

# Utilization of Oil Shale as a Source of Energy

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# Introduction

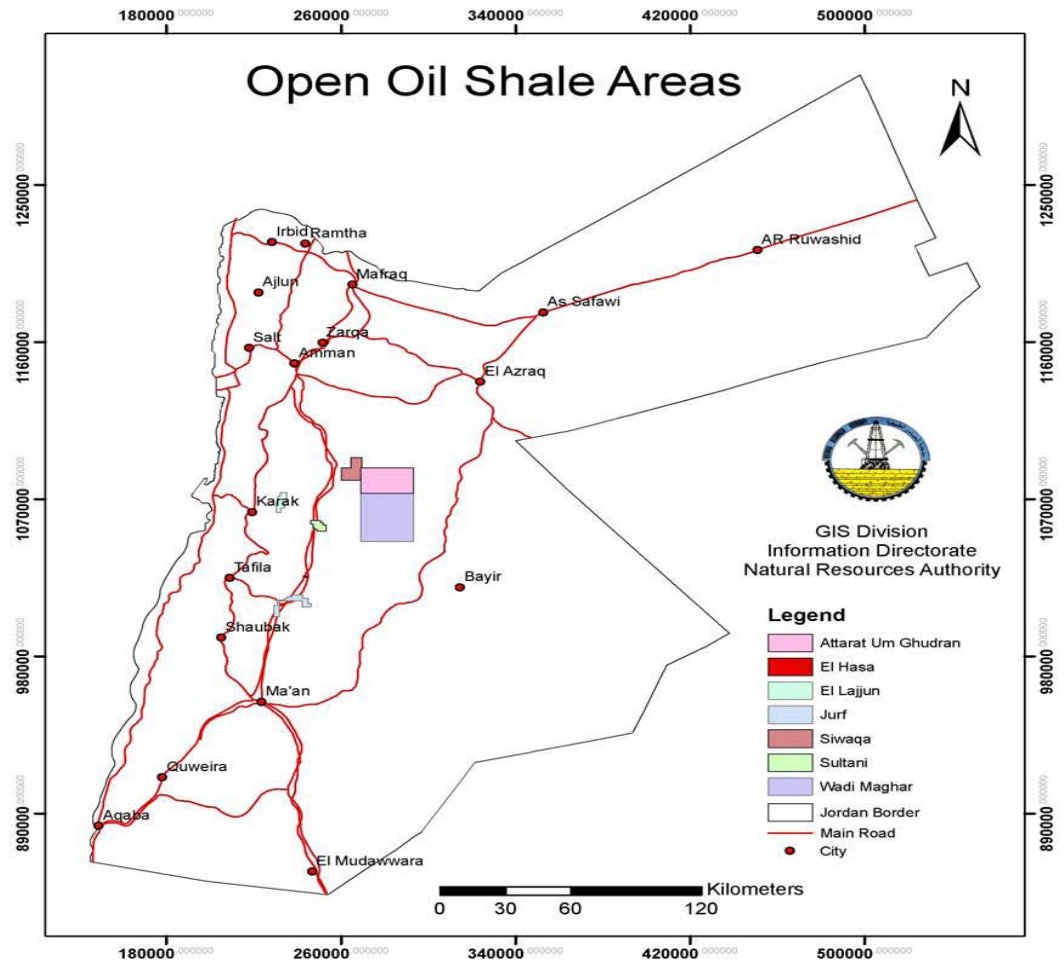
The growth of **petroleum price**, the **gradual decrease** in conventional energy resources, and the **growth of heavy industry**, have placed great pressure on energy supplies. Consequently, many researchers have been motivated to investigate efficient means to use oil shale as an alternative energy as soon as possible.

