DOE/TIC-10734

Office of Energy Conversion
Energy Resource Development
Federal Energy Administration

Recommended Government Program for Development of In Situ Oil Shale Technology

September 30, 1974

Contents

I. SUMMARY

Successful development of in situ oil shale processing methods will open a large resource potential. In situ shale oil production could conceivably reach a million barrels per day by the early 1990's. The long-term environmental effects of a major oil shale industry--both beneficial and harmful impacts--are not yet known. The effects from surface retorting will be different from in situ processing. However, in situ technology, in contrast to surface retorting, is at an early stage. To increase the probability that at least one of these methods will prove both environmentally and commercially acceptable for large-scale operations in the 1980's, in situ technology should be developed on an immediate, high priority basis. Federal government action is needed to ensure full and prompt evaluation of the in situ option. This action is warranted both by the predominant Federal ownership of the oil shale resource itself and by the large potential it has for contributing to the Nation's energy supply.

The Department of Interior and the Atomic Energy Commission have proposed different development programs. The Interior plan would sell in situ leases to industry which would be more attractive than those unsuccessfully offered in Wyoming recently. Industry development of several in situ methods would be expected about 1980. Cooperative Government-industry research would be an added incentive to industry. The AEC proposes a Government program to demonstrate modified in situ technology

by 1980. It is estimated to cost about $100 million with participation offered to industry at low cost.

A program closely akin to the Interior proposal is recommended, based largely on discussions with Interior, the AEC and industry representatives. Major responsibility falls on industry under this plan, where most of the in situ expertise resides. Several techniques should develop rapidly and at moderate government expense.

Interior should initiate a leasing and cooperative research program immediately and should revise the current government research program in early 1975 after evaluation and selection of industry's cooperative research proposals. At that time, specific research responsibilities should be assigned to the AEC laboratories (Lawrence Livermore Laboratory and Sandia Corporation) with appropriate funding to cooperate with the Bureau of Mines and other Interior agencies. Lead responsibility for overseeing the overall Federal Oil Shale research program should be assigned to Interior; however, firm policy direction from high authority should be provided Interior to ensure (1) that the program is pursued on an expedited basis, and (2) that the extensive technical capabilities of the AEC laboratories are utilized.

It is recommended that four leases be offered for sale in early 1976, rather than two as proposed by Interior, to develop additional processing methods. The deferred bonus bidding terms of the prototype leasing program should be modified to increase the number of installments, allow deductions for test expenses, and permit the lessee to quit the lease on test failure.

Legislation should be proposed to change the Mineral Leasing Act of 1920 to provide a separate leasing allowance for in situ processing.

These recommendations should produce accelerated development of in situ processes. In the unlikely event that a leasing sale fails to attract suitable bids, government expenditures should be increased substantially to fund several large field tests of in situ processes under government direction but in concert with industry to facilitiate rapid technical development.

II. IN SITU DEVELOPMENT

In Situ Processing Opens Large Resourace Potential

The oil shale deposits of the Green River formation, located in Colorado, Wyoming and Utah, are the world's largest reserves. Most of the nearly two trillion barrels of shale oil resources (recent Interior estimate) are located in shales too lean or too deeply buried for profitable oil production by mining and surface retorting operations and thus present a unique opportunity for in situ processing. The latter is in its technical infancy, however, and a sound and expeditious program is needed to develop effective in situ methods. The most important reason for early development of in situ technology is to provide an alternative path to development of the Nation's oil shale reserves in case large-scale development by surface retorting is blocked by environmental or other considerations.

The Department of Interior and the Atomic Energy Commission have proposed alternative means of developing in situ technology. Consultations with Interior, the AEC, and industry representatives (see Appendix for meeting summaries) have produced a recommendation closely akin to the Interior proposal. However, support from the AEC laboratories (Lawrence Livermore Laboratory and Sandia Corporation) is included. The following report discusses these proposals and the recommended program.

Conventional Processing Will Challenge Industry

The Piceance Creek Basin, ranging over 1,250 square miles in western Colorado, is the richest single area of recoverable oil shale in the United States. Over 80 percent of future shale oil production is expected from this area. Primary commercial interest for production both by conventional mining followed by surface retorting (ex situ) and by in situ retorting is concentrated here.

Shale deposits in the Piceance Basin can be grouped in three zones: A relatively shallow (upper) zone which includes the rich Mahogany Ledge; a relatively deep, aquifer leached zone below the shallow zone; and a deep, unleached zone. Rich Mahogany deposits are found in the Uinta Basin in Utah also.

Industry estimates reserves of approximately 80 billion barrels in the Mahogany zone of these two basins in deposits at least 30 feet thick and averaging 30 gallons of oil per ton of shale. This represents a resource target worth over 20 years of the total 1973 domestic production rate of petroleum. Indeed, the "accelerated" production case of Project Independence Blueprint's Oil Shale Task Force report predicts only a five percent usage of this prime resource by conventional mining and surface retorting through 1990.

The accelerated case estimates a rate of 1.6 million barrels per day in 1990, which is equivalent to 16 processing complexes producing 100,000 barrels per day each. All of this is assumed to be from surface retorting. The task force report goes into considerable detail to show how sorely industry would be taxed to achieve this level with surface retorting technology that is ready now for commercial pioneering. Production of about 800,000 barrels per day is planned for the 1980's by nine companies and joint ventures through 13 projects for mining and surface retorting. Providing that environmental impacts prove acceptable, most of these plans, as well as additional projects, should develop provided also that a stable U.S. energy policy emerges and crude prices remain at present levels relative to the general economy.

Need for an Early In Situ Option

There are many areas of environmental unknown at present. For the industrial plants now under consideration, the concerns are limited and relatively well defined. However, the long-term environmental effects of a major oil shale industry cannot be ascertained at this time due to numerous variables. Both beneficial and harmful impacts will occur, which will have to be weighed incrementally as experience is gained. Both in situ and ex situ methods will have their own, unique sets of positve and negative characteristics vis-a-vis the environment. The extent to which either approach ultimately will be used on a large scale cannot be determined at this time. If the Nation's objective is to acquire the capability for large scale production at the earliest possible date, it would be prudent to move immediately to develop the in situ option. This will provide insurance against the possibility of future actions that limit the extent of surface retorting.

Future In Situ Technical Prospects

In situ clearly has potential as a primary recovery method. In addition, greatly increased overall recovery may be accomplished by "modified in situ" processing following mining and surface retorting operations in the Mahogany zone. Processing shale after rubblizing it into an existing or created void to produce permeability in an otherwise impermeable material is termed modified in situ. Air is forced downward through such a permeable column to retort oil from the shale by burning part of the combustible material. Such a secondary recovery method in combination with mining may prove to be the most efficient overall recovery scheme. Another very high recovery method which now appears economical for shallow deposits is open pit mining followed by surface retorting.

Modified in situ processing as a primary recovery means appears to be a particularly promising method to recover oil from the leaner upper zone shales that are uneconomical for mining and surface retorting. Oil recovery of 50 percent or more has been predicted by some engineers, although others expect no more than 20 percent.

In situ retorting schemes are proposed to produce the deep, unleached zone shales, also.* Shell has made preliminary field tests on a process to produce a porous chamber in an otherwise impermeable zone. Soluble

minerals in the shale are leached with hot water, followed by steam injection into the permeable area to produce the oil. Various other heating fluids such as hot methane have been tested by industry in limited field experiments. Generally, fracturing has been used to produce permeability. All of these methods are at an early development stage and will require considerable additional laboratory and field work.

Both mining and in situ operations within the leached zone (the generally permeable saline aquifer zone where the abundant nahcolite mineral has been leached out of the shale) present difficult technical problems. Pumping to create a workable water-free bubble in this zone probably will be too expensive, if technically feasible.

Further studies, such as those recently commissioned by the Bureau of Mines, will help to clarify prospects for efficient recovery methods for the lower zones. The present Bureau studies concern the feasibility of single pass open pit mining, underground mining, and modified in situ processing of deep deposits. These types of studies are needed to develop a sound basin plan for high resource recovery before a center basin leasing program should be extended beyond the stage of initial leases for in situ process testing and pioneering commercialization.

Characteristics of In Situ Processing

Many benefits have been cited for in situ processing relative to conventional operations. Opinions differ about such advantages and they should be considered speculative at present. The large water requirements of surface retorting, largely for spent shale disposal, are predicted by some to be halved for in situ operations at the same production levels. However, aquifer poisoning by underground leaching is a potential problem for in situ processing, much the same as the leaching of surface shale disposal piles produced by ex situ operations is a potential source of pollution for surface water courses.

Reduced surface disturbance by in situ operations compared with surface retorting is often stated as an advantage. Some shale removal and surface disposal will be necessary for modified in situ operations, but the disposal volume would be reduced to a third or less. However, some companies expect considerable surface disturbance from in situ facilities and point to the considerable network of injection and producing wells, compressors, gas treating equipment, access roads, and service lines which will be required for a commercial operation. Because of this, in situ operations may involve a larger surface area than the equivalent conventional operation. The important consideration, however, is not so much size of area as the nature of disturbed areas

after restoration. Clearly, no sizable disturbance will be allowed unless assurance of acceptable rehabilitation is available.

A lower labor requirement is expected for in situ processing, resulting in a smaller associated population effect on the shale areas of Colorado and Utah.

