Shfela Oil Shale Pilot

Addendum to the Environmental Document

October 2011
Israel is blessed with large amounts of oil shale that, if produced, can ensure Israel’s energy independence. IEI has comprehensive knowledge and practical experience in producing oil from oil shale using subsurface oil extraction (In Situ Conversion Process) technology. This method has only minimal and temporary environmental impact which can be mitigated throughout the lifetime of the project.

As part of the conditions of the license given by the Ministry of Infrastructure, IEI is obligated to perform an experimental oil extraction pilot in order to prove technical feasibility while meeting different milestones, including environmental sustainability and minimal impact. IEI is preparing to conduct the required pilot. The pilot objectives are:

A. Demonstrating the technical feasibility of the In Situ Conversation Process in Israeli oil shale.
B. Measuring the material mass balance and energy balance of the process; determining quality, quantity and composition of the produced liquids and gases and studying rock properties in the subsurface formation.
C. Evaluating the economic feasibility of the process.
D. Demonstrating compliance with the environment requirements during production and process conditions.

In coordination with the Ministry of Environmental Protection and in accordance with its guidelines, prior to the submission for approval for oil drilling to the Regional Committee of Building and Planning, IEI prepared, through Top Environment and Acoustics LTD, a detailed document discussing the environmental aspects of the project, using the appropriate format of environmental impacts. This document examined all of the pilot’s components and environmental issues and recommended ways to ensure minimal environmental impact (Top Environment and Acoustics: R10278-747, June 2010 and Top Acoustics: R10097-747, January 12th, 2010).

Preparation of the document was performed under the guidance and direction of the Ministry of Environmental Protection through meetings and field trips. Chapters A-B of the Environmental Document were submitted to the professional entities in the Environmental Ministry at the beginning of the year (2010). Based on their remarks, the preparation of chapters C-E was completed and submitted to the ministry for review (IEI’s letters 230 and 231, June 9th, 2010), as well as to additional relevant regulatory agencies (Ministry of Health, Ministry of Agriculture, Planning Committee, Matte Yehuda Regional Council, INPA, SPNI, JNF and more).

In meetings presenting the document, experts from the Ministry of Environmental Protection raised questions and requested clarification on several issues. All of the remarks and suggestions were grouped in a letter from the Ministry of Environmental Protection to the chairman of the regional committee in
Because the document is very detailed, we would like to summarize the nature of the planned drilling project (the pilot). The project is limited in scope and duration. An accurate description of the pilot is a scientific experiment of the oil extraction technology under field conditions. The pilot covers 1.9 acres in an agricultural area distant from population and of which only 1.2 acres will be used for the production process. The pilot will not create any hazards that may disturb the nearby residents, animals, and/or vegetation. At the end of the project, the area will be reclaimed to its original state and use. All of the activities performed in the area are well known and are simple in nature. The only component of the pilot that has not been tested in Israel is the underground heating of Israeli oil shale. This process was thoroughly analyzed in the Environmental Document and shown to have very limited impact in space and time.

We have replied to the many questions in details, and in many cases have exceeded the detail level required for an Environmental Document at the current stage of the planning process and before receiving the approval from the appropriate planning institutions. After receiving the Regional Council Committee’s approval, there will be a detailed engineering phase (detailed design), and the company will present it to the Ministry of Environmental Protection. We have responded also to questions regarding the commercial stage project, although it exceeds the scope of the request for information about the pilot’s performance.
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I. General

In order to clarify the topics that will be discussed in this document, we have included a detailed and updated description of the pilot plant.

The total duration of activities in the field is expected to be two and a half years comprised of seven steps (slight time changes may occur depending on the petrophysical characteristics of the rocks in the site):

1. Initial preparation of the site for drilling - 10 days.
2. Preparing and drilling formations up to 300 m - 270 days.
3. Preparing the surface facilities for heating and production - 100 days.
4. Heating and production - 270 days. During this stage, only 500 barrels will be produced.
5. Cooling and production - 120 days. During this stage, monitoring and follow up diagnostics on the natural cooling process will be performed as well as continued hydrocarbon production (until the stage where the production will be negligible).
6. Coring - 60 days.
7. Surface rehabilitation – 10 days.

Figure 1: Illustration of site
Drilling

There will be 17-19 vertical wells. The final number, location and depth of the drillings will be determined by the data obtained at the end of drilling the first well at the site.
The following is the description of the wells:
6 heating wells in a hexagon pattern with 3 meter sides.
2 production wells (primary and secondary) at the center of the heating hexagon.
3-4 observation and monitoring wells within the hexagon.
Up to 4 dewatering wells, to be used if necessary as underground monitoring wells around the production area.
2-3 groundwater monitoring wells at a distance of up to a few tens of meters from the production area that will be placed in accordance with the Hydrogeology Service’s directions.
The pilot is a small-scale experiment to test underground oil shale extraction using electrical heating to slowly heat part of the oil shale layer. The heated layer will be up to 50 m thick (the thickness will be finalized in the detailed design phase) at a depth of 250-300 m. The heating results in pyrolysis (the process of kerogen thermally cracking in the absence of oxygen) of the organic matter in the rock and converts it into light fuels and gas. Liquid pyrolysis products will be produced using pumps, and the gas will be produced at formation pressures up to seven atmospheres.
Figure 4: Cross section of the pilot showing the heated area

(Heat spreads up to 9 meters from the heating elements. Beyond this distance and on the surface, the rock is not affected by the heat and remains at ambient temperature of 25°C).

The produced products will be piped to a facility on site to separate the gas, oil, and water. After temporary storage on site, the oil will be transported for analysis and refinery lab tests. Gas treatment will include a process to remove sulfur, hydrocarbon condensates, and water. The gas products will be piped to a treatment process including an H₂S absorption system and thermal oxidizer. The oxidation products will be emitted through the stack. The collection and piping system located on the surface will start at the wellheads and will lead to the treatment equipment on the site. As opposed to the oil production and refining methods known today, significant upgrading occurs during the slow heating of the ground; therefore, the expected hydrocarbon product is a light high quality fuel, lacking the heavy components normally found in crude oil.
By heating the subsurface volume of the hexagon, within one year, cumulative oil production will be 500 barrels of oil (5 barrels per day at the peak of production) and 42,500 cubic meters of gas. During heating of the ground, the products will be produced through the production wells. Both before and while heating, natural salt water (~7000 mg/l chlorides) will be pumped from the production wells and will be collected in a holding tank before being transported for treatment at an approved site. This fraction of the water constitutes a small part of the water existing in the rock while the rest of the water is held in the pores by capillary forces. As heating starts, the temperature rises to 100°C, turning the water into steam which will then be produced. The steam will be cooled and condensed using heat exchangers and the water will be collected in a holding tank for future transport from the site to an approved treatment facility.

Heating of the subsurface will continue until the average rock temperature reaches about 300°C. The products generated in the subsurface will flow to the production wells primarily in the gas phase. The hydrocarbons that condense during the process will be pumped. The rest of the products that have not condensed will be produced as gases.

The gas will pass a filtration, purification, and oxidation treatment process and will not be stored at the pilot site. The gas will flow to a dry H₂S absorption system (Sulfatreat) that will reduce the H₂S level.
the absorption system, it flows to a thermal oxidizer where it will be completely oxidized. The levels of emissions in the stack will be below the regulatory standards. The liquids from the production well will be cooled in the heat exchangers and transferred to an oil/water separator. The sour and salty water will be stored in holding tanks until it is transferred to an approved treatment facility.

**Figure 6: Thermal oxidizer**

The fuel products (up to 80 cubic meters) will be held in oil tanks until they are transferred to the refinery and lab facilities, in Israel and/or abroad, for chemical analysis and characterization. For a detailed work description of the site and the different project stages, please see chapter C in the Environmental Document- Appendixes 3.2-3.4 (pages 4-27).

**Figure 7: Similar oil shale pilot in Colorado**
II. Q & A's

A. A. Infrastructure: Questions 1-7

1. Detailed plan- there wasn’t any detailed plan describing the locations of the facilities at the site (size, etc.)

![Figure 8: Sketch of the planned site](image)

Location of the different facilities will be organized on the planned site (as shown above). The size of the pad is 5 dunams, and because it is well planned, the space designated for facilities is relatively small. A schematic description of the layout of the site was displayed in Appendix 3.1.1 of the Environmental Document. An estimated detail of the general system characteristics, while noting the large-sized tanks, was displayed in Appendix 3.4.3.3 B of the document. An updated schematic plan is displayed in Figure 8. Please note that there may be changes in the exact placement of the facilities as they appear on the site, but these changes will not affect the environmental impact as tested and displayed in this document and in previous ones.
A detailed engineering design for the pilot will be performed immediately upon receiving the District Council Committee’s approval. In the design plan, there will be specific and final specifications of all of the relevant data- tank volumes, main equipment sizing, heat exchanger transfer areas, diameter and length of pipes, equipment and inspection tools and other planning detailed specifications. The company will present the Ministry with a detailed engineering plan for review.

2. **There are no sketches of additional infrastructure (drainage, electricity, water) and there is no specific place for the transformation station.**

**Sewage**: the pilot site will not have a sewage system. The workers’ restrooms will be mobile. All of the processed water will be transferred to containers and transported to an approved treatment site. The containers will be stationed at the spill containment pallet in case of a leak; the liquids will be transferred to a tanker and transported to an approved treatment facility.

**Electricity**: the power line feeding the pilot is an existing route which is marked in the pilot plan in the figure above. The location suggested for the transformer was added and displayed in the plan (final location will be determined in the future detailed design phase with the electric company).
The water line in the pilot is based on extending an existing water line leading from the agricultural area in the vicinity. This is presented in the sketch.

3. Specifications- lack of detailed specifications of different structures throughout the process (such product treatment center, thermal oxidizer).

All of the treatment facilities that will be located on site have standard specification details that are widely used in Israel and worldwide. Water/oil separation facilities, heat exchangers, piping, and pumping and storage systems will go through a detailed engineering and planning phase after receiving the District Committee’s approval. The detailed planning will include equipment specifications which will be available for review and audit throughout the planning phase by all authorization entities.