# What is oil shale?

- It is a fine-grained sedimentary rock containing solid, combustible **organic matter** in a mineral matrix. The organic matter, often called kerogen
- . Oil shale generally contains enough **oil** that it will burn without any additional processing, and it is known as "the rock that burns".
- This shale oil is a potentially valuable fossil fuel, but the present methods of mining and refining it are **expensive, damage the land, pollute water, and produce carcinogenic wastes**

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## Main Characteristics of the Studied Oil Shale Deposits

| Indices                         | El-Lajjun | Sultani | Juref Ed-Darawish | Attaraat Um-Ghudran | Wadi Maghar | El-Thamad | Khan Ezzabib |
|---------------------------------|-----------|---------|-------------------|---------------------|-------------|-----------|--------------|
| Geologic reserves, billion tons | 1.3       | 0.99    | 8.6               | 11.3                | 32          | 11.4      | n.a.         |
| Surface area, sq. km            | 20        | 24      | 150               | 226                 | 29          | 150       | n.a.         |
| Overburden, thickness, m        | 31        | 69      | 47                | 47                  | 40          | 142–400   | 66           |
| Oil shale thickness, m          | 29        | 32      | 68                | 36                  | 40          | 72–200    | 39–45        |
| Number of drilled wells         | 135       | 57      | 50                | 41                  | 21          | 12        | –            |
| Organic matter, %               | 28        | 25      | 18                | 29                  | 20          | 25        | n.a.         |
| Average oil content, %          | 10.5      | 9.7     | 5.7               | 11.0                | 6.8         | 10.5      | 6.9          |
| Moisture content, %             | 2.1       | 5.5     | 4.5               | 3.25                | 2.9         | 2.5       | n.a.         |
| Ash content, %                  | 54.7      | 55.5    | 58.4              | 53.2                | 57.5        | 54.7      | n.a.         |
| Sulfur content, %               | 3.1       | 2.4     | 2.4               | 2.6                 | 2.6         | 3.2       | n.a.         |
| Density, g/cm <sup>3</sup>      | 1.81      | 1.96    | 2.1               | 1.8                 | 2.03        | 1.8       | n.a.         |
| Calorific value:                |           |         |                   |                     |             |           |              |
| Kcal/kg                         | 1650      | 1526    | 1100              | 1730                | 1090        | 1800      | n.a.         |
| KJ/kg                           | 6906      | 6380    | 4603              | 7235                | 4773        | 6903      | n.a.         |

# Oil Shale Industry

- oil shale industry has not developed because historically, the **cost** of oil derived from oil shale has been significantly higher than conventional pumped oil
- . More recently, prices for crude oil have again risen to levels that may make oil shale-based oil production commercially viable,

- . Both mining and processing of oil shale involve a variety of **environmental impacts**, such as global warming and greenhouse gas emissions, disturbance of mined land, disposal of spent shale, use of water resources, and impacts on air and water quality..

# Oil Shale Mining and Processing

- Oil shale can be mined using one of two methods: **underground mining** and **surface mining**. After mining, the oil shale is transported to a facility for either further utilization by **direct burning** or for shale oil extraction

Oil may be extracted from oil shale by one of the following technologies:

- Retorting
- Supercritical
- In situ Rerorting

# Retorting:

- It is the process of **heating shale** to the temperature at which kerogen is decomposed or pyrolysed in the absence of oxygen into gas, condensable oil, and a solid residue. **Decomposition begins at relatively low temperature (300°C)**, but proceeds more rapidly and more completely at higher temperature.

# Supercritical

- A **supercritical fluid** is any substance at a temperature and pressure **above its thermodynamic critical point**.
- It has the unique **ability** to diffuse through solids like a gas, and **dissolve** materials like a liquid.
- . These properties make it suitable as a substitute for **organic solvents** in a process called Supercritical Fluid Extraction.
- **Carbon dioxide** and **water** are the most commonly used supercritical fluids.

The following problems arise during the utilization of oil shale:

1. The fact that **large quantities of heat** are required to obtain a usable fuel from the rock means that this is a far less efficient source of energy than conventional oil.
2. Another implication of the high energy needs for processing is that significantly more greenhouse gases are **released per barrel** of usable fuel produced.

3. The **rock expands** in size upon heating, meaning you can't put it back in the ground (two metric tons of rock are required to obtain a barrel of synthetic crude).
4. **Three** barrels of water are needed **per barrel** of oil produced,.

**To overcome these problems**, Shell Oil is currently developing an in-situ retorting process known as thermally conductive **in-situ conversion**.