In situ shale oil has been predicted by some to be considerably cheaper to produce than production by surface retorting. This is questioned seriously by others who see expensive solutions to technical problems confronting in situ operations.

Industry Has Considerable In Situ Experience

Many companies have made large expenditures to develop in situ techniques for tertiary petroleum recover from oil sands and shale oil recovery from shales. A recent survey by the Oil and Gas Journal (March 25, 1974,) shows that the oil industry is operating or has recently terminated 177 separate projects to increase its experience in the recovery of petroleum by means more sophisticated than conventional waterflooding. Near-future projects are expected to consume over $100 million, most to be spent in 1974.

In situ shale processing has been studied in the laboratory by most of the oil companies. Some have spent large sums on field tests of promising ideas. Occidental Petroleum Corporation's spending on their current development effort

for modified in situ processing is approaching $10 million. Shell recently spent about $6 million on field tests of their leaching and steam in situ recovery concept for deep zone areas. Mobil, Arco, Sinclair (now part of Arco), Exxon, Equity and others have made significant expenditures, also. Much of the work has involved fracturing by hydraulic or chemical explosive means to create permeability followed by air combustion or hot fluid injection to retort the fractured formation.

Occidental's modified in situ field work began near DeBeque, Colorado, in August, 1972. The first field test was a 30'x30'x72' mined and collapsed retort using an initial void space of 20 percent. They produced 25 barrels per day of raw oil and reached 60 percent oil yield from the rubble (Fischer assay basis), according to company officials. Their second test or "room" is 30'x30'x90', which they are now retorting. A 10 percent initial void space was mined out for this test and the resultant tighter rubble has produced a greater input air pressure drop and a lower air rate. In turn the oil rate has dropped to about 10 barrels per day. Their third "room," which is 30'x30'x120', is underway now. Greater than 20 percent of the shale was removed for the initial void space. A fourth "room" is being mined now to produce a commercially sized rubble volume of 120'x120'x330' which should be retorted during all of next year. Relatively barren rock (two to three

gallons per ton) is being removed and the entire seam (five gallons per ton to high grade) will be retorted. With high yield from such "retorts" spaced closely together, Occidental hopes to approach 50 percent recovery of the total oil in a given shale deposit.

Interior's recent Prototype Oil Shale Leasing Program sale demonstrated serious industry interest in in situ processing. Although the four Colorado and Utah tracts were not selected by Interior with in situ processing as the expected recovery method, a number of in situ bid proposals were received for them. Occidental bid over $16 million for the Colorado-a tract and over $25 million for the Utah-a tract. The Geokinetics Group bid $52.5 million for the Colorado-b tract and $11.5 million for the Utah-b tract. None of these bids were successful, but they represent strong evidence of industry's interest. Lack of industry bidding on the two Wyoming leases offered, which could only be developed by in situ processing, is not considered significant because there are no promising in situ techniques available to develop the thin beds characteristic of Wyoming shales.

Government Needs Complement those of Industry

Industry needs field prototype experience indicating successful application of an in situ process to a significant oil shale resource target. They realize that many engineering techniques must be developed or refined before a process can be commercialized. And they are deterred from committing large

expenditures to field development because of the uncertainties of oil shale land availability for commercialization, price stability and national energy policy. This environment presents a very high risk when industry's profit opportunity appears to have limited prospects. Mining and surface retorting operations now appear little more than marginally attractive because of rapid inflation. The prospect of developing a successful in situ process with reduced investment and operating costs (compared to surface retorting) appears questionable to some companies. Limited technical manpower must be committed to the most promising new energy areas in synthetic fuels, and many companies wonder whether coal liquefaction is the next most attractive technology beyond conventional oil shale technology.

The government desires to accelerate domestic energy development, including in situ oil shale processing, to mitigate oil import effects. Given the present industry environment discussed above, a major government effort will be needed to accelerate in situ technical development.

An in situ development program should provide the government with needed information for basin development planning to conserve resources through future leasing policies. This includes technical, geologic, hydrologic and environmental data. The Department of Interior has a budget of $11.7 million in the current fiscal year for oil shale research which includes a number

of programs to collect this important background information. These programs are run within Interior by the Bureau of Mines, the U.S. Geological Survey, the Bureau of Land Management, and the Fish and Wildlife Service. Interior plans a step-up in their activities during FY 1976 and is requesting a $19.6 million oil shale budget.

The Assistant Secretary of the Interior for Energy and Minerals coordinates these research activities with the assistance of the Office of Research and Development. Clear definition of the research objectives of the agencies and periodic progress review by the Assistant Secretary is essential to an effective program, where the subprogram responsibilities are so fragmented.