The main equipment with long lead times with high environmental importance has already been engineered, and the required specifications have been sent to potential vendors. This equipment includes units to remove the H₂S from the gas flow (Sulfatreat) and the thermal oxidizer. Specifications for the purchasing of this equipment include initial gas flow data (peak flow and gas composition) and the requirements for the components of gas emissions. The following sketches illustrate a schematic description of the hydrogen sulfide treatment unit, thermal oxidizer and the calculation used for preparing the specifications:

![Diagram of hydrogen sulfide treatment facility]

*Figure 10: Hydrogen sulfide treatment facility*
1. Calculation of weight concentration \( \text{H}_2\text{S} \) into gas flow

Weight conc kg/m\(^3\) \( W = V_{\text{H}_2\text{S}} \times \text{MW}_{\text{H}_2\text{S}} / 22.4 \)

\( V_{\text{H}_2\text{S}} \)-mol fraction of \( \text{H}_2\text{S} \) in gas = 0.138 (see Tab 1)

\( \text{MW}_{\text{H}_2\text{S}} \)-molecular weight of \( \text{H}_2\text{S} = 34.08 \)

22.4 m\(^3\) volume of one kg-mol

\[ W = 0.23 \text{ kg H}_2\text{S} \text{ per 1 Nm}^3 \text{ of gas} \]

2. Calculation of \( \text{H}_2\text{S} \) mass balance into gas flow (PIPE1)

Peak flow of gas \( PL \) see graph 2

Mass peak load of \( \text{H}_2\text{S} \) kg/hr (\( MPL \))

Cumulative gas flow (CGF) Nm\(^3\) see graph 1

Cumulative \( \text{H}_2\text{S} \) mass flow \( M_{\text{H}_2\text{S}} \)

\[ PL = 20 \text{ Nm}^3/\text{hr} \]

\[ MPL = W_{\text{H}_2\text{S}} \]

\[ WPL = 5 \text{ kg/hr} \]

\[ CGF = 43000 \text{ Nm}^3 \]

\[ M_{\text{H}_2\text{S}} = W_{\text{H}_2\text{S}} \times CGF \]

\[ M_{\text{H}_2\text{S}} = 9813 \text{ kg} \]

3. Material balance of sulphur treater

Peak flow of gas \( PL \) see graph 2

Mass peak load of \( \text{H}_2\text{S} \) kg/hr (\( MPL \))

Cumulative \( \text{H}_2\text{S} \) mass flow \( M_{\text{H}_2\text{S}} \)

Allowable quantity of \( \text{H}_2\text{S} \) coming to oxidizer \( e = a \times d/c \)

Duration of gas production \( T \)

\[ T = 270 \text{ day} = 6480 \text{ hr} \]

\[ R = 4824 \text{ kg} \]

4. Calculation of the minimum required sulphur treater capacity

Required sulfur removal capacity of Sulphur Treat \( R = M_{\text{H}_2\text{S}} \times e \times T \)

\[ R = 4824 \text{ kg} \]

NOTE: Minimum weight of Sulfatreat 410HP material at 25% loading (FW)

\[ FW = 19294 \text{ kg} \]

(a) Allowable quantity of \( \text{SO}_2 \) pollutants in the flue gas 1.8 kg/hr
(b) Molecular weight of \( \text{SO}_2 \) 64.06
(c) Molecular weight of \( \text{SO}_3 \) 80.06
(d) Molecular weight of \( \text{H}_2\text{S} \) 34.08
(e) Allowable quantity of \( \text{H}_2\text{S} \) coming to oxidizer

Case #1: \( \text{H}_2\text{S} + 1.5 \text{O}_2 + \text{H}_2\text{O} = \text{SO}_3 \)

Allowable quantity of \( \text{H}_2\text{S} \) coming to oxidizer \( e = a \times M_b \) 0.96 kg/hr

Case #2: \( \text{H}_2\text{S} + 2 \text{O}_2 = \text{H}_2\text{O} + \text{SO}_2 \)

Allowable quantity of \( \text{H}_2\text{S} \) coming to oxidizer \( e = a \times M_c \) 0.77 kg/hr

Oxidation of \( \text{H}_2\text{S} \) to \( \text{SO}_3 \) is possible only when the catalyzer and special conditions are available, similar to sulphuric acid units production.

This way the allowable amounts that go into the oxidizer in the worst case are 0.77 kg/hr.

In the technical requirements for design and supply of the sulphatreat. The given value is 0.77 kg/hr.

Figure 11: Thermal oxidizer performance
The stack gas quality requirements were defined to meet the standard of quality and stack emissions according to TA LUFT 2002 regulations during extreme overload pollutants situations (as displayed in table 2, answer to question 10).

4. Water and soil monitoring- some clarifications should be made regarding the ruling factor and the analysis that should be performed. Who gets the data over time?

A. Groundwater monitoring – the monitoring plan will be finalized and performed in full cooperation with the Water Authority and in accordance with their guidelines. In addition to the Water Authority, all of the data will be submitted for review by the Ministries of Infrastructure, The Ministry of Environment Protection, and the Ministry of Health.

B. Surface run-off monitoring- this will be performed according to the Ministry of Environment Protection regulations and will be transferred for review at the Ministry of Infrastructure, Drainage Authority, Water Authority, and the Ministry of Health.

C. Soil monitoring (surface) – this will be performed according to the regulations of the Ministry of Environment Protection and labs that will be selected by them. All of the data will be transferred to relevant authorities as required.

D. Underground monitoring- see answer at clause 29 below.

5. Products treatment- presenting a document of approval by the refinery regarding products treatment: water and fuel different products.

A. Fuel products- the total amount of the oil products in the pilot is estimated at 500 barrels (80 m³) for the whole production period. The oil products will be stored in designated tanks and will be transferred for lab analysis and refinery tests in Israel or abroad. Choosing the appropriate refinery will depend on the lab’s capability to analyze the products’ properties. The decision will be made during the pilot’s detailed design and construction and before its operation. When this commercial issue is finalized, we will update the licensing authorities appropriately.

B. Produced gases- produced simultaneously with the oil products. The produced gas will be fully oxidized and will be emitted at the pilot’s stack while meeting the authorized emissions level.

C. Water- (from dewatering wells, heating wells and production wells)- all of the water products will be concentrated in designated containers and treated at an approved off site treatment facility.

6. Water pollution- no official opinion of Water Authority was expressed regarding the procedures and means to prevent hazardous.

As required for any water drilling in Israel, the pilot’s drillings will have to be approved by the Water Authority drilling committee working under the water law. This committee is managed by the Water Authority and participants from the Ministry of Environment Protection, Ministry of Health, NPA,
Geological Institute and additional authorities. The approval of the drilling committee is valid only with a signature from the head of the Water Authority approving the committee.

7. Upscale of the pilot- it is not clear what the correlation to the environmental influences is during the mass production. For example, are gas emissions rate at this stage of the pilot a proper index to the emission rate at the commercial stage?

The composition and volume of the gases and liquids produced from the defined oil shale unit after pyrolysis in the pilot is very similar to the commercial project’s products. This is also true regarding concentrations, rates, and types of organic compounds that will be produced.

The geological similarity between the production layer in the pilot to other oil shale units located in the licensing area, including the future commercial facility, ensure a high level of similarity between the pilot and the production process with respect to the quantities of the products and their compositions.

The pilot is a small scale experiment, under field conditions, and as such it is focused on implementing the technology under the local geological conditions. Future development of the project will depend upon the pilot’s results but also on a variety of findings that will be learned during its operation. The learning process in this project is gradual from start to the commercial stage and will include several steps: geologic study, lab simulations, small field experiment, small commercial production, and only eventually- large commercial production. The pilot is the most important part of the whole scientific learning process. It is only one piece of the development chain, and its purpose is to widen the knowledge base available to us. The knowledge base includes the learnings from the pilot, geological appraisal wells in the licensed area, theoretical research and numerical models, lab tests performed in Israel and the USA, and hydrology and geochemical tests in the field and lab, etc.

Planning and execution of each stage in the development process will be based on previously collected data. The next stage, after the pilot and before the commercial stage, will be planning, licensing, and construction of a demonstration facility that will produce 2000-5000 barrels a day which will provide the relevant parameters for scaling up. This facility is planned to operate for a relatively long period of time before continuing to the next phase.

The findings received so far in the survey drilling, based on analysis performed in Ben Gurion University (in the geochemical and geomechanical labs of the Geology and Environment Science department), were used as a basis for the pilot planning. The combination of data and the geological research as a whole will allow for quantitative understanding of the process and for planning of the next steps.
Figure 12: IEI’s LECO device to measure organic matter and sulfur in the rock at the department of Geology and Environment, BGU in the Negev.

The combination of the accumulated knowledge from the survey wells, the pilot, and deep understanding of the hydrogeological system will answer the questions of the commercial production process’s impact on water in the subsurface.

The production process in the pilot and in the demo facilities is similar. The recovery efficiency of oil in the pilot should be similar to the recovery efficiency in commercial production. In reference to this, we would like to mention that the American tests showed that theoretical calculations, based on lab data, were able to closely simulate the production data of the pilots and demos, a result that strengthens the relation between the dynamic processes of in-situ heating on different scales.

The main technological difference between the pilot and the next phases will be the use of horizontal wells. Using horizontal wells is a common and accepted practice in the oil and gas industry. The wide experience in using this technique is the basis for concluding that results from the pilot data can be extrapolated to future projects of larger scale.

The produced water in the pilot will be treated by a third party, but the pilot’s data will be used for planning full treatment facilities for all liquid flows (salt and sour) for the future projects.

Measuring the gas emissions in the pilot will provide a base for calculating the emissions in the commercial stage and, therefore, will be the basis for the engineering planning. There are a few
aspects that are different between the pilot and the future development stages. In the pilot, all produced gases will go through the oxidizer because the gas quantities are too small to use efficiently. In the commercial stage, the gases will be produced at sufficient quantities to be utilized. Therefore, gas treatment on the commercial stage will be different than during the pilot. In the pilot, the H2S treatment will include a permanent absorption system containing iron oxide (Fe\textsubscript{2}O\textsubscript{3}) that reacts with the H\textsubscript{2}S in order to create a solid phase iron sulfur compound (pyrite). In the future steps of the project, we will use more efficient methods to process sulfur, such as LO-CAT technology or Claus processing (oxidizing the H\textsubscript{2}S) to create elemental sulfur. The Claus process is superior to the absorption system, but the large size and high cost of the claus plant makes it economical only during the commercial stage.

B. B. Air: questions 8-16

8. Greenhouse emissions- calculations of greenhouse emissions should be detailed (not only CO\textsubscript{2}) to a certain amount of produced oil shale (rule of thumb: X-oil shale expect-Y methane emissions, Z Cos emissions). A meeting should be scheduled with Dr. Siman Tov, district air pollution coordinator.

Below you will find explanations and calculation detailing the greenhouse gas emissions from the chimney during the pilot relative to the oil shale produced.

The expected gas composition, based on the data gathered during pilots performed in Colorado, is listed in Table 1 below in volume percentage (%VOL). Sulfur concentration is based on the Israeli oil shale kerogen. The table below is an update to the information presented in table 3.4.2 on page 18 of the Environmental Document based on the updated data from the survey wells (as received after the completion of the environmental document).

<table>
<thead>
<tr>
<th>Gas</th>
<th>Volume %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>24</td>
</tr>
<tr>
<td>Methane</td>
<td>32</td>
</tr>
<tr>
<td>Ethane</td>
<td>8</td>
</tr>
<tr>
<td>Propane</td>
<td>6</td>
</tr>
<tr>
<td>Butane</td>
<td>5</td>
</tr>
<tr>
<td>H\textsubscript{2}S</td>
<td>15</td>
</tr>
<tr>
<td>CO\textsubscript{x}</td>
<td>4</td>
</tr>
</tbody>
</table>
Gas production is illustrated in the graph below (based on a 2:1 oil: gas production ratio)

![Graph showing cumulative gas volume vs Days M3 2010](image)

**Figure 13: Expected cumulative gas production**

According to updated calculations there will be 42,500 cubic meters of total gas produced. All of the produced gas in the pilot will be transferred to the thermal oxidizer such that all of the organic components (except hydrogen and H$_2$S) will oxidize into CO$_2$ and water. In volumetric terms, 50,000 cubic meters of CO$_2$ will be emitted to the environment during the pilot. Total methane emission after the thermal oxidizer (99.9% oxidation efficiency) will be 13.6 cubic meters.

