RENEWABLE ENERGY APPLICATIONS FOR OIL SHALE PRODUCTION

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INTRODUCTION:

To reduce the environmental impact of oil shale extraction it would be valuable to use renewable energy sources to provide power to heat the oil shale. This poster presents analysis of different renewable resources that could be used to provide this energy. This work is based on calculations by Alan Burnham of American Shale Oil (AMSO) of how much power is needed to extract 100,000 barrels per day for a medium oil shale (20gal/ton) and rich oil shale (30gal/ton).

WIND POWER:

Wind resources are abundant near the Green River Formation, particularly in Wyoming where an annual average speed of 8.5m/s can be found in large areas.

The power produced by one wind turbine is modeled using this equation:

\[ P_{\text{produced/turbine}} = \frac{1}{2} \cdot \rho \cdot \Omega^2 \cdot R^2 \cdot C_p \cdot \nu \]

with:
- \( \rho \): Air density
- \( \nu \): Wind speed
- \( R \): Rotor Radius
- \( C_p \): Specific turbine efficiency

This equation applied to several wind turbines leads to the following table*:

<table>
<thead>
<tr>
<th>Wind turbine</th>
<th>Quantity needed for rich oil shale (kW)</th>
<th>Area needed (kms)</th>
<th>Quantity needed for medium oil shale (kW)</th>
<th>Area needed (kms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 MW</td>
<td>300</td>
<td>11.3</td>
<td>360</td>
<td>15.2</td>
</tr>
<tr>
<td>7.5 MW</td>
<td>450</td>
<td>17.0</td>
<td>620</td>
<td>23.4</td>
</tr>
<tr>
<td>2.3 MW</td>
<td>1100</td>
<td>41.6</td>
<td>1500</td>
<td>56.7</td>
</tr>
</tbody>
</table>

* These calculations have been made with \( \nu \geq 1 \) kg/m² and a average wind speed of 8.5m/s. ** Average values of water 3.3% and 5%. *** Turbines arranged in rows with 3 times rotor diameter between turbines and 10 times rotor diameter between rows.

By using wind power to provide the energy to retort the oil shale, the CO₂ emissions associated with retorting are avoided. To have a good average wind speed we can build the wind turbines in the southwest of Wyoming (seen in the blue areas in the opposite map such as the Laramie Mountains).

SOLAR ENERGY:

Photovoltaics:

The table below shows how large a solar farm would have to be to provide enough energy to extract 100,000 barrels per day:

<table>
<thead>
<tr>
<th>Power needed per day (MW)</th>
<th>Medium Oil Shale</th>
<th>Rich Oil Shale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water 1.3%</td>
<td>3 214</td>
<td>3 720</td>
</tr>
<tr>
<td>Water 5%</td>
<td>2 311</td>
<td>2 675</td>
</tr>
</tbody>
</table>

Area needed (kms)*** (type : 145W panels):

- 44.3
- 51.3
- 31.9
- 36.9

Area needed (kms)*** (type : 300W panels):

- 35.1
- 40.1
- 25.3
- 29.2

* Considering twice the size of a panel.

These results do not consider any storage of the energy. If the site needs to run 24h, then it may be necessary to store the equivalent of 3 days of energy. Compressed air storage, pumped hydro or NaS batteries could be used to store energy, but it would be more cost effective.

Solar Thermal:

Solar thermal energy produces energy by heating water. This technology is more efficient than solar photovoltaics, but it uses water which is limited in supply in Colorado.

Considering a typical water-cooled parabolic trough plant that consumes 800gal/MWh, 29 million of gallons of water per day would be necessary to provide enough energy to extract oil shale of medium richness and 20 million for a rich oil shale.

However, a good way to avoid water issues would be to use a hybrid parallel wet/dry coolers7 that could reduce the energy cost penalty and save about 80% of the water compared to a water-cooled plant8.

GEOTHERMAL ENERGY:

Oil shale needs to be heated to ~350°C for in-situ processes and ~500°C for surface retorting. Geothermal energy is a resource we could use to preheat the rock and reduce the amount of energy we need to heat and extract oil shale.

The state of Colorado has a large geothermal resource, up to more than 100°C/km.

In the Southern Piceance Basin in Colorado, temperatures sufficient for a geothermal resource are present at reasonable drillable depths. At least 100°C is expected in a depth range of 2.5 to 3.3km.

CONCLUSION AND PERSPECTIVE:

Oil shale production requires a large amount of energy to extract 100,000 barrels of oil per day. However, oil shale sites could reduce their carbon footprint by using renewable energies available in the states of Colorado or Wyoming. The best compromise would be a hybrid system using both geothermal and other renewable energies.

A continuation of the project would be to perform a more in depth analysis of certain aspects of each type of energy to design an efficient hybrid system. Furthermore, one can consider the shale gas that is extracted with shale oil to provide energy.

ACKNOWLEDGMENT:

The author gratefully acknowledges Joseph Beach, REMRSEC Facilities Manager CSM Physics, for his help on solar energy and Stuart Simmons, Department of Geology and Geological Engineering CSM, for his help on geothermal energy.

REFERENCES: