or a thermal power station where shale is used as a source fuel.

Suncor: The Canadian company Suncor conducted a feasibility study and test program for retorting Jordanian oil shale. The oil shale sample was tested using Alberta Taciuk Processor (ATP). Engineering and economical analysis shows that this is a viable process.

The ATP combines the extraction, upgrading and energy generating steps of producing oil from oil shale; it requires less capital and equipment than other traditional processing techniques. The ATP is a rotating kiln that heats oil shale to 500 °C, releasing the shale's hydrocarbon vapors. These vapors are then captured, condensed and processed into oil. The spent shale is used to fuel the operation making it energy self-sufficient.

Pyropower: Based on the results of combustion of 75 tons of Jordanian Sultani oil shale in Finland, Pyropower concluded the following:

1. The sample of oil shale is an acceptable fuel in an Ahlstrom Pyroflow CFB where it burns cleanly and efficiently.
2. Combustion efficiency in excess of 98.5% was demonstrated.
3. Both SO_2 and NO_X emissions and CO emissions were acceptably low. The tests demonstrated that over 90% of the fuel sulfur was absorbed by the calcium in the oil shale. Typical emissions measured during these tests were:
   SO_2 <20 ppm
   NO_X 60-120 ppm
   CO <50 ppm
   These values will generally meet the most stringent environmental requirements.

All feasibility studies and test burns have concluded that the Jordanian oil shale burns very stably, even at loads as low as 40%. Low SO_2 and NO_X emission levels can be achieved in the CFB combustor, and high carbon burn out (~99%) can be achieved.

Shale Ash Studies: Studies conducted by Bechtel concluded that shale ash binding matter does not respond to the standard requirements for Portland cements with respect to the regularity of volume variation during the first week of hardening.

Moreover, a sample of shale ash from the combustion test was studied chemically and physically at the Jordan Cement Lab in 1988 and concluded the following results:

- The tested oil shale ash has shown good ability for grinding which assist in increasing the earlier strengthen for the cement.
- The test proved that cement that contained some ash became stronger after 3-7 days.
- When ash was mixed with cement at more than 20%, some negative impact appeared due to the high content of P_2O_5 in the ash.

According to the chemical composition of oil shale ash, some 87% of cement raw materials can be replaced by this shale ash

which has the following chemical composition:

Oxide	*wt %*
Calcium	48
Silicon	29
Aluminum	7
Iron	3

A special study was conducted by the Royal Scientific Society to study all factors and components such as mechanical properties, strength, permeability and self-binding properties of Jordanian oil shale ash. This study has drawn attention to the fact that the large quantities of high calcium ash from the Jordan's oil shale are a suitable and cheap material for production of a wide range of valuable materials such as:

- Fertilizer and soil conditioner
- Construction material
- Cement
- Industrial products such as adhesives, varnishes, pesticides, benzene, urea resins.

Oil Shale in the Kingdom's Energy Master Plan (The Strategy)

As a result of great attention to the energy sector from King Abdullah Ibn Al-Hussain II, a Royal Committee was formed headed by His Highness Price Hamzah-Ibn Al-Hussain to overlook and coordinate efforts in the sector.

The Committee initiated a process of revising the Energy Sector's Strategy which aims at securing the country's needs for energy and facilitating local and foreign investment in energy related projects.

Jordan's Energy Master Plan will inject about $3 billion of public and private sector capital. This plan will cover all related activities of the sector from the exploitation of oil shale and other conventional energy resources. The plan also covers legislative and regulatory reforms.

The GOJ has decided to start preparing for an integrated technical and economic feasibility study to determine the optimal use of this strategic resource of oil shale. The GOJ has evaluated various options and considered oil shale as the most appropriate option that suits Jordan's economy in the near future

The Cabinet and the Royal Energy Committee have approved the oil shale strategy, which is driven by the following factors:

1. Jordan is a non-oil producing country which is deeply affected by the world energy situation.
2. Energy imports create a financial burden on the national economy: the energy bill reached 23% of the GDP in 2006.
3. Conventional fossil energy will be depleted sooner than expected.
4. High energy prices have fundamentally changed the economics of unconventional resources and therefore increased the potential for oil shale to be an energy source in the future and will improve the economics of investment in this field.
5. Jordan ranks third in oil shale reserves and has become one of the most attractive investment and operational acreage holders for oil shale development.

