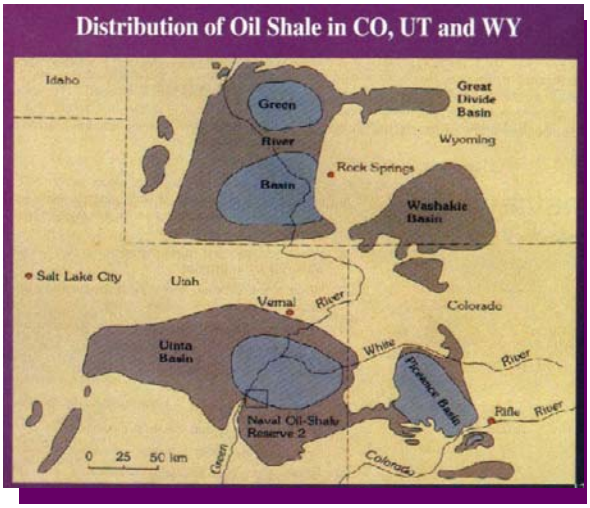
U.S. Department of Energy • Office of Fossil Energy
National Energy Technology Laboratory
Strategic Center for Natural Gas and Oil

2007 Oil Shale Environmental Issues and Needs Workshop



October 18, 2007
Colorado School of Mines
Golden, Colorado

Disclaimer

Note of Thanks to Workshop Participants

This report is one step along the path to identifying effective research and development efforts to address environmental issues and needs associated with development of United States Oil Shale resources (especially those of the Green River Formation) of Colorado, Utah and Wyoming. We thank all the participants and their companies for their contribution of time and insights in participating in the 2007 Workshop and in helping to prepare this document.

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Executive Summary

The 2007 Oil Shale Environmental Issues and Research Needs Workshop held in Golden, Colorado on October 18, 2007 confirmed a high level of interest on the part of stakeholders in identifying R&D opportunities related to the environmental issues surrounding potential development of oil shale resources in the Western U.S. The Workshop was sponsored by the National Energy Technology Laboratory and the Colorado School of Mines, and was held in conjunction with the Colorado School of Mines' 27th Oil Shale Symposium at the Green Center on the Colorado School of Mines campus in Golden, Colorado.

One central theme of the workshop was that potential oil shale development should be evaluated in concert with the ongoing and future development of all natural resources region-wide. Thus, strategies to manage the environmental aspects of air, water, solid waste, and carbon should be addressed on a regional basis taking into account all natural resource development, not just oil shale.

Another general theme was that information and data should be shared publicly as much as possible, and a set of baseline environmental data should be established for air, land and water as a starting point for modeling and forecasting.

There was general support for a Federal government role in four areas. It was noted that the government could:

- Facilitate communication among industry, state and federal regulators, and other stakeholders,

- Provide funding and direction for a data gathering and regional systems modeling efforts that can be used to determine the costs and benefits of various resource development scenarios taking into account the cumulative impacts of the entire spectrum of land use options.

- Collect an objective "baseline" data set and make this data available to the largest possible number of users while preserving the intellectual property rights of technology developers, and

- Identify, collect and publicly disseminate historical data and information from oil shale development that occurred during the 1970s and 1980s.

There was general support for re-establishment of a collaborative effort similar to that of the Oil Shale Environmental Task Force, active from 1978 to 1984. The previous Task Force organized an umbrella organization of oil shale researchers that included National Labs, universities, and others.

This approach, or something similar, could be beneficial in that it would:

- Provide a framework for organizations to contribute data and expertise in a transparent and collaborative manner,

- Act as an aggregator of data and a developer of regional/basin level assessments, work that no individual technology or resource developer has an economic motivation to pursue,

- Provide a mechanism for strengthening the interaction among state and local governments, the public, various federal agencies, the industry, environmental groups, and others interested in ensuring that any oil shale industry is developed in an environmentally sound manner, and

- Provide input to DOE for its management of R&D opportunities funded by the Office of Fossil Energy

Two environmental challenges that were highlighted by the attendees that had not been so prominent in the challenges identified during previous workshops were:

- The challenge of quantifying the level of mercury emissions that might accompany either surface retorting or in situ recovery of oil from oil shale. The concern was that this challenge was not specifically identified and the levels of mercury emissions associated with 1980s technologies would be unacceptable today.

- The challenge of dealing with the large volumes of carbon dioxide that could be generated by either surface or *in situ* processes, and the notion that underground sequestration is a possible solution that needs evaluated comprehensively -- both the volume to be generated and the potential places to store it.

More than 60 professionals attended the 2007 workshop and represented a cross section of stakeholders involved in oil shale development activity. The group's top priorities identified at the workshop include:

- An integrated basin/regional baseline for surface and groundwater data (both quality and quantity) and customized GIS-based analytical tools for analyzing and working with the data.

- Accurate, predictive regional models for release, fate and transport of air emissions from oil shale operations and other activities.

- Research to evaluate generated contaminants and water consumption, and evaluation of Best Available Control Technology.

- Regional energy/resource system model that will enable cost/benefit analysis of a large variety of resource development and land use alternatives in a comprehensive way.

While the participants provided many thoughts and perspectives on a wide variety of issues and concerns, these four elements appeared to form common threads through much of the discussion.

Finally, the Next Steps outlined at the conclusion of the Workshop included:

1. Preparation of a draft report on the proceedings of the workshop, distribution of the draft report for comments, and preparation of a final report.

2. Integration of the findings from the Workshop into NETL's planning of its future R&D portfolio.

3. Engagement of the wider oil shale community to ascertain the level of interest in forming a collaborative effort similar to the previous Oil Shale Environmental Task Force to help to further develop an oil shale environmental R&D strategy.

Purpose of the 2007 Workshop

The 2007 Oil Shale Environmental Issues and Research Needs Workshop was held on Thursday October 18th, immediately after the 27th Oil Shale Symposium, at the Green Center on the Colorado School of Mines (CSM) campus in Golden, Colorado.

The Workshop was sponsored by the National Energy Technology Laboratory (NETL) and CSM. The purpose of the 2007 Workshop was to re-assess and prioritize the listing of R&D needs identified during the 2006 Workshop, and to provide additional detail on what tasks could be undertaken to address the highest priority needs. The entire issue of socio-economic challenges and their critical R&D needs, while very important, was set aside for the purposes of this workshop, in order to more closely focus on environmental R&D needs of a more technical nature, given the limited amount of time available.

A secondary objective was to gather a sense for how the industry, academic, government and regulatory stakeholders value an organized collaborative effort among stakeholders to address the questions surrounding the environmental impacts of potential oil shale development.

The make up of both the 2006 and 2007 Workshop attendee lists were quite similar, as the figures below show.

Figure 1: 2006 Oil Shale Environmental Workshop Attendees

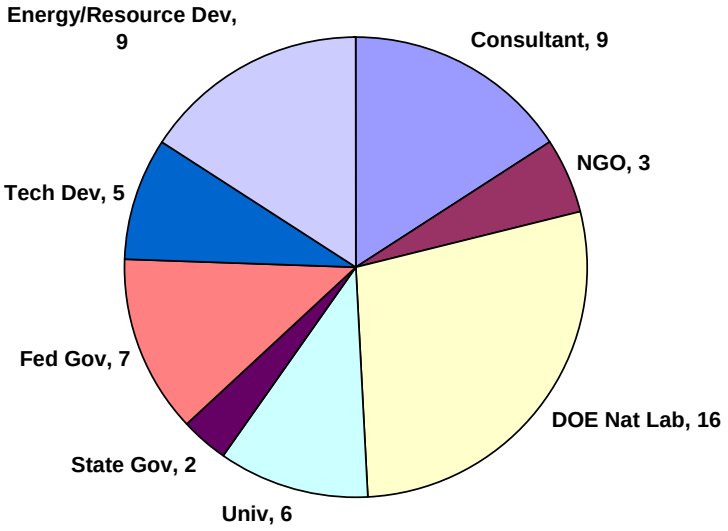
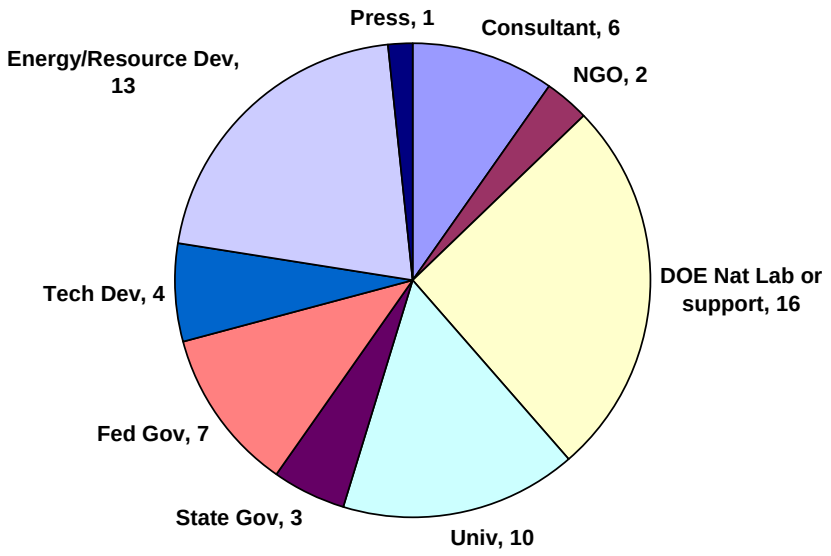


Figure 2: 2007 Oil Shale Environmental Workshop Attendees



Each workshop included a mix of attendees from industry, state and federal governments, universities, non-government organizations, consultants and technology developers. Attendance at the 2006 workshop was a total of 57 stakeholders, and at the 2007 meeting a total of 62 participants. Appendix A provides a listing of the 2007 Workshop participants.

Workshop Agenda and Process

The workshop began with a welcome by Dag Nummedal, the Director of the Colorado Energy Research Institute. This was followed by a brief description of the Workshop expectations and a review of the 2006 Oil Shale Environmental Issues and Needs Workshop, by Brad Tomer of the Strategic Center for Natural Gas and Oil at DOE's National Energy Technology Laboratory (NETL). Mr. Tomer also introduced the facilitators for the workshop, Art Hartstein and Steve Zukor of Technology and Management Services, Inc., a support contractor for NETL.

Five invited speakers were introduced and each delivered brief presentations on their perspectives concerning the need for R&D related to environmental issues associated with the potential commercial development of oil shale in the Western United States. These speakers were asked to comment on the breadth and current relevancy of the

challenges and R&D needs prepared during the 2006 workshop. The speakers included:

- Tony Dammer, Director, Office of Petroleum Reserves, DOE
- Glen Vawter, EGL Oil Shale, LLC and Exec. Dir. of National Oil Shale Association
- Larry Svoboda, NEPA Program Director, EPA Region 8
- Dave Hogle, Regional Energy Advisor, EPA Region 8
- Sherri Thompson, Project Manager for BLM Colorado Oil Shale EIS

The presentations were made in the context of the ongoing research related to oil shale development that is underway on a number of government R&D leases that the Bureau of Land Management (BLM) has leased to companies in Colorado and Utah, possibly to be followed by a commercial leasing program (see Appendix B).

A summary of these speakers' comments are provided in the following section of the report and the available presentations (some did not provide written comments) are attached in Appendix C.

Following the invited speakers, the attendees were invited to react to a list of Key Environmental Challenges prepared during the 2006 environmental workshop. This list was prepared prior to the meeting and was a simplified version of a more detailed list contained within the Final Report prepared after the 2006 Oil Shale Environmental Workshop. Based on the reactions and comments of the group, a revised list of environmental challenges was prepared for the participants to use in re-evaluating the list of R&D needs that had been prepared in a similar manner from the same 2006 document. The challenges and needs were categorized under the three general topical areas of Air, Water and Land environmental challenges. The issue of socio-economic challenges and their R&D needs was set aside for the purposes of this workshop, given the limited amount of time available.

The attendees were then divided into two breakout groups to best utilize the time available and assure that each participant had a chance to express his or her views.

The first item that each breakout session addressed was the sufficiency of the environmental R&D needs as listed, appreciating that the underlying environmental challenges had been updated by the discussions of the larger group session. Each participant was asked to introduce him or her self and comment on last year's list of environmental needs. The fundamental question posed was: In light of the current set of environmental challenges before you, should any of last year's R&D needs be discarded or modified, and should any new ones be added?