9. Calculations- based on the existing data in the Environmental Document, the SO$_2$ calculating is: assuming that the SO$_2$ rate will be 1.8 kg/hr. and the oxidation’s facility adsorption will be 425 m$^3$/hr. The emitted nitrogen oxide concentration is 4000 mg/ m$^3$ (this data does not match the data presented to us on the meeting with IEI on July 11, 2010).

We assume that your question refers to the sulfur oxide emissions and not nitrogen oxide emissions. As for the calculations and the data, we agree that an emission rate of 1.8 kg/hr and a rate of flow of 425 m$^3$/hr give an estimated 4000 mg/ m$^3$ concentration.

$$\text{Rate (kg/hr)} / \text{Rate (m}^3\text{/hr}) = \text{Concentration (mg/m}^3\text{)}$$

The reason for the data mismatch relates to the fact that Dr. Vinegar used different units when presenting the calculations to you – micrograms and not milligrams.

The detailed calculations displayed at answer num. 3 matches the TA-LUFT 2002 regulation as disclosed in paragraph 10 below.
10. The stack pollution concentration rate was not disclosed; including dispersion calculations, the height of the planned stack was not mentioned as well, since according to the height, dispersion calculations were made. As explained in the Environmental Document in Appendixes 3.4.3.3 C- table 3.4.5 (page 24) and 4.3.2.1 (page 45), the emissions from the thermal oxidizer will not exceed the allowed amounts in TA-LUFT 2002 as displayed in the table below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Max. Allowed Amounts (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2S</td>
<td>0.015</td>
</tr>
<tr>
<td>NH3</td>
<td>0.015</td>
</tr>
<tr>
<td>VOC</td>
<td>0.50</td>
</tr>
<tr>
<td>SOx</td>
<td>1.8</td>
</tr>
<tr>
<td>NOx</td>
<td>1.8</td>
</tr>
<tr>
<td>Particulates</td>
<td>0.20</td>
</tr>
<tr>
<td>Radon</td>
<td>-</td>
</tr>
</tbody>
</table>

The stack diameter and height of the thermal oxidizer will be calculated during the detailed engineering phase in accordance with the air quality standards required in the pilot. A detailed emissions calculation and air pollution prediction model were displayed in the Environmental Document in Appendixes 4.3.2.2 and 4.3.2.3 (pages 46-50). Lacking a detailed plan of the stack emissions, an explanation was given regarding the assumption that the stack will be 10 meters above the surface. As for the stack’s inner diameter, two possible values were taken, 0.15 meters and 0.3 meters, and for gas rates, two possible values of 0.12 m³/sec. and 0.24 m³/sec. The maximum amounts allowed and displayed in the table were used in the calculations of the dispersion data from the stack.

11. Emission of different pollutions to the air

A. We never received detailed data of oil shale chemical composition.

The oil shale rock composition is displayed below in the answer to question 17. The kerogen stored in the oil shale is a 3- dimensionally crossliked hydrocarbon structure with carbon chains that range between C25-C100 including sulfur derivatives, mainly thiophene, with total sulfur content of 1.5% (rock weight) and about 0.5% pyrite. During pyrolysis the kerogen converts to liquid products, gas, and coke. The liquid products include hydrocarbon chains with carbon number up to C25 (see Figure 14). The produced fluids have carbons chains up to C25 and gaseous products such as hydrogen and H2S.
Figure 14: Carbon number distribution of liquids produced with IN-SITU processing

The composition and liquid characteristics are shown below in table 3. This table is presented in addition to table 3.4.3 on page 18 and 3.4.4 on page 19 of the Environmental Document:

**Table 3: Composition and characteristics of the expected liquid products**

<table>
<thead>
<tr>
<th>Properties of crude oil</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity (@ 60F)</td>
<td>0.85</td>
</tr>
<tr>
<td>API Gravity</td>
<td>35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elements, wt %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>80</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>12</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.5</td>
</tr>
<tr>
<td>Sulfur</td>
<td>6.5</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compounds, vol %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffins</td>
<td>40</td>
</tr>
<tr>
<td>Naphthenes</td>
<td>29</td>
</tr>
<tr>
<td>Other Aromatics</td>
<td>30</td>
</tr>
</tbody>
</table>
The residual organic matter remains in the subsurface as coke (charcoal like material). This process sequesters carbon in the subsurface while other crude oil refining techniques require upgrading systems such as FCC (fluid catalytic cracking) that enlarges the environmental impact during the production of refined products.

B. testing volatile organics and metals is not enough as described below:
Compared to the volatile organics –there are many materials with lower emission standards than the rest (volatile organics from group 1 and 2, inorganic gases, carcinogens). If these materials will be detected in full scan, what steps will the company take to prevent emissions over the relevant standard?
As described in the Environmental Document Appendixes 3.5.2 (pages 29-31), 4.3.2.4 (pages 50-53) and emphasized in table 4.3.5 in page 52, the monitoring and control mechanism is comprehensive and includes a number of elements. Its purpose is to cover the widest range of potential pollutants. During the pilot’s operation we will perform GC/MS analysis sampling of the stack emissions. All of the detected compositions will be compared to the TA LUFT 2002 standards, including volatile organic material from groups 1 and 2, inorganic gases, and carcinogen gases.

Because of the gas composition (as displayed in Table 1), we do not expect any aromatic compounds including carcinogens in the gas phase as a result of the oxidizing process. If products of incomplete combustion (PIC) are detected in the stack we will adjust the operating parameters in the thermal oxidizer to ensure full oxidation (extending the time in the oxidation cell, warming up the temperature in the oxidizer or adding oxygen encouraging compounds according to the manufacturer’s specifications).

C. metal- if metal particles will be found at low rates during metal scanning for particles, what steps will the company takes?
As explained in the Environmental Document, paragraph 3.4.3.3 C (page 22), the gas that flows from the production well will initially go through a mechanical filter and then through two layers of absorbing media in the Sulfatreat equipment. These layers are 10 meters thick, and the flow rate of the gas in them is extremely low in order to ensure that no solid particles will reach the thermal oxidizer. Nevertheless, if metal particles will appear at the stack over the allowed concentrations, we will adjust the filtering system accordingly. For example, if the mechanical filter does not work properly, we will use the backup filter that is attached, or we will change the filters type to match the emitted materials and their particle size.
12. Emission monitoring- the specification of the monitoring plan includes monitoring locations in every drilling and selected places on the surface, including the emission sampling in the first 150 days, as the heating starts.

As a supplement to the information presented in the chapter discussing monitoring in the pilot (Appendix 4.3.2.4 (pages 50-53) in the Environmental Document), below are details of the proposed monitoring plan for the pilot and their rationale.

Monitoring will be performed as the pilot is energized and will continue throughout the entire duration of the pilot until the site is reclaimed. For data collection and follow-up monitoring, we will use the PI system (Figure 15) configured to our pilot’s needs and requirements.

![Figure 15: Simplified monitoring and gas emission plan](image)

It is important to note that the plan will include the following elements:

A. Stack monitoring of NOx’s, SOx’s. The data will be collected and presented by the PI system and will be available to the Ministry of Environment Protection.

B. Monthly samplings of the stack emission by a licensed and well-known third party. The data will be transferred to the Ministry of Environment Protection.

C. Monitoring: using gas monitoring tubes at chosen sampling sites in the pilot area. The monitoring will be performed around every one of the wells, gas, and products treatment systems, around storage tanks, and around the outer fence of the site. The measurement will
be performed weekly by an IEI team member. The data will be registered and will be available at all times to the Ministry of Environment Protection.

D. Daily manual measuring of hydrocarbon concentration (%LEL) and hydrogen sulfide in the site presented at paragraph C.

E. An array of shallow holes to sample the soil in the pilot area.

The environmental monitoring plan is currently in the preparation phase and will be coordinated with the Ministry of Environmental Protection before entering the pilot site. Monitoring reports will be transferred periodically to the Ministry of Environment Protection according to a procedure that will be coordinated in advance.

13. Location of the continuous monitoring sites- environmental monitoring has to be performed in the site’s circumference and not inside the site, as mentioned in paragraph 4.3.2.4, to allow comparison to the environmental concentration.

Location of the environmental monitoring sites will be corrected and performed according to the MOE guidance.

14. Non-focal gas emissions- if non-focal emissions will be found near the pilot, what are the means available to respond to such incident? Is there an additional solution to stopping the heat and waiting for the ground to cool? A plan should be submitted in case such emission does occur.

The non-focal gas emission was studied quantitively by the Idaho National Laboratory for an oil shale production project in Colorado. (1)Wood, T. R. et al “A First Order Evaluation of Atmospheric Emissions from a Hypothetical In-Situ Oil Shale Retort”, Oil Shale Symposium, Colorado School of Mines, Golden, October 2009. The research showed that even if high estimates are assumed for effective diffusion coefficients, diffusion through cracks (100 times the accepted value in the literature), and passing through a 210 meters overburden layer (smaller thickness than the pilot area), gas concentrations, even after 300,000 years, are low and do not reach the authorized amount.

The diffusion coefficient in the G’hareb Formation (as measured by IEI) is 10,000 smaller (Figure 18) than the values used in the above-mentioned research simulations. Regarding this matter, the Hydrology Institute expert- Dr. Israel Gev, and Geological expert- Dr. Moshe Shirav, while replying to the joint committee in the matter of environment and health questions, (led by Dov Hanin, dated July 12th, 2010), argued that there is no possibility for non-focal emissions for the typical geological conditions of the area.

At the Shfela basin there are several geological units blocking gas moving from the production area upwards: the Gh’areb Formation, above the heated area, has a very low hydraulic conductivity (~0.1...
mD) and it is saturated with saline water. In order for gases to penetrate the saturated pores in the rock, the gas pressure must exceed the rock’s pore pressure (the hydrostatic pressure and the capillary entry pressure). For the pore size of these rocks and the large depth of the pilot, the gas pressure has to be higher than hundreds of PSI. That is why gas cannot “escape” the heated volume of the pilot through the rocks that surround it.

Above the Gh’areb Formation lays the Taqyie Formation, which is a tight marl clay and is 150-200 meters thick. This unit is even more impenetrable than the Gh’areb Formation and is not penetrable by gas or liquid. This can be demonstrated at the Ramat Hovav area where pollutant water penetration through the Eocene chalk layer above results in water flow on top of the Taqyie Formation (without penetration) towards the nearby stream. This phenomenon demonstrates the sealing efficiency of the Taqyie Formation.

For reassurance, during and after heating, IEI will perform ground gas monitoring as described in paragraph 12 to demonstrate that there are no non-focal emissions.

Although we are certain that there is no need for concern, and there will not be any emissions of such kind, with reference to your question, “in case that emission will be discovered”, IEI will perform the following:

A. Stop the heating at all heaters. At every step of the pilot, the time that it takes from stopping the heaters to a complete stop of hydrocarbons production is a maximum of five days.