The GOJ appointed two international Consultancy Companies: Charles River International-England and Behre and Dolbear (through a grant from the United States Trade and Development Agency). These consultant services are intended to:

- Provide a clear vision along with a short and long-term strategy to address oil shale use either through direct burning or retorting.
- Provide competent advice and assistance on technical, financial, economical and legal aspects.
- Develop a detailed and well determined Negotiation Strategy that shall lead to successful commercial agreements and project closure.
- Review the terms of the draft Commercial Agreements and advise the GOJ during the course of negotiations on the terms and conditions that shall lead

to a successful negotiation and project closure.
- Analyze current shale oil extraction recovery and technologies and examine their suitability for use in Jordan.
- Apply the best international expertise to the development of an oil shale industry in Jordan.
- Facilitate the implementation of near-term actions leading to the commercial production of the Jordanian shale oil resources.
- Identify key decision points, risks, key implementation issues and implications in terms of the required project management skills.
- Provide recommendations and advice for royalties and suggest best revenue sharing arrangements.
- Ensure that the project shall follow local and international standards regarding equipment, environment and water consumption.
- Identify key environmentally acceptable oil shale waste disposal practices.
- Increase understanding of engineering issues concerning the design and scale-up of oil shale extraction and utilization.

The GOJ has taken a number of steps to encourage foreign investments in oil shale processing and use, including the following:
- Keeping the door open for companies interested in investing in oil shale development.
- Providing all available related data free of charge.
- Granting exploration and mining rights for areas with adequate deposits, whether for pilot or commercial projects; for either oil extraction or power generation.
- Signing long term purchase agreements of the energy products of any oil shale project.
- Facilitating all the logistics needed for oil shale utilization.

Jordan is currently working in three directions:
1. exploitation of deep oil shale in cooperation with Shell
2. near-surface mining
3. cooperation with Estonia to build a CFB power plant

The GOJ strategy for oil shale is being implemented in two phases and is designed to achieve the following objectives:
- To encourage development of oil shale through direct burning, surface and deep-mining retorting.
- To license a small portion of resources to allow companies to develop their technologies and capabilities.
- To award acreage in the future to successful companies.
- To develop competition for access to future resources.

Implementation of the oil shale strategy will open up the market to competition and create several investment opportunities. The strategy for this exploitation is proposed to make Jordan the first in the world to have a diversified and comprehensive oil shale implementation program that will present oil shale processing technologies in commercial application such as:

Galoter, Kiviter, Athabasca Taciuk Process (ATP), Petrosix, In-Situe Conversion Process (ICP) and Circulating Fluid Bed Technology (CFB)

The exploitation appraisal expected to cover the full lifecycle of all activities necessary to exploit oil shale including:
- Construction
- Development
- Ownership
- Operation and expansion of all the necessary production facilities
- Mining operation
- Processing and storage facilities • Power generation
- Transport and distribution infrastructure
- The wholesale and retail of finished or semi-finished products either to the domestic market or for export
- Sales or safe disposal of by-products • Plant and mine decommissioning, land remediation activities
- Commercial transactions

Phase 1

In March 2006 the government decided to issue a Call for Proposals to fourteen companies for developing a surface retorting oil shale facility in Jordan. The intention of the call for proposals was to:

- Identify those companies ready to move quickly towards a real project.
- Allocate different areas other than that defined for the Shell concessions to different companies.

The bidding process was completed with only seven proposals received from companies that were qualified. The proposals were evaluated based on a series of clearly defined and well-focused criteria.

Companies were prioritized through two key measures: capability and strategic interest. The capability assessment was based on track record, technology assessment, project management, and financial factors.

Strategic interest was based on the level of interest in Jordanian resources, regional focus, and whether investment in Jordan would provide an opportunity for the companies to develop and prove the capabilities of their technology. The strategy gave the companies the opportunity to demonstrate their competencies and for the government of Jordan to award companies with increased resources should the evaluation demonstrate a viable project.

Jordan has recently signed Memoranda of Understanding (MOUs) with five qualified companies to conduct full-fledged bankable feasibility studies, including technical and economic viability, for the use of both surface retorting and in-situ conversion technologies, and to assess the hydrocarbon production potential and suitability for exploitation. The signing of these MOUs will be followed by good faith negotiations on concluding legally binding concession agreements to allow for the actual exploration and the commercial exploitation of oil shale.

The following five companies have signed MOU's and currently involved in techno-economical studies:

*Shell***:** In June 2006, the Governmebt of Jordan (GOJ) signed an MOU with Royal Dutch Shell to test the extraction of deep oil shale resources using Shell's In-situ Conversion Process in the Azraq and Al-Jafr blocks of central Jordan. The government is currently negotiating with Shell to to reach an agreement use the new extraction technique and go ahead with the project.

The project study will take about ten years and shall consist of the following main Phases:

1. Negotiation of the commercial agreement and GOJ approval (one year)
2. Exploration and assessment of oil shale resources (2 years)
3. Appraisal of selected prospects (2-3 years)
4. Localization of demonstration project (2-5 years)
5. Project definition and final commercial investment (4-5 years)

*Petrobras***:** In March 2007 Jordan signed an MOU with Brazil's state-owned Petrobras for the exploration of oil shale in the Attarat deposit and to conduct a technical and economical feasibility study for the use of Petrosix™ for the production of oil from oil shale. The MOU is for 24 months and the Jordanian government will award Petrobras a concession for the exploitation of oil shale in part of al-Attarat area if the project is economically viable.