# in-situ conversion

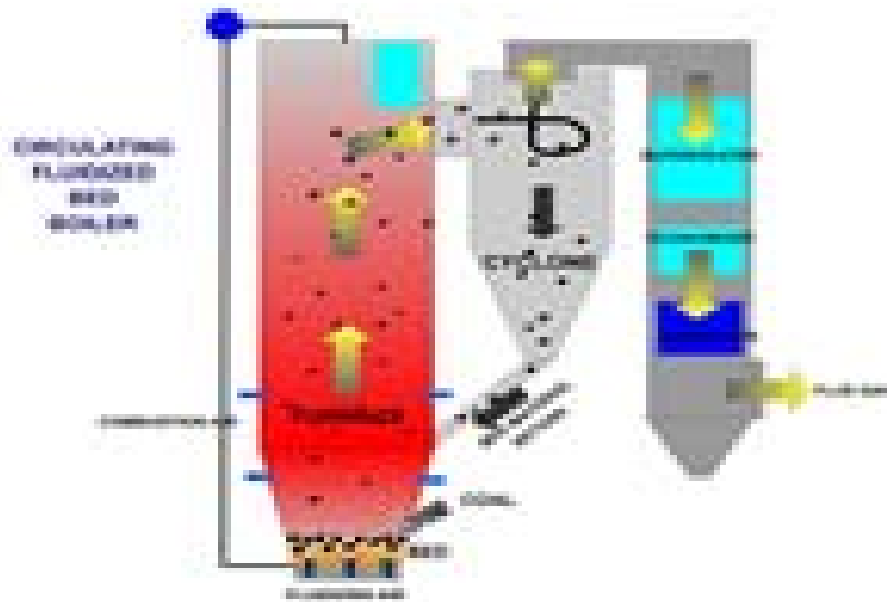
- This process involves **heating underground oil shale**, using electric heaters placed in deep vertical holes drilled through a section of oil shale.
- The rocks are then heated until the hydrocarbons boil off, the lightest and most desirable first.

- **The volume of oil shale is heated over a period of two to three years, until it reaches 650–700 °F, at which point oil is released from the shale.**
- **The released product is gathered in collection wells positioned within the heated zone.**

- This involves use of **ground-freezing** technology to establish an underground barrier called a "freeze wall" around the perimeter of the extraction zone.
- The freeze wall is created by **pumping refrigerated** fluid through a series of wells drilled (8 to 12 feet apart) around the extraction zone.
- **The freeze wall prevents groundwater from entering the extraction zone**, and keeps hydrocarbons and other products generated by the in-situ retorting from leaving the project perimeter.

# Direct Burning

The second method to utilize oil shale is by directed burning. Initially the rock is crushed into small size particles. The most common unit to burn it is the circulation fluidized bed combustion unit. CFB combustion is a promising technology for clean and efficient utilization of fuels yielding low harmful emissions, due to the relatively low combustion temperature



# Mechanism of oil shale combustion

- During its combustion, oil shale undergoes the following stages:
- **Ignition**, considered as the process initiating the combustion phenomenon, is very important due to its influence on flame stability, pollutant formation and emission, and flame extinction.
- **Devolatilization** . After heated up to a certain temperature, oil shale emits the volatile gaseous matters, that are ignited and undergoes a **homogenous combustion**.
- **Solid char particles combustion** , that are ignited as a result of volatile combustion, followed by a heterogeneous reaction, which involves the direct attack of oxygen on the solid particles

# Oil shale ash

- It is an **inorganic byproduct** of combustion of oil shale and retorted shale. Since it can cause environmental problems, attempts were made to benefit from such materials, especially in the construction industry.

- Combustion of oil shale produces significant amounts of  $\text{SO}_2$  and  $\text{NO}_x$ , well-known **pollutants** causing acid rain and photochemical smog. In addition large quantities of **ash** is formed as a result of burning oil shale.

## SO<sub>2</sub> concentration

- increases with bed temperature when first reaching its maximum value at 750 °C, and above 750 °C it decreases with increased bed temperature.
- drastically decreases with increasing circulating ratio.
- increase secondary air ratio and increases with increased particle size.