B. Sending the gas pressure in the subsurface by opening the gas valve at the production wellheads.

C. Sending the produced gas to a gas treatment system on the surface.

These actions will rapidly reduce the underground pressure in the heated volume, and the potential non-focal emissions, if any, will be stopped.

15. Gas treatment- the layer below the oil shale layer is apparently water- resistant, is it sealed for gas passing downwards as well?

There are several reasons why gas will not flow downwards:

A. Gas flows upwards, not downwards, since the gas density is lower than 0.004 g/ml and the brine density is over 1.00 g/ml. Therefore, the gas will float in a saline-saturated environment.

B. Geologically, there is a series of non-penetrable rock layers located below the heating area. The first is the G’hareb Formation and the upper part of the Mishash Formation (100 meters thick), which is a chalk layer with a permeability of 0.1 mD (extremely low permeability). Below that is a massive chert layer which is 10 meters thick and does not contain any water or porosity. This layer is non-penetrable to liquid or gas. Below it lays the Menucha Formation, which is a chalky, non-permeable layer with a number of marl inclusions that
minimizes its penetration ability. The thickness of this layer ranges between 130-180 meters. All of these layers are impermeable and very thick.

C. The impermeable geological layers described above are water saturated. Since the static water level is 170 meters deep (about 200 m above the heated area), for gas to penetrate into the rock, the gas pressure must exceed the pore entry pressure. For the pores size in the formation rocks and at the great depth of the pilot, the gas pressure has to be higher than hundreds of psi. These pressures are much higher than the pressures of the pilot’s area (100 psi). Therefore, gases will not flow downwards from the heated area to the Judea Aquifer.

In addition, to support the above findings, the Department of Geology and Environmental Science at the Ben Gurion University is performing laboratory permeability tests of the layer below the oil shale layer. The testing is performed on all of the cores from the 3 drilling sites that the company completed and will be done on future samples that will be extracted in the remainder appraisal wells. When the test results are received, we will update the relevant regulatory authorities with the information.

16. The wind regime - what is the exact wind regime of the pilot area? Wind directions data at the risks survey in the pilot (page 25) is different than the data that appears in the body of the document. Which raises the question of how trustable is the risks analysis testing the gas dispersion from the pilot area to different distances in the area.

According to the hazard survey (Appendix 1 in the Environmental Document), three scenarios coordinated with the Ministry of Environment Protection were tested:

A. Poisonous gas leak emitted from the piping to the absorption facilities, thus scattering poisonous gas in the wind’s direction.

B. Leak of poisonous gas from piping between the production well and the absorption unit creating a fire of the gas cloud.

C. Theoretical fire at the fuel tanks.

It was found that wind speed has an influence only in the first scenario. With that, given extreme environment conditions, the range for dangerous conditions are very short and are restricted to the facility borders. There is no risk for the population living and/or working nearby because of the large distances from the site. For the two other scenarios, a thermal flow was tested and found that it is not influenced by wind direction at all and that the influence range is very small and does not exceed the site’s borders. There was a mistake presenting the wind direction in the survey document, but as mentioned before, that does not change our conclusion that with risk analysis, it is still meaningless.

The most common winds in the area based on the Nativ Ha L”H station and based on the Climate Atlas of Physical and Environmental planning in Israel, are west-south-west.
C. Soil: Questions 17-30

17. The soil composition- what is the oil shale composition? What are the materials before pyrolysis and after?

Table 4: The mineralogy (weight percentage from dry rock) of Ghareb Formation initially and after the planned heating in the subsurface.

<table>
<thead>
<tr>
<th>Postheating Wt%</th>
<th>preheating Wt%</th>
<th>Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>55-75%</td>
<td>50-70%</td>
<td>Calcite</td>
</tr>
<tr>
<td>10-20%</td>
<td>10-20%</td>
<td>Silica</td>
</tr>
<tr>
<td>10%</td>
<td>10%</td>
<td>Apatite</td>
</tr>
<tr>
<td>5%</td>
<td>5%</td>
<td>Illite (clay)</td>
</tr>
<tr>
<td>0</td>
<td>0.5%</td>
<td>Pyrite</td>
</tr>
<tr>
<td>0</td>
<td>10-15%</td>
<td>Kerogen</td>
</tr>
<tr>
<td>3-5%</td>
<td>0</td>
<td>Coke</td>
</tr>
</tbody>
</table>

In addition, a saturated oil shale sample has 20% (wt) water. There will not be an influence on the stability of the main rock minerals since they change their characteristics at a much higher temperature than where pyrolysis of the organic material occurs (325°C). During the process, the clay is expected to lose adsorbed water, the pyrite will decompose to pyrrhotite and the kerogen will release hydrocarbon liquids and gases. The byproduct of the pyrolysis process will be solid carbonaceous material such as coke. In addition, all of the water in the rock pores will be produced and the rock porosity will increase about 10 VOL %. These changes will be tested after the pilot by coring the subsurface oil shale that underwent pyrolysis. In fact, this analysis is one of the objectives of the pilot.

18. The influence on the kerogen material- what happens to the kerogen material close to the heaters, what if it will reach 600°C (chemical process and their products wise)?

The pyrolysis process starts at about 300°C. The chemical processes occurring in the temperature ranges between 300-600°C are similar; therefore, no difference is expected in the area in the vicinity of the heaters compared with the rest of the heated zone. The charcoal - like material (coke) that is left at the end of the pyrolysis process will be warmed to 600°C, but no change will occur.

The heaters working at 600°C transfer the energy to the wellbore, thereby heating the rocks at the borehole to 550°C. The heat diffuses outwards from the well and through the rock by thermal...
conduction while the temperature drops logarithmically outwards from the well. The temperature of the wellbore is high enough to convert the kerogen to coke with a hydrogen- to -carbon ratio of about CH₆₆. The main minerals of the rock are stable in the wellbore at these temperatures, and the organic composition will not be substantially different than its initial composition except for the carbon to hydrogen ratio.

19. Heating the ground outside of the hexagon- what temperature will the soil reach at the area surrounding the hexagon?

Figure 16 displays the temperature drop profiles of the heating volume along an axis intersecting two heaters. The heaters are displayed on both sides of the -0 axis (“horns”). At the distance of 9 meters from the heating source, the rock will remain at its initial temperature throughout the heating period.

![Figure 16: Temperature profile of the heating volume along an axis intersecting two heaters](image)

Heat conductivity in the subsurface was listed in Appendix 3.4.2 (pages 14-16) and in Appendix 4.2.4.7 (pages 40-41) of the Environmental Document. It emphasized that the rock heat conductivity is very low, resulting in an expected thermal gradient that is very steep (fast temperature decline). Therefore, it was explained that outside the heated hexagon, the temperature drops rapidly in all directions as displayed in the above graph.
Figure 17 illustrates a simulation of the heated hexagon as heat spreads at different times. The temperature inside the hexagon is high because of the superposition of the heat conducted from the six heaters. Due to the low heat conductivity the rocks, the temperature from this heating volume will drop fast and will completely fade away at a distance of 9 meters from the hexagon’s borders.

![Simulation of temperature change over time in the hexagon](image)

*Figure 17: Demonstration of temperature change over time in the hexagon*

(Every color demonstrates a change of 50°C, pyrolysis temperature is yellow color)

20. Oil shale report findings- it has come to our attention that Dr. Avihu Burg’s report examining the oil shale matter will be completed in the near future. We ask to receive the report’s findings.

Dr. Burg’s report was published and distributed for your review in parallel with this document. As a whole, the document shows that the hydraulic conductivity of the oil shale layer is very low. Please see figure 18 below taken from the report.
21. **Lateral Convection - what is the possibility for gas penetration above and under lateral convection in the Gh’arab Formation?**

Please see above further details in questions 14 and 15.

Geologically, there are a series of impenetrable rocks located below the heated zone. The first one is the Gh’arab Formation, below it is the Mishash Formation (100 meters thick), with 0.1 mD permeability chalk layers (very low permeability). Below is 10 meters of massive chert that does not contain any water or pores. This layer is non-permeable to liquids or gas. Below the chert, lies the Menucha Formation, which is also a chalky low permeability layer, with several marl horizons, reducing its permeability even more. The thickness of the layers in the basin ranges between 130-180 meters.

These very low permeability geological layers are water-saturated since the static water level is 170 meters deep (about 150 meters above the heated area). In order for gas to penetrate the saturated pores of the rock, the gas pressure has to exceed the capillary entry pressure in the rock pores. For the size of the pores in these formation rocks and at the large depth of the heated area, the gas pressure has to be higher than hundreds of psi. These pressures are much higher than the pressure that the heated area will experience (100 psi). Therefore gas cannot flow out from the pilot’s volume.

22. **Cracking - no response was given that rejects existing cracking in the geological formations; also, won’t the drilling cause preferred convection routes for gas?**

A detailed response, supported with data from the pilot, will be given only after the company will get the permit to drill at the site. The hydrological tests of the three survey wells in our license area,
testing 100 m open section of water producers in Gh’areb Formation, showed very low hydraulic conductivity ranging $10^{10} - 10^{11}$ m a minute and an effective permeability of 0.1 mD. This fact shows that the natural cracks in the Ghareb layer are closed or are very tiny. Any open cracks in the unit would be few and their influence minimal.

During the pilot, gas pressures in the heated volume will be kept at ~ 100 psi which are low compared to the existing hydrostatic pressure (~275 psi). Therefore, even if there are open cracks or cracks that will appear, the brine will flow towards the heated area and towards the production wells. Gas will not flow outwards.

With respect to the wells, all of the pilot’s wells will be cased and cemented throughout the overburden, including the Eocene chalk unit, marl, Taqiya Formation, and the upper part of the Gh’areb Formation (total depth of 200 meters at least). The cement layer is completely sealed to the low pressures that will be in the pilot. Cement quality tests will be performed using cement bond logs before and after the pilot.

Two plugs will be installed at the bottom of the well casing, preventing any gas leaks. This procedure of drilling completion is acceptable at all operating oil and gas wells in the world, even when pressures are much higher.
23. Quantification Material Model (page 40) – how does the calculation performed in regards to the expected material on the surface and was it proved? What are the expected faults in the model?

The pilot will have a calculation of the expected liquid and gases which are expected to be produced from the subsurface as a result of the heating procedure. The results of the calculation will be compared to the actual planned amount to be produced. Thus, it will be assumed that all of the liquid and gas material will be removed from the subsurface.
Numerical simulation, which will be used for this purpose, is the same simulator used in the Mahogany Demonstration Project (South) in Colorado. The calculation is performed by STARS, a commercial reservoir simulation program developed by CMG in Calgary, Canada. STARS calculates non-isothermal conditions with multiple phases and multiple components. Many oil and gas companies around the world use the STARS program for reservoir engineering.

The main parameters influencing the STARS numerical simulations are: petrophysical data, such as rock thermal conductivity, porosity, permeability, water saturation percentages, gas and oil in the rock and geochemical data such as kerogen concentration, pyrolysis temperature and the kinetic reactions. Based on reliable data, the error using this calculation model should not exceed 2%.

The petrophysical data was measured by Shell Petrophysical Services Laboratory in Houston and tested original rock samples from the pilot area in Colorado. Analogous results were obtained in rock samples taken in the Shefela basin area by IEI.

The geochemical data was measured with the analysis of oil shale samples from Colorado and Jordan by Shell Unconventional Resources in Houston by special pyrolysis cells. IEI is using similar pyrolysis cells located at the Geology and Environment Department, Ben Gurion University for testing of the oil shale from Israel. As expected, the geochemical data of oil shale in Israel show a large similarity to the data from oil shale from Jordan.
The graph illustrated in figure 21 presents the predicted results at the Colorado pilot compared to the field data. This graph shows the reliability level and quality of the simulation that was made before the Colorado test and its exact match with the actual results.

IEI’s scientists have a large amount of laboratory and field experience on performing numerical simulations and field pilots. Because of this, the company is confident of its estimates regarding the expected subsurface conditions while heating even for the different field conditions in the Shfela area. One of the pilot’s goals is to prove this argument and justify its use in similar simulations to the next phases of the project.

Figure 21: Colorado’s pilot result graph with preliminary simulation
(Dots on the graph present measurements in the field and the line presents preliminary simulation)

24. Heat dispersing- the heated layer’s width is about 50 meters. What distance from the heaters are the heat expected to reach? (upwards/downwards).

On this matter please see below, in addition to the answer to question 19.

The initial data for heat diffusion from the pilot is the pilot’s temperature at the end of the heating process. The data for heat transfer in the rock are taken from the data from the Colorado pilot. Thus, for low heat conductivity, the temperature decreases rapidly away from the pilot volume. Figure 22 below shows that even after 300 days of heating, the temperature 9 meters from the heating source remains at 25°C.
Figure 22: Heat diffusion from the pilot

The graph in figure 23 below demonstrates the temperature change on the surface, and it is clear that the pilot has no influence on the surface. Temperatures will rise by 0.001 °C only 175,000 days after the heating (480 years).

Figure 23: Temperature change on the surface
25. Change in the volume of the soil as seen in Colorado there should be a reference regarding the soil’s volume change phenomenon is there a chance that the growth of the soil will affect directly the soil pores?

This fear has no base; the calculations below show the changes in the rock volume upwards and downwards as a result of heating and the expected subsidence on the surface because of material loss in the pilot. These two calculations show minor changes on the surface: (1.18x10^-7 cm).

3. B. Earth’s surface’s thermo-elastic deformation as a result of pilot’s heating

In this case we use the same computational area as in the previous section. We use the well-known equations for elastic deformations, which in our case of a 2-dimensional vertically directed area are:

\[
\frac{E}{2(1+\sigma)} \left( \frac{\partial^2 U_x}{\partial x^2} + \frac{\partial^2 U_z}{\partial z^2} \right) + \frac{E}{2(1+\sigma)(1-2\sigma)} \left( \frac{\partial^2 U_x}{\partial x \partial z} + \frac{\partial^2 U_z}{\partial z \partial x} \right) = -\frac{E}{3(1-2\sigma)} \frac{\partial T}{\partial x} = 0
\]

\[
\frac{E}{2(1+\sigma)} \left( \frac{\partial^2 U_x}{\partial x^2} + \frac{\partial^2 U_z}{\partial z^2} \right) + \frac{E}{2(1+\sigma)(1-2\sigma)} \left( \frac{\partial^2 U_x}{\partial x \partial z} + \frac{\partial^2 U_z}{\partial z \partial x} \right) = 0
\]

- where \( U_1 \) is the deformation vector, \( E \) is Young modulus, \( \sigma \) is the Poisson coefficient and \( \alpha \) is the coefficient of thermal volume expansion.

(L. Landau, E. Lifshitz, Course of Theoretical Physics, Theory of Elasticity. Vol. 7, p.)

We use all the assumptions about the temperature distribution the same as in previous section, as well as the same grid.

These equations are solved numerically by Richardson-type iterative procedure, and we obtained the following results:

In the vertical direction along the \( z \)-axis we have upward directed deformations about 0.4 cm at the Pilot’s center, than the deformations grow up to 8.5 cm at the depth 280 m and then the deformations decrease to 0.0045 cm at the Earth’s surface.

The horizontal deformations are about 0.5 cm at the Pilot’s center, and decrease to the 2 x 10^-7 cm at the Earth’s surface.

The calculation uses average volume change coefficient for chalk rocks (25X10^-6) \((\Delta V/V)/^\circ\text{C}\). (Clark, Properties of Rocks Ref.) and shows that maximum change possible on the surface is 0.004 cm only and only after 3000 years (1 million days).
Figure 24 shows the vertical deformation at different depths created by heating the rock’s volume at the pilot. Negative values show upwards displacement and positive values show downwards displacement. Since there is no change on the surface there will be no influence on the soil’s porosity on the surface.

In Appendix 4.2.4.4 (page 38) in the Environmental Document, there was a general remark regarding the soil stability. It was disclosed that during the heating, two processes occur that influence the rock stability: the organic matter that is still solid in this state turns into gas and liquid that are produced through the production well. In addition, inside the heated volume, microcracks occur related to the gas and liquid transportation inside the rock. After the heating phase stops, the gaps and cracks that are emptied of organic matter cool and fill with water from the surrounding areas. Therefore, there is no real lost of volume and there are no unfilled gaps. In regards to elastic deformation created in the extreme condition of complete loss of material (not 10% as occurs during the heating procedure), see the following analytical models:
4. EARTH SURFACE’S ELASTIC DEFORMATION AS A RESULT OF OIL PRODUCTION

In this case we can use the solution of the problem of elastic deformations distribution in the unbounded elastic media under the uniform comprehensive compression with a spherical cavity. The solution is:

\[ \sigma_{rr} = -p \left( 1 - \frac{R^3}{r^3} \right) \]

\[ \sigma_{\theta\theta} = \sigma_{\phi\phi} = -p \left( 1 + \frac{R^3}{2r^3} \right) \]

- where \( \sigma_{ik} \) is the stress tensor, \( R \) - cavity’s radius, \( r \) - distance from the origin, \( p \) - external pressure.

(L. Landau, E. Lifshitz Course of Theoretical Physics, Theory of Elasticity. Vol. 7, p.)

From this solution we can calculate the deformations tensor \( U_{ik} \) using the well-known formula:

\[ U_{ik} = \frac{1}{9K} \delta_{ik} \sigma_{ll} + \frac{1}{2\mu} \left( \sigma_{ik} - \frac{1}{3} \delta_{ik} \sigma_{ll} \right) \]

- where \( K \) is the bulk modulus and \( \mu \) is the shear modulus.
Having in mind that the radial deformation $U_r$ is determined as $U_{rr} = \frac{\delta u_r}{\delta r}$ we must calculate the $U_{rr}$:

$$U_{rr} = \left( \frac{1}{9K} - \frac{1}{6\mu} \right) \sigma_{ii} + \frac{1}{2\mu} \sigma_{rr}$$

Using the formulas:

$$K = \frac{E}{3(1 - 2\sigma)}$$
$$\mu = \frac{E}{2(1 + \sigma)}$$

- where $E$ is the Young’s modulus, and $\sigma$ is the Poisson coefficient we obtain for the $U_{rr}$:

$$U_{rr} = \frac{P}{E} (2\sigma - 1) + \frac{P}{E} (1 + \sigma) \left( \frac{R}{r} \right)^3$$

Calculating the deformation $U_r$ we have:

$$U_r = \int U_{rr} dr$$

$$U_r = \frac{P}{E} (2\sigma - 1) r - \frac{P}{2E} (1 + \sigma) \frac{R^3}{r^2}$$

For $\sigma$, we can take 0.2, but what is the $\frac{P}{E}$-ratio? We can use the results of the Professional Report submitted to IEI by Y.H.Hatzor, 14 June 2010: in this Report is used the Kirsch solution which is 2-dimensional variant of L. Landau and E.Lifshitz solution for the spherical cavity. In prof. Hatzor’s report the following values are used:

$E = 10 \times 10^5 Pa$ and $p = 5400 \times 10^3 Pa$.

Now we have: $\frac{P}{E} = 5.4 \times 10^{-4}$, and

$$U_r = -3.24 \times 10^{-4} \left[ 1 + \left( \frac{R}{r} \right)^3 \right]$$

If we take $R = 25m$ and $r = 350m$, the effect of the cavity is:

$$U_r = -3.24 \times 10^{-4} \left( \frac{R}{r} \right)^3 = 1.18 \times 10^{-7} cm$$

which is completely negligible.

26. Cracking- some information is still missing regarding soil cracking. What if it will still occur? How will that affect the procedure?

Please see additional information in question 22 above.

As we progressed with analyzing the appraisal wells (see further details in Dr. Avi Burg’s report) and performed additional tests that specified the hydraulic characteristics of the oil shale and while comparing different solution types (some slug test results of Bouwer-Rice and Hvorslev were used as well), it was found that the survey wells show similar hydraulic conductivity values in the range of $10^{-5}$.
10^-10^-1 m a minute. These values are very low and put the oil shale layer in the category of aquiclude rocks. These values represent the total average in the Ghareb Formation, including contribution from natural fractures.

The hydraulic conductivity tests indicate the values at the well site. Moreover, in the Beit Guvrin site we had two nearby wells that share a common open hole section. The two wells share a 36 meters common area, 366-402 meters deep, and the distance between the two wells is only 8 meters. The two water levels in the two wells are closing the gap between them extremely slow and in fact suggest that they will never fully meet. This shows that correlation between the two drillings, if any, is minor. **This means that there are no open crack systems allowing water transfer in the area between the two wells.**

The low hydraulic conductivity values along with the lack of connectivity between the two wells in Bet Guvrin reject the possibility of open fractures in the oil shale layer. If such fractures exist, the oil shale layer’s hydraulic conductivity would be much higher.

The lack of open cracks is also characteristic of the thick layer between the Yarkon Taninim aquifer to the heated zone in the Ghareb. This unit has an aquiclude character- chalk and marl chalk comprise to the Menucha formation and the lower part of the Mishash formation. The strong confinement of the Judea Group aquifer in the license area shows that there are no major cracks in the dividing layer. If such cracks had existed, there would have been no water confinement, and water would have been able to pass between the two layers. The result would have been increased water salinity at the upper part of the Havurat Yehuda aquifer. Since this aquifer is confined and its water quality is high, it is obvious that there is no massive cracking with water flow through the ‘dividing layer’.

In any case, similar to question 22 above, even if there are open cracks at the heating layer, they would be very small and their influence will be minor. The liquids flow will be into the heating volume, not outwards, because the pressures in the pilot will be below hydrostatic pressure at these depths. If saline water flows into the pilot more energy will be required in order to heat the pilot volume. It will be possible to observe this by comparing numerical simulations of the pilot with the real pilot data.

With respect to the possibility of fracturing in the pilot area and around the heaters: working pressures in the subsurface will be controlled and will be around 100 psi, while the minimum pressures required for cracking at this depth are several hundreds of psi according to the Terzaghi’s equation (Terzaghi, Terzaghi, K., “Die Berechnung der Durchlassigkeitsziffer des Tone aus dem Verlauf der Hydrodynamischen Spannungserscheinungen,” Sber. Akad. Wiss., Wien, 132:105, 1923).
27. Soil Stability – what will fill the gaps and cracks emptied from the organic matter during the production process, and afterwards (when ends) respectively to the oil extracting?

