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# PROCESS/ECONOMIC STRATEGY FOR UPGRADING SHALE OIL

J.W. Bunger, C.P. Russell, P.A.V. Devineni, D.E. Cogswell and J.W. Wiser
**James W. Bunger and Associates, Inc.,**
P.O. Box 520037, Salt Lake City, UT 84152-0037.

***ABSTRACT***

A prime difficulty with the production of transportation fuels from Western U.S. shale oil is the high heteroatom content, especially nitrogen. Nitrogen containing molecules are known to have high market value for non-fuel uses. Selective extraction of nitrogen-containing molecules from shale oil recovers these potentially valuable components while upgrading the remaining shale oil for refining to transportation fuels. A thermodynamically logical separation process sequence consisting of primarily distillation and liquid-liquid extraction has been shown effective in selective isolation of polar heteroatom-containing molecules. The polar fraction may be processed for the production of chemical intermediates and specialty chemicals of high value.

Projected material balances show an overall product split of 80% refinery feed and 20% polar products. Based on product values and composition, a preliminary economic analysis yields 30% internal rate of return. A summary of the economic strategy, process results and promising products will be presented.

**KEYWORDS:** Shale Oil, Upgrading, Strategy

## INTRODUCTION

Green River Shale Oil (Western U.S.) is comprised of polar compounds, principally nitrogen and oxygen types, and non-polar compounds, principally paraffins, olefins and aromatics. The former may be valuable source of specialty and fine chemical while the latter may be refined into fuels and other petroleum products. To take full advantage of the values of the polar types, efficient processes for extraction, conversion and utilization of these types must be developed.

## COMPOUND TYPES IN SHALE OIL

The compound types found in shale oil include homologs, analogs and benzologs of pyridines, pyrroles, amides, ketones, nitriles, carboxylic acids, thiophenes and aromatic hydrocarbons. Some of these types are of extremely high value in their pure form. JWBA estimates that up to 10% of a shale oil barrel may be manufacturable into products of value greater than $1,000/bbl.

## ECONOMIC STRATEGY

Figure-1 shows the economic strategy for a value-addition venture from shale oil. Because recovery of shale oil has been a long-time historical focus, the technology and economics of retorting are fairly will understood (1). A guaranteed purchase of raw shale oil at $30/bbl (non-hydrotreated) may be sufficient to attract a qualified producer into production.

The intermediate stage of value-addition targets both broad-range concentrates and feedstocks for finishing by existing manufacturers of specialty and fine chemicals. In both cases, shale oil becomes a substitute source of feedstock. For broad-range concentrates, shale oil may substitute for coal tars; for specialty chemicals shale oil products may compete economically with synthetically produced chemicals or intermediates.

## PROCESS STRATEGY

Figure-2 shows a process strategy and a possible suite of products obtainable from shale oil. Shale oil is first separated by a thermodynamically logical sequence by molecular weight and polarity. The non-polar compounds are sent to a conventional petroleum refinery for manufacture of fuels, lube oils and waxes. Heavy ends may be used for asphalt or asphalt blending stock. The use of shale oil for specialty asphalt additives has been previously reported (2).

The polar fractions may be further separated to produce concentrates of specific types. Liquid-liquid extraction using acid, base, polar or polar-aromatics solvents all may play a role. Also, liquid-solid adsorption may be used to isolate specific types (3-5).

For large molecules, some form of dealkylation is needed to reduce the molecules to their bare-ring or mildly-methylated form. Hydrodealkylation is one such process which has shown promise. The resulting products are finished into concentrates of specific types which may prove marketable for production of specialty and fine chemicals.

## VENTURE STRATEGY

Before unconventional feedstocks can be incorporated into the marketplace as substitutes for conventional feedstocks or a source of new products, technology must be developed to exploit potential values found in these materials. There has been relatively little attention paid to utilizing shale oil as a source of nitrogen and oxygen-based molecular types and the prospects for breakthrough discoveries is high.

It is likely that future discoveries of new products with new activities (biological, toxicological, etc.) and properties (materials, polymers, etc.) will include unconventional resources such as shale oil, coal liquids, biomass, tar sand bitumen and other fossil sources not commonly assimilated into the energy economy today.

Ultimately, an opportunity for profitable investment must be developed. This involves not only price/cost relationships, but also market trends and acceptance of products. Current results show favorable price/cost relationships and markets for potential shale oil products are growing. The main task is to actually produce products for inspection and introduction to the buyer. Recent results aimed at achieving these objectives will be reported.

## REFERENCES


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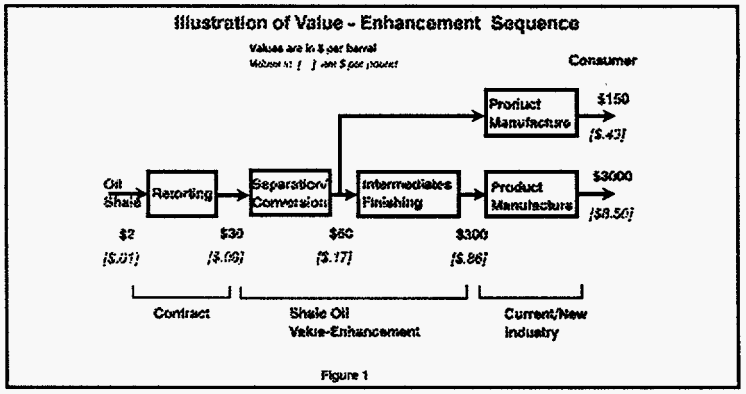

Figure 1

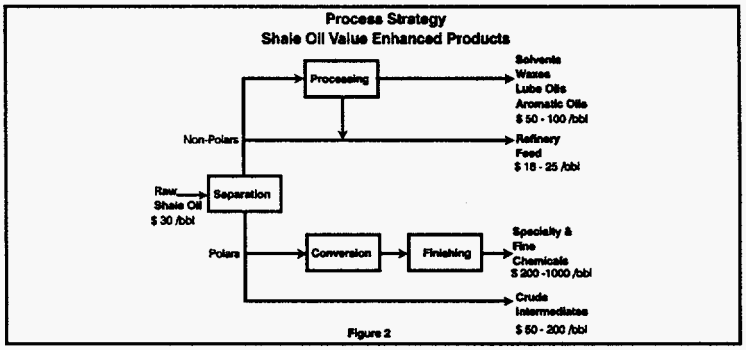

Figure 2