OSEJ - Oil Shale Energy of Jordan: In November 5th, 2006, Jordan signed an MOU with the Oil Shale Energy of Jordan to carry out feasibility studies on surface oil shale deposits in one third of the Al-Lajjun block to investigate retorting the oil shale as a source for liquid and gaseous fuel by employing the Galoter technology.

Preliminary results of the Jordan shale thermal processing tests conducted by the Russian Institute in 1997 have shown that the UTT 3000 technology makes it possible to use shale of any fractional composition and quality without their preliminary sizing for producing high calorific liquid and gas fuels.

The study concluded that the Jordan oil shale is fully suited for use in UTT-3000 plants which is a high efficient and environmentally safe facility to produce oil and fuel gas or a thermal power station where shale is used as a source fuel.

JEM - Jordan Energy & Mining: On November 5th, 2006, Jordan has signed an MOU with Jordan Energy & Mining to carry out feasibility studies on surface oil shale deposits in one third of the Al-Lajjun block to investigate retorting the oil shale as a source for liquid and gaseous fuel by employing the AOSTRA-Taciuk Process (ATP).

INCOSIN - International Corporation for Oil Shale Investment: On November 5th, 2006, Jordan signed an MOU with the International Corporation for Oil Shale Investment, to carry out feasibility studies on surface oil shale deposits in one third of the Al-Lajjun block to investigate retorting the oil shale as a source for liquid and gaseous fuel by employing the Kiviter technology. Because the Kiviter retort cannot accept fines below of 2.5-12 cm and the Galoter retort requires fines of < 2.5 cm, the two retorts complement each other for full resource utilization.

Phase 2

Some of the other companies which participated in Phase 1 were deemed not to be qualified and instead it was decided to offer them the opportunity to participate in Phase 2 at a later stage, such that they had more time to develop their capabilities.

The objective of Phase 2 is:

- To attract interest from high capability companies to invest in oil shale development in Jordan.
- To develop and execute a further licensing round.
- During Phase 2, a marketing strategy has been developed and implemented to achieve the goal of attracting higher quality companies through raising the profile of Jordan.
- It is planned that a further licensing round will be undertaken.

It is important to communicate clearly to investors what resource is being offered in order to give them confidence that the area has been appraised and studied, has high quality oil shale, little overburden, and very good access to existing infrastructure. During Phase 1, confidence in these issues with regards to the Al-Lajjun area resulted in most companies expressing interest in this area.

With Petrobras and Shell, companies that clearly have the capabilities, it is intended to capture their ongoing interest in Jordan through direct negotiation with them. In these discussions, GOJ will ascertain their interests in Jordan and attempt to develop a tailored approach to acreage and exploitation rights. Such direct negotiation may ultimately lead to concession agreements.

Prior to awarding any acreage to these companies, the GOJ will wish to ensure that the companies have the capabilities to develop oil shale and that the acreage they are awarded be suitable in size and scale to the capabilities of the company. It is planned that a tender process be used for license award. This will require the companies to submit proposals and if successful to be awarded defined acreage rights. This process provides the information necessary for the GOJ to assess the capabilities of the companies and to then award suitable acreage rights.

Conclusions

There is a clear economic interest for Jordan to have oil shale developed as a strategic energy source. In the medium and long term, oil shale will dominate the world's energy supply system. Oil shale is seen as a viable option at today's oil prices so that oil shale production will result in significant savings in foreign exchange, improve Jordan's energy supply and security and create new jobs.

Jordan is developing competition for access to its oil shale resources and has encouraged private sector involvement in this field so that Jordan is at this stage well placed in terms of implementing its strategy. The time seems right to recognize

and pursue the potential of Jordan's oil shale and to include oil shale in the mix of energy resources, policies, and programs to sustain Jordan's economic growth and vitality and bolster national energy security.

After discovering the vast oil shale reserve, Jordan has become one of the most attractive investment and operational acreage holders in regards to oil shale development. Investment in oil shale is now open in Jordan on the basis of production sharing agreement and/or any agreement which suits Jordan.

The sharp rising of crude oil prices in the international markets will improve the economics of investment in the field of the shale oil. Jordan is currently licensing a small portion of its oil shale resources and is expected to award more once the extent of resources is determined and the interest and capabilities of companies are verified.

The current oil shale policy will lead to a multi-purpose process (consisting of electricity generation, thermal retorting, cement production as well as mineral extraction) that could achieve high utilization-factors for both the oil shale's chemical and energy potentials.

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