In this matter please also see answer 25 above.

During heating, the fractures and tiny pores that will be created in the rock in the heated volume will be filled with steam and gases of oil products. After the heating stops, the gas pressure will be reduced in the pilot’s volume, the remaining kerogen will not undergo pyrolysis, and the heated area will lose heat gradually until its temperature is below 100°C. When the pilot’s temperature is under 100°C, natural saline water from the surroundings of the heated area will gradually accumulate in the rock’s pores space and fill its volume. Therefore, at the end of the pilot, there is no actual volume loss and there will not be empty vugs remaining in the heating area.

28. Pressures- what happens to the subsurface pressures after the low pressure process stops?

During the heating phase, there are pressure differences between the hydrostatic pressure in the pilot’s depth and the wells, working pressure (~100 psi, 7 atm) ensuring there will not be a flow from the pilot outwards, but rather inwards to the production wells.

When the heating is stopped, in conjunction with the production process, the pressures will gradually be lowered until the pressure will be balanced as the water flows slowly into the heated volume. The temperature and pressures will gradually balance in the pilot volume until they will become equal to the hydrostatic pressure and the ambient temperature.

29. Ground- what is the heated soil wetness profile at the end of the process? Won’t the heat pass through the wetness in the ground?

In this matter please see answers to questions 19, 24 and 27 above.

The heated ground (deep subsurface) will be back to its water saturation profile at the end of the process by the slow flow of water into the heated volume. The tight packing and low permeability of the rocks in the Ghareb Formation results in a very low contribution of the liquid flow to the heat transfer in the rock. As explained above, the results of the hydrological tests, the chemical analysis, and the well log analysis that was performed shows that the oil shale layers in the licensed area are an aquiclude (even with the high porosity), almost completely sealed to free flow, and they contain saline water. Therefore the thermal characteristics of the rocks in the production layer and the rocks that surround it have water saturated rock characteristics. Since the heat passing upwards from the heated volume is negligible, there will not be any changes in the temperature or moisture to the rocks on or near the surface in the saturated or non-saturated zones, and there will be no influence on the soil for agriculture (the process does not extract water from depths relevant to agriculture).
30. Structure-is there a planned soil survey before work starts to mark the map for the tested areas and retest them after the pilot ends, including soil cooling and returning the area back to its previous condition. Will there be GCMS tests performed (testing the organic matter in the soil)?

In addition to Appendix 3.5.2 in the Environmental Document- monitoring and tracking the treatment and production system (pages 29-32) and in addition to subsurface monitoring described in Appendixes 3.6-3.7 of the Environmental Document (pages 31-32), there will be an organic material analysis done by GC/MS on surface soils before, during, and after the pilot. The sample locations and the test results during each stage will be presented to the Ministry of Environmental Protection. In order to eliminate external influences that are not related to the pilots operations, it is important to compare the survey’s test results during similar weather conditions and similar seasons.

D. Water: Questions 31-34

31. Extracted water- in Page 75 the term ‘extracted water’ is mentioned. What type of water does that refer to? What is its source and potential contamination source? It's also mentioned that “if contaminated water will be found it will be transferred to a designated treatment facility at the refineries”. What type of treatment will be required? Are the refineries prepared for it?

As explained in chapter 3.4.3.4 of the Environmental Document (page 26) there are three types of produced water in the pilot. In order to explain the term ‘extracted water’ which we’ve referred to in Appendix 5.3.2, page 75, we will repeat the original explanation (Appendix 3.4.3.4) for the different water types in the pilot and add further details for clarification:

1. Fresh water – water supplied for continuous use (Mekorot line/local water conductor).

2. Natural extracted water- Water that will be extracted from the subsurface by pumps will be produced from dewatering wells surrounding the heated area before, during, and after the heating process. The natural saline water will be extracted before the heating procedure and therefore will not be influenced by the procedure at all (the brackish water contains at least thousands of mg Cl- per liter.). The maximum estimated water amount is 1000 m³. The natural water will be collected and stored according to the Ministry of Environment Protection’s guidelines and will be transferred along with the rest of the water to an approved...
treatment facility. It is important to note that after drilling the first test well at the pilot’s site, hydrological tests will be performed to check if the water can be extracted. So far, the findings from the survey drillings indicate that the recovery rate of the water in the wells will be very slow, and that it will be impossible to substantially dewater the pilot’s volume (recovery rate will be so small that after pumping out the well, it will take months to refill). In this case, the expected amount of water will be much smaller and the natural water will be produced as displayed in the next Appendix.

3. Water (steam) extracted from the subsurface during the initial heating stage, if dewatering will not be possible by pumping, the water (located in the heated volume) will be extracted as steam when the temperature reaches about 100°C. Since the water is being produced during heating, it may be contaminated as described in Appendix C below. Therefore, we refer to it as industrial water, and it will be collected in accordance with the guidance of the Ministry of Environmental Protection and will be transferred to an approved treatment facility.

4. Industrial Water- water produced as a byproduct during pyrolysis and categorized as industrial water or ‘sour water’. Natural water produced as steam and extracted with the rest of the production products are added to this water. The estimated natural water volume is 400 m³. The sour water is expected to contain dissolved H₂S, dissolved hydrocarbons in solution, and possibly heavy metals at very low concentrations. We estimate that the total amount of water will be 3000 barrels which of course, depends on the original porosity of the heated volume at the pilot’s site. The water will be collected to the water tank and transferred to an approved treatment facility. If onsite treatment is needed, acid neutralization of the H₂S and creating dissolved sulfide salts can be implemented before transferring the water off site.

32. Salt water treatment- the estimate is for thousands of m³ of salt water. In salt water, salt concentration reaches thousands, it usually disposes as brine. At the Environmental Document it is mentioned that the water will be transferred to sewage treatment facility. Which facility will transfer the dewatering water? Can the facility treat salt water? What is the full solution from the dewatering stage to the end solution?

In this matter, please also see answer to question 31 above and Appendix 3.4.1 of the Environmental Document (pages 12-13).

The pore water will be extracted before and during the heating process from dewatering wells just outside the heating hexagon. The purpose of the dewatering wells is to extract pore water in order to create a cone of pressure depression around the pilot’s volume that will assist with efficiency of the oil...
shale heating process and to use as a protective barrier, preventing any possibility for contamination in the vicinity of the pilot.

The maximum estimated water amount is about 1,000 m³. A better estimate of this amount will be possible after the first well is drilled at the pilot site.

Unlike the information written in the Environmental Document, the natural water will be collected and stored according to the regulations of the Ministry of Environmental Protection and will be disposed together with all water at an approved treatment facility. The data received from the appraisal drilling shows a possibility that the dewatering rate will be so slow that dewatering at the pilot by pumping the water will be impractical. The expected water amount will be substantially smaller and we expect not to exceed 150 barrels of brackish water (a level of 7000 mg/Cl-/liter). The water will be collected and stored according to the regulations of the Ministry of Environmental Protection and will be disposed at an approved treatment facility.

33. Sour water - how will the sour water and pore water created get to the refineries?

In this matter please see answer to question 31 above. Water disposal will be done with authorized tanks and according to the instructions of the Ministry of Environmental Protection. The water will be transferred to a facility in Ramat Hovav.

34. Water dripping - can salt water containing organic matter from bitumen chalk rocks drip from Mt. Scopus group to Yehuda group?

All of the collected data show that there is complete isolation between the different geological units. Further detail is included in Dr. Avihu Burg’s report, as well as in question 15 above.

In addition, in all wells drilled thus far in the Shfela area that penetrated the oil shale layer, the logs of the electrical resistance data showed low resistivity (high salt content) throughout the geological section. If water was leaking downwards we would expect to see a gradual change in the electrical resistance entering the aquifer unit of Yehuda group. However, the data shows that the boundary between the Menuha formation to the Yehuda group is sharp and occurs over only a few meters. Therefore, we do not expect to observe a gradual change due to mixing of water from the different groups, which strengthens the arguments regarding a complete separation between the two geological units.

In the summary of his report, Dr. Avihu Burg refers to this question by saying “according to the data the hydraulic heads in oil shale are higher than the Yehuda group aquifer. Even so, the combination of a thick dividing unit with aquiclude character (chalk and marl chalk belong to the Menucha formation...
and the lower part of the Mishash formation), the strong confinement of the Yehuda Group aquifer at pressures of tens of atmospheres and the aquicludic character of the oil shale unit eliminates concerns of water leaking from the oil shale to the Judea Group and contaminating it. The fact that such contamination has never been found until this day in areas where the Judea Group aquifer is confined (although natural water at the oil shale unit are saltier than the Judea Group aquifer water), shows that the hydraulic disconnection between the units is efficient. There is no fear that conducting cracks exist inside the dividing unit since if there were any, there wouldn’t be such strong confinement, as for “you cannot hold the rope at both sides”- if there is confinement there are no cracks, if there are cracks there is no confinement”.

E. Emergencies: questions 35-38

35. Risks survey- in an incident where underground fine occurs from oxygen penetration to the subsurface, what are the additional hazards that can occur in such incidents (such as unplanned new emissions, ground instability) and how will the situation be treated? A calculation of engineering powers, chemistry, extinguishment and technicians should be included in consideration.

During the production process of the pilot, the oil shale is heated in the subsurface, and the organic matter (kerogen) within the rock is converted in a reducing environment (lack of oxygen) into liquid and gas which are then extracted to the surface. Therefore, the production process occurs in a naturally reducing environment and not an oxidizing one. Since the In-Situ process is performed under positive pressure of 100 psi (about 7 atmospheres), oxygen penetration is not possible.

In fact, many attempts to create conditions which allow oxygen to penetrate the subsurface in oil shale projects in Colorado failed to sustain subsurface burning. Self-ignition of oil shale can only occur in areas where oil shale is on the surface and with contact with air and low rock moisture.

The scenarios mentioned in the pilot’s risks survey refer to (Appendix 5.1.2 pages 28-42 to the risk survey Appendix) the ones that carry high-risk potential, even if low probability. Such a scenario (oxygen penetration to the subsurface and its ignition) is not included since it is clearly impossible.

36. Hazard treatment- a hazards list should be prepared for immediate treatment during the project with consultation with the ministry. The list should include hazards treatment timeline (contamination spots, noise, non-planned emissions, etc.)

IEI is committed to any required planning and will act according to the required procedures. The professional team, on behalf of IEI, that will concentrate on the list preparation, with the consultation...
and guidance of the Ministry of Environmental Protection, included Dr. Amram Pruginin and Eng. Yaakov Barak from Ludan Engineering.

As for possible emergency events and hazard treatments, a HAZOP will be prepared and delivered to the Ministry of Environmental Protection.

37. **Fire Scenario- what are the actions that will be taken to prevent fire scenarios (such as the fire which occurred in June 2010 in the area) also, what is the suggested procedure protecting the pilot if fire breaks out on the surface? How can environmental damage be prevented?**

The pilot will be placed in a bare area away from forests (the closest forest is 200 meters away with a fire protection path in between) such that the fire event in the area on June 2010 is preventable considering the pilot’s characteristics and its planned location.

A risk assessment survey was conducted for the pilot by Chemic Engineering and Safety, a company whose field of expertise is fire prevention and evaluation. The survey, coordinated with the Ministry of Environmental Protection, considered two possible fire scenarios and tested their likelihood, spread, and consequences.

The first scenario tested the possibility of creating an H₂S cloud that ignites from a power line spark or a different source of sparks (pages 35-38 of the Hazards Survey). An analysis of the results determined: “the chance of such a scenario to exist is very small, even negligible, since the power lines and electrical facilities will be categorized as CLASS I DIV, so sparks that can cause a scenario as mentioned above are not possible. Therefore, there will not be an environmental influence such as burning of a nearby forest” (page 36).

In the second scenario the heat wave distances for possible fires at the gas tank (pages 39-42 of the Hazards Survey) were evaluated. The scenario referred to a case where a tank containing 7.5 ton of oil burst and fire in the spill containment area, creating a flame supplying 6930 kg/m for 20 seconds. Analysis of the results concluded that “the fire event lasts 20 seconds, after that the fire is extinguished as a result of lack of flammable matter. The heat waves are short-length; therefore there is no need to have heat-protection equipment around the site’s area” (page 42 of the Hazards Survey).

As explained in the Hazards Survey document (page 28), there will be a modern fire fighting system at the pilot site, which will be planned, tested and maintained as required by law. Such a system can handle fire scenarios as described above. Moreover, we plan to initiate a fire safety plan for the site during the detailed planning phase following the permit approval. The safety plan will be transferred to the Ministry of Environmental Protection and the relevant authorized authorities.
38. Contamination outside the heating area- what are the methods of preventing subsurface contamination spread, even if outside of the heating area? (Page 3 Appendix 3.1- water dewatering) what actions are planned to clean the subsurface if needed?

In this matter, please also see answers to questions 15, 21 and 22 above.

The hydrological measurements at the three survey drillings showed that the Ghareb Formation has very low permeability (~0.1mD). This means that liquids or gaseous products cannot flow outside the heated volume and into the surrounding water saturated rocks. In addition, the pressure difference between the lower pressure in the pilot’s volume and the hydrostatic pressure around it forces water to flow inward and not outward. Therefore, there is no possibility for contamination to spread in the subsurface. Under any condition, the dewatering wells will be an additional protective barrier to catch and prevent the spreading of any contaminants outside the pilot’s volume. At the end of the heating process, water will enter the heated area and flash to steam, a self- cleaning process of the residual fuel that will be produced and removed from the ground (as occurred in the pilots in Colorado).

F. Monitoring: Questions 39-42

39. Groundwater- what is the plan for groundwater monitoring during and after work?

Groundwater monitoring at the pilot was discussed and planned with the cooperation of the Water Authority and will be performed according to its guidelines (see also Appendix 4.A above). A broad view and explanation of the monitoring plan is described in Appendixes 3.5.1 (pages 27-28) and 3.7 (pages 31-32) in the Environmental Document.

In summary, the observation and monitoring wells will be drilled within and outside the pilot’s hexagon at various distances and downstream of the natural water gradient. The monitoring will commence immediately after completing the drilling and will continue throughout the heating process and the production that follows. In general, the monitoring will include monitoring the water levels and comprehensive analysis of the dissolved components in the water, including the main ingredients, trace elements and organic matter. After completing the project, subsurface and groundwater temperature monitoring will be performed.
40. Cracking- how will the cracking procedure (that might spread to larger distances than the heated hexagon) monitoring be performed? There is a fear of decreasing the soil’s plasticity by the dewatering process. Consideration should be taken for monitoring the creation of cracks because of the drilling and ground heating.

Regarding the concern about cracking, we will clarify again that most of the natural cracks in the unit are either closed or very small. Open cracks in this unit are very few, and their influences are negligible. As described in questions 25-26 above, micro-rock cracking due to the heating process will only occur within the limits of the heated zone.

As explained in questions 22, 26, 31 and 32 above, the Ghareb Formation has low permeability since most of the water located in the rock’s pore space is held by capillary forces. Therefore, it is estimated that water production at the dewatering wells will be limited. Therefore, no change is expected to occur in the rock’s plasticity. The dewatering wells will not extract water from the units above the Ghareb Formation. There are no concerns regarding the influence of the dewatering wells on the upper units or at the surface.

41. The subsurface- what is the monitoring plan for tracking changes of the subsurface temperature during and after work?

Measuring the temperature in the subsurface is one of the main components of the pilot. Therefore the heaters include thermocouples for measuring temperatures. The pilot will use 10 “Type K” thermocouples. In addition to that, three observation and monitoring wells are planned to be drilled in the pilot’s hexagonal volume. Finally, the dewatering wells which surround the pilot’s hexagon will be used for temperature monitoring outside the hexagon area. STARS simulations (the industry standard) will use all this data to model the changes in temperature around the pilot. Even after completing the project, the temperature monitoring of the subsurface will continue. For more details, please see also Appendix 3.4.2 in the Environmental Document, (page 13).

42. Water and gas monitoring- what is the method of monitoring water and gas emitted through the cracks to areas outside the defined heated area?

A. Referring to the water monitoring- see answer 39 above.

B. Referring to gas emissions- as mentioned and explained above (see in further detail in questions 15, 21, 22, 26 and 38 of this document) there is no expected gas emission outside the heated volume in general and to the surface in particular. In order to prove that, IEI will measure gas concentration rates in the area surrounding the pilot as described in the answer to question 12.
G. Noise: Question 43

43. The expected noise levels at the elderly home are mentioned in the Environmental Document but refer only to the evening time. What are the predicted noise levels during the day time?

There is no essential difference in the type of activity during the day and night time; therefore noise rates will be similar throughout the day.

Appendix 4.4 of the Environmental Document discusses the influences of possible noise from the pilot (pages 54-62). The reference to this issue emphasizes the fact that the pilot is 830 m away from the elderly home. For that reason, the tests, as per recommendations, were considered under strict parameters to ensure low noise levels throughout the day. The value used for planning was set to be 3dBA lower than allowed values, according to the restrictions of such structure (structure “A”, - that is- 42dBA and 32dBA during day and night time- accordingly.)

The predicted noise levels in the pilot facility were analyzed taking into consideration the noise levels during night time which are more stringent than the ones during day time. The allowed noise levels permitted during night time are 10 dBA lower than the levels allowed during daytime. Since the acoustic planning was determined by the lower values, the expected noise levels during day time will be lower than the allowed values.

H. The production process: questions 44-48

44. Operative reserve- considering the size of the structures, pipes and tanks, there should be a reference to which operative reserve is planned, the maximum size of structures (air treatment, gas and liquids absorption) planned in the area.

The detailed operation plan, starting with the approval of the regional committee, will include detailed engineering analysis of hold times, volumes, number of units and their placement, all within the determined pilot area.

The operative reserve matter is less relevant to the pilot’s operation since that was made for limited field research and not for regular production. That is why for example, the water storage volumes designated for disposal will be adjusted to the disposal tanks volumes and to the maximum water production rate. The planning data of the H₂S disposal systems and the thermal oxidizer will consider the extreme conditions and will be adjusted in size accordingly. As required, the company will present the Ministry with the engineered detailed planning when it is completed.
45. The production process- we request an explanation of the production process. In the Environmental Document it is mentioned that the production itself will be performed during 6 days of the week while the heating process and the products leaving will be continuous. Can there be environmental impacts for that such gas creation, gas evasion, etc?

Detailed descriptions and explanations of the heating and production process at the site are discussed in Appendix 3.4 of the Environmental Document (pages 12-26). The reference in page 12 to a 6 day work refers to the continuous activity at the site, in addition to the heating and production, maintenance, logistical support (transferring and transporting equipment to and from the site), visits to the site etc. The heating process and production (2 barrels a day on average) will be continuous and operate 24/7. The site will be occupied and monitored continuously. Work performance at the site will require a regular occupancy of two employees for a full 24 hr. During Sabbaths and holy days those shifts will operate on a sabbatical manner, while responding to emergencies only. Any non essential operations will be performed during the 6 working days of the week. This format is accepted and customary in the Israeli law. There is no reason for an environmental impact since the whole process is continuously monitored.

46. Operation time- which operations will be performed during the day, during the night only, and which operations will be performed throughout the day?

As described in the Environmental Document, Appendix 3.3.2.2 (page 9), the drilling operations will be performed throughout the whole day. The establishment and preparation of the area will be performed, as mentioned in Appendix 3.3.3 of the Environmental Document (page 10), during daytime only. The heating, production, and monitoring will be performed, as described in question 45 above, throughout the whole day- 7 days a week.

All maintenance and logistic operation will be performed (material disposal, truck transportation) only during the daytime of working days of the week.

47. Drillings specifications- more details should be supplied regarding the drilling’s well diameters, the concrete covering depth, the building and anchoring materials, the drilling technology and the materials used for drilling (for lubrication purposes, for example).

IEI has hired the service of a leading international company to plan its drillings. Below are the drilling sketches prepared by them and the descriptions of components:
Figure 25: Heating wells sketch and its components description
Figure 26: Heating wells sketch and its components description
Figure 27: Groundwater wells sketch and its components details
Figure 28: Observation and monitoring wells sketch and its components details
Figure 29: Dewatering wells sketch and its components description
48. Storage tanks- how many storage tanks for liquids collections are planned? (Considering page 25, means to prevent ground contamination from liquids).

All of the liquid containers (different water types extracted from the subsurface and fuel products) will be placed in established spill containment pallets to prevent spreading of spills at the site. In the event of a spill into the spill containment pallet, the liquid will be extracted to a disposal tank and transferred to an approved treatment facility.

The detailed engineering plan, which will be preformed after receiving the approval for the pilot, will include a detailed description of volumes, number of units and their placement within the defined pilot area. As mentioned, with the completion of the detailed engineered design, the company will provide this information to the Ministry of Environmental Protection.

I. Products: questions 49-52

49. Gas created during the process- there’s not enough details in the report regarding the produced gas during the process. Are the amounts of 425000 m³ gas and 1062 tons of gas correct? Precise amounts should be detailed including treatment methods. What is the energy amount? What are the environmental influences of such amount? What facilities are required for such production? What are the risks for fire and explosion by the presence of hydrogen sulfide and methane?

Regarding this matter, please also see answers to questions 8-11 above.

The total amount of produced gas is only 42,500 st.m³, less than mentioned in the question above (also see Appendix 3.4.3.1 in the Environmental Document, page 17). The gas amount created is described in figure 13 and its composition in table 1, question 8 above. All of the gas produced in the pilot will be treated to dispose of H₂S in a Sulfatreat system.

In this system, layers of granular reactant adsorb the hydrogen sulfide. After removing the hydrogen sulfide, the gas flows to the thermal oxidizer facility (see our answer to question 9).