**NO and NO<sub>2</sub>-concentration were found to:**

- Increase with bed temperature when first reaching the maximum at 850 °C, and above 850 °C they decrease with increased bed temperature.
- Decreases with secondary air ratio

## N<sub>2</sub>O concentration was found to:

- reduces with increasing bed temperature.
- increase with secondary air ratio.

In general, the amount of NO<sub>x</sub> emissions is complex when particle diameter is less than 900 μm. When particle size is over 900 μm, the amount of NO<sub>x</sub> decreases.

# Oil shale economics

- The **extraction and processing** of oil shale is directly **linked** to the **oil price** ..
- According to the survey conducted by the RAND, a surface retorting complex (mine, retorting plant, upgrading plant, supporting utilities, and spent shale reclamation) is **unlikely to be profitable unless real crude oil prices are at least US\$70 to US\$95 per barrel.**
- Once commercial plants are in **operation** and experience-based learning takes place, costs are expected to decline to **US\$35–US\$48 per barrel after 12 years.**

- After production of **1000 million barrels**, costs are estimated to decline further to **US\$ 30 – US\$40 per barrel**.
- In 2005, Shell announced that **its in situ extraction technology** deployed in Colorado could be competitive at prices over **US \$30** per barrel.
- However, it is possible that the real competitive price level will be higher as the costs for building an underground wall of frozen water to contain melted shale have significantly escalated.

# Current research on oil shale in Jordan

- A funded project by MOHE research fund is currently undergoing, three universities are involved in addition to NERC. The project is of two parts:
- **Direct burning and power generation**, which has the following main objectives :
  - To design, construct and test a direct combustion unit, which will be used to directly burn crushed oil shale.
  - The thermal energy generated upon burning oil shale will be extracted using a heat exchanger.

- An attempt will be carried out to utilize this extracted energy to **drive a turbine**, which may be used for electrical power generation.
- The effect of burning oil shale on the **environment** will be investigated through the measurement of almost all pollutants emitted during the combustion process.
- An attempt will be carried out to minimize the sulfur oxides emitted during the burning of oil shale.

# Microwave shale oil extraction

- Crushed Jordanian oil shale bathed in crude oil would be ultrasonicated and irradiated with microwaves in different sets of laboratory-scale experimental trials to optimize the maximum kerogen liquidation rate as a function of variety of chemical and physical parameters.
- Affinity of kerogen to crude oil as well as to a mixture of organic solvents-JOS would be examined in two laboratory experiments.
- The first set would measure kerogen content in CO before and after ultrasonication and microwave treatment of the JOS-CO mixture using different chemical and physical factors.
- The second set would focus on chemical and morphological changes of the particles of JOS after treatment.

- **Microwave shale oil extraction** has the following main objectives:
  - To optimize the maximum kerogen liquidation rate as a function of variety of chemical and physical parameters.
  - To find the affinity of kerogen to crude oil as well as to a mixture of organic solvents-
  - An attempt will be carried out to minimize the sulfur oxides emitted during the burning of shale oil

# Solvent extraction

- About twenty grams of finely ground oil shale samples (<160 $\mu$ m) will be **extracted in silica** thimbles with 300 ml of solvent mixtures (e.g. dichloromethane (DCM), methanol, hexane, and toluene) for 24 hrs.
- Activated copper will be used to **eliminate free sulfur** from the extract.
- The solvent mixture will be removed from the extract first by a vacuum pumping of rotary evaporator at a low temperature (40-45 oC).
- The extract will be transferred into a clean 10 ml glass vial and completely dried under a stream of nitrogen gas.
- The weight of total extract will then be determined.

**Solvent extraction**, which has the following main objectives:

- Establish the relationship between the mineralogy of oil shale and extraction behavior.
- Determine the optimized parameters that control shale oil extraction.
- Develop mathematical models to relate the extractability of oil shale with the different parameters.
- An attempt will be carried out to minimize the sulfur oxides emitted during the burning of shale oil

# Continuous Stirring Tank Reactor (CSTR) extraction

- Oil shale samples will be processed under different operating conditions, (e.g. temperature, grain size, extraction time, stirring, solvent type).
- The solvent mixture will be removed from the extract using the method outlined in the previous method.

# Conclusion

- Due to continuous escalating of crude oil, it is time to start making use of oil shale and shale oil.