Another valuable source of background data comes from the prototype leases. The companies pursuing development on these leases supply Interior with all information which they obtain about the tracts. Interior uses this information in their internal evaluations, but makes public only that which is non-proprietary.

III. ATOMIC ENERGY COMMISSION AND DEPARTMENT OF INTERIOR PROPOSALS

A. Department of Interior Proposal

Interior Proposes Leasing and Government-Industry Research

Interior's proposal aims to accelerate industry development of in situ technology while obtaining information for planning a continuing leasing program for oil shale deposits. Such information is necessary to promote efficient resource utilization. Their objective is readying alternative in situ recovery methods for commercial application by 1980.

The program consists of government-industry cooperative programs and competitive leasing of two attractive new prototype tracts for in situ development as an extension of the current Prototype Oil Shale Leasing Program. Interior expects substantial industry participation at moderate government expense. Information from both program elements would shape ongoing government oil shale research.

Call for cooperative research proposals from industry would be made by Interior in October or November, 1974. Proposals would be open to requests for government technical assistance, funding, test acreage on government land, or a combination of these. Evaluation and selection of industry's proposals in early 1975 would be based on promise of early technical assessment to assist Interior with the final decision to proceed

with sale of the prototype in situ leases in early 1976. Patent and confidentiality agreements would be negotiated to protect proprietary interests.

Lease nominations would be requested from industry during the November-February period, also. By about June, 1975, two tracts each of about 5,120 acres or less would be selected and preparation of a supplemental environmental impact statement for their development begun. Public hearings and submission of a final statement should be completed by the early 1976 lease sale date.

Proposed leasing terms for the two in situ tracts are similar to those of the recent prototype leases. Sale would be by competitive bonus bidding with payment in five equal annual installments of which the last two could be offset by development expenditures. A program leading to a minimum eventual in situ production of 30,000 barrels per day subject to royalty would be required. Contingency for research failure would allow release of the lessee from further lease obligations.

According to the Interior plan, industry development activity on the two leases during the four years through 1979 coupled with supportive government research programs should bring two in situ techniques (probably including a modified in situ process) to technical readiness for commercialization by 1980. They feel that this proposal fits the Congressional guidelines of the Mining and Minerals Act of 1970 which assert that it is government policy to encourage mineral resource development by private enterprise.

Proposal Has Major Industry Involvement

The chief advantage of the Interior plan is its assignment of the major technical development responsibility to industry. Industry has much experience in in situ operations and the broad technical talent to develop a practical approach to commercial oil shale operations if it can be done at expected price levels. Government's technical abilities in this field would complement those of industry.

This arrangement appears to have the best chance of developing commercially practical techniques. Further, development by industry should produce the most rapid application of in situ techniques to large commercial operations. And there would be close coordination with ex situ oil shale developments by industry to promote an efficient combination of shale processing methods where appropriate.

This program moderates government expense to develop technology while providing information needed for future lease planning and environmental control. In providing supplemental technical assistance, government organizations such as the Bureau of Mines and the Atomic Energy Commission should have ample opportunity to contribute to the progress of in situ development.

Parallel Development Emphasized

At least two in situ techniques would be tested by the Interior approach if industry responds. A lease offered in the upper zone of the Piceance Basin probably would draw modified in situ bids from at least Occidental Petroleum and the Geokinetics Group who made modified in situ bids for the recent Colorado and Utah leases. Several companies

have expressed interest in a lower zone lease to determine the feasibility of purely in situ methods in this area. A leasing and cooperative research program would provide a large incentive for these companies and others to develop their proprietary concepts.

Companies Favor Leasing Incentive

All companies interviewed said that suitable shale leases would be the major incentive needed to start substantial industry in situ development activity. Two leases, chosen by Interior from industry nominations which are likely to be made in the Piceance Basin, would be attractive for the various in situ techniques now under early development by industry. These leases would be in sharp contrast to those recently offered in Wyoming for which applicable techniques do not appear promising. And some of the companies interviewed, which have not given serious consideration to a substantial in situ development program in the past, would try to participate now in a lease offering, particularly because of the possibility of cooperative research.

It was disclosed in many of the industry interviews that companies are accustomed to dealing with Interior for mineral leases and would have confidence in the stability of such a program. Another advantage is Interior's readiness to implement

both the in situ leasing and cooperative research programs based on established procedures. The overall program should move readily with no schedule slippage expected.

More In Situ Leases Are Needed

Limiting the lease to two tracts is a disadvantage of the Interior proposal. The offer of four tracts, for example, would double industry's commitments and improve the likelihood of at least one development successfully reaching commercial scale in the early 1980's. Two lean, upper zone tracts, with and without aquifer intrusion, might be chosen to encourage the development of differing modified in situ techniques. Two deep, unleached zone tracts probably would bring forth different in situ approaches for the deep zone, again broadening technical development.