As explained in the Environmental Document Appendixes 3.4.3.3 C – table 3.4.5 (page 24) and 4.3.2.1 (page 45) the emissions from the thermal oxidizer will not exceed the TA-LUFT 2002 regulations, as described in the answer to question 10, table 2 above. In this framework, total SOx and NOx amounts emitted will be smaller than 1.8 kg/h.

Calculating the risks for fire/explosion for the hydrogen sulfide and methane will be performed on the engineered detailed design of the pilot facility, including a detailed equipment list and MTBF analysis regarding the entire facility. Upon completion of the required analysis, we will transfer the data for the Ministry’s review.
50. Composition of the oil shale level - what are the products of the oil shale coming out of the ground? There is no description of the accompanying products for fuel and gas (even if in small doses). What products are they? What materials may be emitted beside the requested materials?

The gas components created are listed in table 1, and oil products in table 3 above. H₂S is the main accompanying material to the produced oil and gas. The treatment of H₂S is described above. Regarding identifying and treating additional accompanying materials, if any, please see the answer to question 11A above.

51. Products treatment system - further details should be supplied regarding the product treatment when considering “typical structure in the oil and gas industry” as mentioned in Appendix 3.4.3.3. Technical specification of the structure should be displayed.

The detailed design plan will be performed following the pilot’s approval by the regional committee and will include specific analysis of the measurements and volumes of the equipment units and their final placement in the designated pilot area. The facility will include components such as filters, heat exchangers, separation tanks, hydrogen sulfide absorption system, oxidizer, storage tanks, and pressure monitoring equipment, and leak prevention methods as recommended within the oil and gas industries. A detailed description of this matter is described in Appendix 3.4.3.3 of the Environmental Document (pages 20-26), including the treatment facility and its general characteristics.

52. Heating process - what happens to the liquid material before it is ready for extraction? How is gas dripping prevented in an early stage of the heating before extraction?

Regarding this matter, please see answers to questions 15, 21 and 22 above.

The production system will operate before the onset of the heating and will produce mobile fluids from the volume. Water is produced first, then steam, and later in the heating process, gases and water and a mixture of hydrocarbon liquids. There will not be a situation when any material, whether it is liquid or gas, waits for extraction in the soil. The liquid products will fill the rock’s porosity (~35%) which initially contained water, and their production will be immediate.

In regards to the concern of gas dripping, see the reference above. We will repeat and emphasize that during the pilot, the gas pressure in the heated volume is lower than the surrounding hydrostatic pressure (~275 psi) and will be kept at about 100 psi. Therefore, even if we assume that the production process is performed within areas with open cracks (which it is not), still the gases and steam will flow into the heated area and towards the production well, and not outwards.

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J. Additional matters: Questions 53-59

53. Technology implementation- it is not clear what will happen if, after the declaration that there is a discovery, given that some of the technologies will be found non practicable/economical, is there a chance that different technologies will be used? If yes, what will be their environmental influences?

A declaration of discovery itself is the authority of the Ministry of Infrastructure only. Therefore the question should be referred to them. In this matter, a declaration of a discovery recognizes the success of the pilot. Demonstrating technical feasibility in the pilot and showing the economic practicability is a condition to such success. Otherwise, the pilot will be declared a failure.

Moreover, before any step up to the development and, if and when IEI asks to test a different technology, this will be presented for examination and approval of the authorized authorities, including the Ministry of Environmental Protection.

The risk survey based on scenario analysis coordinated with the Ministry of Environment Protection was described in the Environmental Document appendix. During the detailed planning phase, we intend to combine a HAZOP procedure for operating the facility with a monitoring plan to address irregular events, either operative or environmental. The HAZOP report, as with any other planned reports, will be transferred to the Ministry of Environmental Protection with full transparency. Preparation of the actual report has already started with a risk survey editor as per the request of the Jerusalem district manager in the Ministry of Environmental Protection. A first draft application was rejected until completion of study of the Environmental Document.

54. Stopping the pilot for environmental damage-what criteria and fences were placed to stop the pilot in a situation where irregular damage to the environment is revealed?

With respect to this question please see our answer regarding the non-centered emissions in question 14.

55. Environmental success/failure criteria - what are the measurements for the success/failure of the pilot environmentally? Does the pilot include a program of the surface rehabilitation?

The pilot will stand by all the requirements and requests that will be defined by the Ministry of Environmental Protection for approval. All of the data and findings produced during the pilot will be used for testing the environmental consequences. In addition to the standard requirements, the pilot
should allow for the possibility of improved methods to keep the environment safe in the future stages.

Regarding the area rehabilitation, we are not testing special technologies that have an unusual influence on the environment. Returning the land back to its previous condition will be performed after clearing the equipment from the site, by reapplying the exposed soil that was kept and reserved for the final reclamation purposes. After completing the reclamation work, the area will be back to its original state for agricultural use.

56. Coordination with additional infrastructures- the Environmental Document does not include a description coordination of additional infrastructures with the relevant authorities, Such as sewage treatment plants, refineries etc. There are no agreements that it is possible.

As described in answers 31-33 above, we do not intend to use the services of sewage treatment plants or refineries for water treatment during the pilot but to transfer it to an authorized company that deals with such water. Coordination with the electric company regarding the required transformers and with Mekorot to arrange water supply to the site, is conditional upon receiving an approval from the district committee for the pilot’s location.

57. Basing on data from previous experience- the Environmental Document does not give details or present relevant data from experience performed in the U.S and other locations.

The richest experimentation in the field was located in the U.S. Specific documentation prepared by the American authorities regarding the influences of the pilot in Colorado on the environment are the following:

Finding of no significant impact / Decision Record Site 1 COC-69167 Oil Shale Test Site.

Environmental Assessment – CO-110-2006-117-EA.

These evaluations determined, based on the pilots performed by ‘Shell Oil and Gas’, that there is no harmful environmental influence expected from the establishment of three demonstration commercial facilities (100 heating and production wells). Below is a part of the BLM document (Bureau of Land Management) approving the execution of the demonstration facility, which has similar technical characteristics to the Israeli pilot but is much larger than the Israeli pilot.
The decision to grant an Oil Shale RD&D lease for Site 1- Oil Shale Test Site (COC-69167) to Shell Frontier, Inc has been made in consideration of the factors described above. The Proposed Action with Mitigation represents an opportunity to develop domestic energy sources and to inform and advance knowledge of commercially viable production, development, and recovery technologies consistent with sound environmental management.

Approved by:  

[Signature]  

Stephen Allred  
Assistant Secretary  
Land and Minerals Management  

Date: 11/9/2006

In addition, a certified recommended document in this matter, for its best update and defined details, is the department of American patents (about 250 registered patents in all included IEI’s lead Scientist- Dr. Harold Vinegar). Below is the link for the recent patents:


Recently a new book was published by the American Chemical Society called "Oil Shale: A Solution to the Liquid Fuel Dilemma" In it, a chapter written by Shell’s scientists describing in detail the technology and some of the performed pilots (see a copy of chapter attached, for further reading of the material please see link below http://pubs.acs.org/isbn/9780841225398)

Shell has performed 7 pilots thus far - 6 of them in Colorado and one in Canada. All of the pilots have ended successfully. The pilot in Canada, producing in similar oil from bitumen at the Viking site near the city Peace River in Alberta province has produced over a quarter million barrels to date.

58. Testing Alternatives- it is not clear how the national alternative testing was performed. According to the GIS there are oil shale deposits all over the country and we should receive a list of every area and the reason it wasn’t chosen (such as nearby aquifers, oil shale quality, compositions etc.).

The unique geological conditions of the oil shale deposits in the Shfela basin are the reason for choosing the area. The size of the deposit, its richness, depth, hydrological isolation – considering all this data leads to one conclusion: the Shfela deposit is the best choice. It is true that oil shale appears in over 25 locations nationwide, but only the Shfela deposit has the potential to make Israel independent of foreign oil while using the subsurface extraction technology.

Below are more detailed arguments regarding the decision to choose the oil shale deposit of the Shfela area:

A. Deposit’s size- the oil shale deposit in the Shfela is the largest in Israel and was described as such in various research articles (example: Sudri & Hubario, 2004, mentioned that “according to the
existing potential there is justification, nationwide, to continue to explore the area” Shirav and Ginzburg 1980,1992,2009). The deposit is 95% of the total oil shale deposits in Israel. (See table 4, Minster 2008). Therefore, the Negev deposits do not offer long term potential for the energy independence for Israel. The research and economic attractions of the Shfela deposit are the most meaningful for the nation.

**Figure 30: Shfela oil shale syncline, Minster 2008**

A. Thickness and richness of the deposit- the Negev deposits are neither thick nor rich enough with organic matter (Minster 2008). Therefore they are not suitable for the oil production process using the “In Situ” method which the company wants to test and develop. This means that production attempt in the Negev will defocus efforts towards the not-rich layers that show no financial feasibility.

B. Hydrological conditions- the Judea group aquifer in the Shfela basin is a confined aquifer located very deep (700-900 below the surface) when the confined unit is the Menuha Formation of Mount Scopes group (Hirsch’s structural maps 1983, and Fleischer and Gafsou 2003).

Below we list the main considerations that guided us in choosing the borders of the licensed area:
A. A major consideration was that Shfelat Yehuda is the deepest syncline where we expect to find the richest and thickest deposits. This was shown to be correct in the geological survey wells performed to date.

B. Another important consideration in choosing this location is that we are confident that there is no hydraulic connection between the oil shale and the aquifer below, ensuring that there is no risk to the aquifer water.

C. The hydrological correspondence to the requested production method also determined that the area should have a thick enough overburden to ensure separation from rainwater (this is not the case in the Har Tuv area).

D. There was an attempt to stay away as much as possible from sensitive areas, in particular the military bases. Also, urban centers were not considered in the search area. National gardens and nature reserves were also excluded from the search area with the understanding that they won’t be used.

E. Since there was no data verifying the early geological estimates, we requested a large license area to map the subsurface and minimize eventually the area used to produce oil and gas. From the licensed area, we will use only 20-30 km² (10% of the licensed area size) where the deposits are suitable for commercial production, allowing for production of all of the oil required to meet Israel’s oil needs. The correct choice of area will minimize the project’s ecological footprint.

F. In summary, IEI licensed area in Shfelat Yehuda is the only area in Israel that presents an opportunity to meet Israel’s oil consumption. The area was chosen after serious considerations, in particular the prevention of possible risk to the underground water.

The Shfelat Yehuda area, with the unique geological and hydrological combination, is the optimal choice, perhaps even worldwide, for oil production from oil shale by IN SITU technology.

The company’s choice in the existing deposit in Shfelat Yehuda came from the desire to concentrate on the huge potential within it, combining especially high quality oil shale uniquely suited to the IN-SITU method. The Ministry of Infrastructure has reviewed the request and decided to approve it because it because it recognizes that it may be a process that will change the energy market in Israel for many generations.


At the managers summary the estimate is for 500-1000 oil barrels during the pilot.

At the Environmental Document there is a mention of only 500 barrels of oil.

The pilots' area and volume did change from January 2010 due to updated geological data acquired since then. The expected oil shale production in the pilot is now only 500 barrels.
K. Appendix - Shell’s In Situ Conversion Process—From Laboratory to Field Pilots