Leasing Terms Should Be Modified

The proposed bonus bidding system is another deterrent to broad industry interest. Sealed bonus bidding may produce larger Federal sale revenues but it places an extra tax on an industrial developer when capital is needed for project development.

Change to a commitment bidding system similar to that employed by Canada would receive the greatest industry response. These commitments would be agreements to pursue research and development on shale deposits, or to spend certain sums of money in stated periods for assessment of reserves and construction of commercial facilities. In bid selection, Government's main concern would be the bidder's qualification to carry out a well-planned enterprise with dispatch. Commitment leases should be non-transferable to prevent speculation and should allow the lessee to drop the lease without further obligation. Note that while commitment bidding would greatly stimulate industry, bid selection becomes difficult when competition is heavy for a limited number of leases.

Use of commitment bidding conflicts with Interior's present policy to sell leases at market value. Policy change is expected to provoke public reaction, causing program delay. However, modification of deferred bonus bidding is possible to achieve approximately the same accelerated activity expected with commitment bidding. Extended payment terms beyond the five installments now proposed would encourage much more program participation. It would better recognize the uncertainty of in situ technology and the time required to evaluate a proposed technique on a test portion of the lease before expansion to commercial scale on the remaining acreage.

Payment by ten rather than five equal annual installments is suggested, with the first payment accompanying the bid offer. In situ field testing expenses during the first, second, third and fourth years would be credited against bonus installments due at the end of each of these years (the second through the fifth payments). Similarly, commercial development expenditures during the third, fourth, fifth and sixth years would be credited against bonus installments due at the end of these years (the fourth through the seventh payment). These extended terms and credits for performance would be major inducements to accelerate the program. The terms would retain the contingency provision proposed by Interior, allowing the lessee to quit the lease on test failure without further obligation.

A test program proposal and its speculative future commercial application to the lease would be submitted by industry with each bid. Submission of a lease development plan for Interior approval prior to the start of commercial operations would be required, as in Interior's present prototype leasing policy.

B. Atomic Energy Commission Proposal

AEC Proposes Rapid Modified In Situ Project

The Atomic Energy Commission sees major promise in the modified in situ technique for shale oil production. They recommend use of the skills of two of their prime contractors, developed during the underground nuclear testing program for military purposes and the Plowshare Program (peaceful applications), to develop the method. A six year project is proposed with an estimated government budget of $100 million dollars. Participation would be offered to industry at low cost. They feel that this development would then have the potential for commercial expansion to produce a million barrels per day of shale oil by 1983 or 1984. This last projection appears far too optimistic (see Chapter II).

The AEC interest in shale development results in part from a Plowshare proposal in 1967 (Bronco Project) to stimulate an oil shale zone by nuclear means. It was planned but not carried out. Lawrence Livermore Laboratory (LLL), (a contract operation for the AEC by the University of California), has been in charge of the Plowshare program and recently has been doing research on non-nuclear alternatives to nuclear stimulation as part of the program. This includes methods for producing fuels by fracturing tight gas sands, gasifying coal in situ and retorting oil shale in situ. Additionally, the Sandia Corporation (another AEC contract laboratory run by Western Electric, a subsidiary of AT&T) recently has broadened their interest in new energy development beyond their traditional

nuclear weapons system engineering function. In situ oil shale development is one of the new areas in which they have made preliminary efforts to apply their accumulated engineering talents.

LLL and Sandia began background research for in situ oil shale development again in 1973. Their FY 1975 budgets for this work are about $1.4 and $0.5 million, respectively. Rock fracturing predictions for chemical high explosives to rubblize the shale and modeling of the subsequent in situ retort process are underway at LLL. Sandia is conducting bench scale in situ experiments. They plan to apply jointly their considerable computer and mathematical modeling skills, developed to simulate complex nuclear explosion phenomena, to design effective laboratory and field in situ experiments. Recently, Sandia contributed sophisticated instrumentation know-how developed for the underground nuclear weapons experiments to the most recent in situ oil shale fracturing tests at Rock Springs, Wyoming, carried out by the Laramie Energy Center of the Bureau of Mines.

Under the AEC proposal, the LLL laboratory program would expand considerably to initiate bench and pilot scale experiments in addition to the present program. Such LLL and Sandia support work would be in parallel to shallow phase and deep phase in situ field tests. LLL would have overall program management responsibility.

Early results from the laboratory experiments would guide final plans for the field tests. The shallow program would get underway in FY 1975 to mine, rubblize, instrument, retort and evaluate two or three chambers (50'x50'x100') using an existing mine offered by Mobil Oil to expedite completion of this phase by the end of FY 1977. Sandia would provide the instrumentation expertise. Deep phase planning also would get underway in FY 1975 with construction starting in FY 1976. Shallow phase results indicating insurmountable technical problems or uneconomical technology would stop the deep phase. Otherwise, rubblization, instrumentation and retorting of three or four large deep chambers would proceed with the completion of their evaluation in FY 1980. Three of these chambers are proposed to be 100'x100'x300' with the fourth 250'x250'x1000'. Industry participation would be expected at the start of the deep phase, if it has not been attracted earlier.

The AEC proposal would expand the current laboratory tests to about $5.2 million for FY 1975, add $6.7 million for field and mining work and $0.7 million for instrumentation work. The second year is estimated at $17.15 million and the third year at $20.6 million. Total for the first three years is approximately $50 million with another $50 million estimated for the final three years, yielding a total six year program cost of approximately $100 million.

It appears that more than half of the program funds would

be committed before an evaluation of the shallow phase results could indicate whether the program should be completed. A parallel nuclear in situ effort is under consideration for perhaps a $70 million addition over the same six year period, but has not been included in this proposal.

The AEC Program Has A Rapid Start

The development by the AEC would make a fast start based on a substantial research program that has been underway over a year. Expansion into field work could take place easily because of the AEC laboratories' long experience with Plowshare projects. And given single agency responsibility to complete the task they should proceed through the development with smooth coordination.

The AEC program develops a technical basis for pioneering commercial application of modified in situ technology by about 1980, if successful. It enables direct technical input of the expertise from the underground nuclear experimental program. Industry participation is expected which would bring valuable in situ experience to the project.

The field work proposed by the AEC program would require an environmental impact statement before beginning operations. It is unlikely that it could be completed sooner than Interior's early 1976 statement completion date. And early field test planning by LLL and Sandia, while awaiting completion of their statement process, would be paralleled under the Interior proposal by industry planning work for bid proposals on the tracts.

Resource Application is Limited

The modified in situ technique is only one approach, with the leaner portion of the upper zone as its chief target. The advance of in situ technology promoted by government needs a broader effort to produce technical information about the much larger resources in the deep zone for which no technology may be near development.

Nominal Industry Participation is Expected

Only limited industry effort in the AEC project is likely. While a number of nominal participants can be expected when the entry cost is low, major industry commitment of technical manpower is remote where there is no opportunity for individual company proprietary advantage. Further, government motives in operating such a large commercially oriented effort would be questioned by many. It is likely that industry would view the project as a Federally backed competitor. And it would create an incentive for an industrial concern or group to suspend parallel development efforts.

AEC Proposal Duplicates Occidental's Work

Occidental Petroleum Corporation has made a substantial investment over the past two years to develop modified in situ technology (see description under Chapter II). They have made definite progress in solving some of the associated engineering problems.

LLL and Sandia have approached Occidental offering major program assistance, but this was rejected. Occidental officials state that these AEC contractors have skills which would be very helpful, but that they are not willing to make information from the entire project public, as the AEC offer required, and lose their proprietary advantage. They insist on a secrecy agreement and patent coverage to protect their commercial interest. Obviously, a cooperative arrangement between Occidental and the AEC laboratories would advance modified in situ technology most rapidly because of Occidental's substantial technical lead.

Failure of the overture to Occidental has led the AEC to make their present proposal which would largely duplicate Occidental's past and ongoing effort (compare the Occidental program, Chapter II, with the AEC plan given earlier in this chapter). The AEC justifies their proposal, in spite of this, by maintaining that the Occidental program does not have sufficient technical support for ultimate success without AEC laboratory assistance. This reasoning seems to be at variance with the Government's policy to encourage mineral resource

development by private enterprise (Mining and Minerals Act of 1970).

Industry Favors Leasing Program

All of the companies interviewed, with the exception of Mobil, feel that the AEC project would suffer for lack of major industry involvement. A fair amount of industry expertise would be available to the project, however, since many oil company contractors would be hired to perform much of the construction and operations work. But wasteful reinvention is likely without significant industry financial involvement and program responsibility. As stated earlier, most companies feel that a leasing program would galvanize industry action and produce several promising approaches to in situ processing.

Mobil Oil studies indicate that modified in situ processing is a high risk operation and can only be developed by large field tests costing $50 to $100 million. They alone prefer a large government-funded program, directed by AEC, because they do not think that industry will undertake such a large, risky development. (See Appendix; record of discussion on September 5).

IV. RECOMMEND GOVERNMENT PROGRAM

Modified Leasing Program is Recommended

A program encouraging industry development of in situ processes is recommended, based on the analysis of the last two chapters. The Department of Interior should be assigned management responsibility for the overall Government program.

Call for in situ lease nominations should be advertised immediately so that sales can be made in early 1976. To meet this schedule, nominations should be closed in March, 1975, and tract selections should be made by June, 1975. Preparation of a supplemental environmental impact statement can begin then, followed in an expeditious manner by public hearings and release of the final statement so that the lease sales will not be delayed.

It is recommended that four tracts, suitable for commercial scale operations, be offered by the in situ leasing program. For example, two lean, upper zone tracts, with and without aquifer intrusion, and two deep, unleached zone tracts might be offered to encourage broad industry activity.

Interior's proposed deferred bonus bidding leasing terms should be modified by increasing the number of installment payments to increase industry participation in the sale. It is suggested that payment be made in ten installments, with the first payment accompanying the bid offer.

Credits for early test and commercial development expenses should be used to provide a high incentive to accelerate lease activities. In situ field testing expenses during the first, second, third and fourth years should be credited against bonus installments due at the end of each of these years (the second through the fifth payments). Similarly, commercial development expenditures during the third, fourth, fifth and sixth years might be credited against bonus installments due at the end of these years (the fourth through the seventh payment). The terms should retain the contingency provision proposed by Interior, allowing the lessee to quit the lease on test failure without further obligation.

Leasing Act Modification is Needed

Legislation should be initiated to modify the Mineral Leasing Act of 1920 to provide a separate leasing allowance for in situ processing. The Act now limits an individual company's total leased oil shale holdings to 5,120 acres (equivalent to eight sections). Companies interested in applying relatively well developed mining and surface retorting technology generally want more acreage than this to extend commercial development of these ex situ methods. Accordingly, these companies are disinclined to commit their leasing potential to in situ development even though they may have a strong interest in it.

Alternatively, it is suggested that an even broader, more desirable change in the Leasing Act of 1920 be considered. A policy permitting individual company holdings of 10,000 to 20,000 acres per state would have a beneficial effect on industry's oil shale activities, generally, as well as greatly increasing their incentive to develop in situ processing. A further inducement for all of industry's oil shale activites would be a policy change excluding producing leases from whatever allowance level is established.

Cooperative Research is Needed

A Government-industry cooperative research program should be advertised immediately, with selection of proposals and supplemental funding requested by April, 1975. Industry proposals should be open to requests for Government technical assistance, funding, test acreage on Government land, or a combination of these. The Government needs this program to gain technical information about industry's current in situ research as assistance for selection of sale tracts from those nominated and to redesign, as appropriate, the Government oil shale research program.

Research Program Manager Recommended

The Department of Interior's FY 1976 request for the Government oil shale research program is $19.6 million. This is fragmented into subprograms run by the Bureau of Mines, the U.S. Geological Survey, the Bureau of Land Mangement and the Fish and Wildlife Service. The Assistant Secretary for Energy and Minerals,

to whom the first two agencies report directly, coordinates the overall research program, assisted by the Office of Research and Development. It is recommended that a single Program Manager be designated for oil shale, with line authority and accountability to the Assistant Secretary for overseeing the total research program.

BuMines/AEC Participation is Important

A great deal of experience and expertise is available within the Government to apply to oil shale development. The Government budget, controlled by Interior, should finance the Laramie Energy Center, the Lawrence Livermore Laboratory and Sandia to participate directly in individual industry field tests. Much cross-fertilization of both industry and the Government laboratories would result to the benefit of the specific project concerned and the overall in situ program. Such direct cooperation must protect proprietary interests of the companies involved. As an example, the Bureau of Mines has operated successfully in this manner for a number of years. Sandia is particularly important to such a program because of their expertise in making underground measurements and developing new measurement techniques.

Integration of AEC Activities

After evaluation of industry cooperative research proposals and appropriate redesign of the Government research program by April, 1975, the Department of Interior should assign

specific research responsibilities to the Atomic Energy Commission laboratories (Lawrence Livermore Laboratory and Sandia Corporation) with adequate funding in coordination with the research efforts of the Bureau of Mines and other Interior agencies. The Atomic Energy Commission laboratories should continue their oil shale work as presently funded in their FY 1975 budgets until the above integration occurs through a a FY 1976 supplemental budget request.

Recommended Program Fits Well in ERDA

Department of Interior program leadership would transfer smoothly into the proposed ERDA organiation Responsibility would fall under the Assistant Administrator for fossil fuels development, who would be closely coordinated with the Assistant Administrator responsible for nuclear matters to whom LLL and Sandia presumably would report. This intra-agency relationship should facilitiate the transfer of specific responsibilities and funds to LLL and Sandia. It should lead also to a closer working relationship between the Bureau of Mines and the AEC contract laboratories which would be beneficial to all. Overall progress toward large-scale commercial production should be evaluated on a continuing basis by the Federal Energy Administration until such time as a Department of Energy and Natural Resources is created.

Development Prospects

These recommendations should produce accelerated development of in situ processes. In the unlikely event that a leasing sale

fails to attract suitable bids, government expenditures should be increased substantially to fund several large field tests of in situ processes in concert with industry and thus ensure rapid technical development.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. In situ oil shale processing--short of a major "crash effort"--has limited potential for reaching substantial energy production levels by 1985, but it has large potential by the 1990's as a primary recovery method and as a secondary method following mining and surface retorting.

2. Full and prompt evaluation of the in situ option is warranted to provide the Nation with an alternative development path in the event that mining and surface retorting is limited by environmental or other reasons.

3. Acceleration now of in situ development could have processes ready for commercial application in the early 1980's so that large-scale production can develop by the 1990's.

4. Field testing is needed to develop and prove the economic, technical and environmental aspects of in situ processes.

5. Parallel development projects are needed to develop in situ techniques applicable to the differing oil shale resource zones.

6. Large in situ development projects should be performed by industry for best chance of technical success and applicability to ensuing commercial operations.

7. Leasing of attractive government lands in commercially sized blocks is the most important incentive for industrial participation in in situ development. In situ bids for the receont Colorado and Utah sales, although unsuccessful, strongly indicate that future sales of appropriate in situ leases will galvanize industry development efforts.

8. Early government-industry cooperative in situ research is important to provide guidance for in situ lease selection and sale award; and it will shape effective government research.

9. The Department of Interior is suited best to direct oil shale leasing, government-industry cooperative research and government research. A smooth transition of this function into ERDA should occur.

10. The Atomic Energy Commission proposal to develop modified in situ technology would be hindered by lack of experience in fossil energy industry development work that is commercially oriented, by limited industry support, and by problems of technology transfer. A large government project may discourage industry's development efforts.

11. Industry response to in situ leasing will be greater if the deferred bonus bidding terms of the recent prototype sales are modified to increase the number of installment allow deductions for test expenses, and permit the lessee to quit the lease on test failure.

12. A change from deferred bonus bidding to commitment bidding will receive the greatest industry response.

13. Modification of the Mineral Leasing Act of 1920 to provide a separate leasing limitation for in situ processing will stimulate industry.

14. In situ development would be accelerated by participation of the Bureau of Mines and the Atomic Energy Commission in industrial field experiments under suitable conditions to protect proprietary information.

Recommendations

1. The Department of Interior should be assigned management responsibility for government in situ development activities.

2. Interior should be given firm, explicit direction to pursue in situ development on an immediate, high-priority basis and to ensure that the extensive technical capabilities of the AEC laboratories are utilized. Target dates for specific accomplishments should be specified.

3. The Federal Energy Administration should be assigned the responsibility to evaluate, on a periodic basis, the progress being made toward large-scale commercial production and should chair an ad hoc inter-agency review committee that would meet quarterly.

4. Call for in situ lease nominations should be advertised immediately so that sales can be held in early 1976 after tract selection and completion of a supplemental environmental impact statement.

5. Four in situ leases suitable for the differing shale zones should be offered for sale, rather than two as proposed by Interior, to develop additional processing methods.

6. Deferred bonus bidding terms should be modified to increase the number of installments, allow deductions for test expenses, and permit the lessee to quit the lease on test failure.

7. A government-industry cooperative research program should be advertised immediately, with selection of proposals and supplemental funding requested by March, 1975. After evaluation of industry cooperative research proposals and appropriate redesign of the government research program, specific research responsibilities should be assigned to the Atomic Energy Commission laboratories (Lawrence Livermore Laboratory and Sandia Corporation) with adequate funding in coordination with the research efforts of the Bureau of Mines and other Interior agencies. The Atomic Energy Commission laboratories should continue their oil shale work as presently funded in their FY 1975 budgets until the above integration occurs through the FY 1976 supplemental budget request.

8. Within Interior, a single Program Manager should be designated for oil shale, with line authority and accountability to the Assistant Secretary for Energy and Minerals for overseeing the total research program.

9. Legislation should be initiated to modify the Mineral Leasing Act of 1920 to provide a separate leasing allowance for in situ processing.

10. In the unlikely event that a leasing sale fails to attract suitable bids, government expenditures should be increased substantially to fund several large field tests of in situ processes in concert with industry to facilitate rapid technical development.

A P P E N D I X

RECOMMENDED GOVERNMENT PROGRAM FOR DEVELOPMENT OF IN SITU OIL SHALE TECHNOLOGY

File Memoranda of Consultations with AEC, DOI and Industry Representatives

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Office of Energy Conversion
Federal Energy Administration

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