After a new list of environmental R&D needs was created, each participant was asked to prioritize the *entire* set of R&D needs in terms of their overall relative importance from the perspective of the participant. Each participant was given three votes to "spend" on any of the R&D needs listed under the three general areas. This was implemented by giving each participant three stickers to place on their three top priority R&D needs

(which were listed at the front of the room on printed cards); an individual could place all his or her stickers on a single topic if they thought it the overwhelming environmental R&D need.

After the votes were tallied and the R&D needs ordered in terms of priority, both of the two breakout groups self-subdivided based on their general areas of expertise or interest. These sub-groups were tasked with generating detailed task write-ups that could be used to define pathways for how the top priority R&D needs could be met. Each team addressed the highest priority needs in their area and prepared as many task write-ups as possible in the time remaining.

During the working lunch break, Art Hartstein delivered an informal presentation on "Lessons Learned from the 1970-80's DOE Oil Shale Environmental Task Force." Art had played an important role in the activities of this task force, as an employee of the U.S. Department of Energy's Office of Fossil Energy.

When the breakout sessions ended, all participants joined for a final summary session. During this session, the breakout sessions' results were shared and the final workshop deliverables were briefly outlined with the commitment to participants that a draft of the results of the workshop would be sent to participants for their comments and review.

Finally, a discussion of the "next steps" and a general thank you to the assembled group for their participation was delivered by Mr. Tomer.

Summary of Prepared Comments by Invited Speakers

This section provides a brief summary of the comments, key concerns and major areas requiring R&D as expressed by the invited speakers. Appendix C provides the speakers' prepared Microsoft PowerPoint™ presentations, if provided,

Tony Dammer, Director, Office of Petroleum Reserves, DOE
Strategic Unconventional Fuels Task Force

Tony Dammer provided an overview of the Strategic Unconventional Task Force's recommendations for the support and acceleration of an oil shale industry. The Task Force's recommended strategy is to:

- Assure access to resources on public lands by commercial leasing.
- Coordinate and streamline regulatory and permitting processes.
- Create a fiscal regime of tax, royalty, and purchase incentives to stimulate investment.
- Support and share risks for technology development and demonstration.
- Prepare an integrated local / regional infrastructure plan.
- Support local planning and education and vocational-tech training to meet development needs, mitigate impacts, maximize jobs, and foster growth.
- Evaluate potential government structures that can promote and accelerate efficient industry development.
- Partner with Alberta on U.S. tar sands development.
- Partner with other countries on oil shale development.

The Task Force identified three major areas where research is needed, and where national laboratories can play a role in understanding potential impacts and designing ways to mitigate them. These are: the impacts of land disturbance (which depends to some degree on the process chosen), impacts of carbon dioxide emissions (climate change is the biggest issue), and water impacts (water use requirements, surface contamination and groundwater contamination).

Glen Vawter, EGL Oil Shale, LLC and Executive Director of the National Oil Shale Association
Environmental Challenges: An Industry Perspective

Glen Vawter provided and industry perspective on the environmental issues and research needs. EGL Oil Shale, LLC (EGL) sees the three major environmental challenges as: water, carbon management, and multiple land use issues. Water is the key issue for in situ technologies: 1) characterizing groundwater and its movements, 2) understanding how EGL's process will affect groundwater, 3) mitigating the impacts of the process, and 4) returning the groundwater to its natural state. The other part is surface water and understanding the affect the EGL process may have on springs and water flow.

Secondarily, carbon management is obviously an important issue. Finally, multiple land use issues are important, and dealing with wildlife issues in the Piceance Basin in particular is important because commercial oil shale development will be a continuous industry.

Some specific ideas for industry/government collaboration would be: 1) baseline and long term monitoring of groundwater and surface water flow and quality, 2) carbon sequestration and disposition, 3) and site monitoring for specific purposes. EGL has been talking to some national labs about collaborating on our site in the collection of environmental data, because it provides the credibility of an impartial source when that data and its analysis are published. Another research need is in the development of new technologies (e.g., cross well tomography) for determining the hydrologic character of the oil shale formations. This would likely be something that is developed at the site level and then applied basin-wide.

The research needs for oil shale development can be categorized in two basic ways. One is *who is doing it*: industry alone, industry/government in collaboration, and government alone. The other way is by geographical area: the site, the general area around the site, the basin, and the region. The level of government activity should increase as the geographical area widens. Industry responsible for the site level research, industry/government collaborative efforts at the area level, and all government at the basin and regional level, makes the most sense.

A cross-cutting need is a central repository and clearing house for environmental and socioeconomic data. The Colorado School of Mines has taken a step in that direction and others are also thinking about ways to accomplish this.

Larry Svoboda, NEPA Program Director EPA Region 8
EPA Air Quality Issues and Activities

Larry Svoboda expressed that for all stakeholders, it is a very important activity to begin to develop an effective model, that we can all agree on, that reflects the best information we have about the state of emissions in this region of the country, and that will allow us to evaluate not only the potential scenarios of oil shale development that might occur in the future, but also where we are right now. He also indicated that its not just visibility in Class 1 areas that is a concern; ozone is showing up in high concentrations in rural areas of the Western US. EPA is currently studying this issue.

Dave Hogle, Regional Energy Advisor for EPA Region 8
EPA Water and Waste Issues

Dave Hogle discussed EPA efforts in the Underground Injection Control (UIC) program. Colorado has not been delegated authority to permit classified underground injection wells under Section 1422 of the Safe Drinking Water Act. So the EPA will be doing the

main UIC program permitting in Colorado. Injection related to oil shale will be classified under the UIC program. Utah does have delegated authority. EPA has issued one permit to an operator on the Western Slope of Colorado for recharge related to oil shale activity. EPA has a UIC group that is ready to handle permitting issues related to UIC.

Recent policy statements have indicated that non-enhanced oil recovery injection activities for carbon sequestration will require classified permits under the UIC program. EPA is preparing to go forward with a rule regarding underground injection of carbon dioxide; perhaps as early as next year. This of course will ultimately impact any underground injection of carbon dioxide generated from oil shale development.

Waste issues are important, particularly for surface retort methods. EPA is currently coordinating with a number of entities on sampling and analytical protocols regarding wastes derived from retort methods. This is currently a high priority for EPA.

In the speaker's opinion, the most valuable R&D contribution from any combination of government, academia and industry, would be to develop a water-treating process that would enable a barrel of water produced from oil and gas or oil shale development operations, to be treated for less than five cents.

Sherri Thompson, Project Manager for BLM Colorado Oil Shale EIS
Challenges Regarding Oil Shale Environmental Issues

Sherri Thompson commented on the fact that until the research results come in from the R&D leases or from private efforts such as what ExxonMobil is doing, BLM can't begin to quantify the potential impacts of oil shale development, and until the impacts can be addressed BLM won't be able to lease on Federal lands. Thus, the biggest challenge facing BLM is the lack of data. Until we get that data we can only agree that there will be air quality impacts, water quality impacts, water use issues, socioeconomic impacts, spent shale issues (both from a content and volume standpoint), surface disturbance issues (both related to impacts on plants and visual impacts). This lack of data will ultimately determine the timing of when oil shale can be developed commercially on Federal lands.

Art Hartstein, Past Program Manager for Oil Shale Program at DOE Office of Fossil Energy, and Program Manager for the Oil Shale Environmental Taskforce from 1978 -1984

Lessons Learned from the 1970s-80s Oil Shale Environmental Task Force (Luncheon Speaker)

In May of 1978, then Governor Lamm of Colorado requested DOE "to assist Colorado by working with us in developing additional research and analyses of current and future efforts" in oil shale. As a result an environmental and health task force was created that

planned, implemented, and coordinated a comprehensive, integrated research program on the environmental and health impacts of oil shale production technologies.

It is clear that there are two types of environmental concerns; those that are site specific and those that have basin-wide impact. While it is anticipated that individual commercial entities will conduct supporting environmental research on their processes and at their sites, the DOE focused on resolving the environmental issues that would limit potential oil production from oil shale basins.

Lesson 1: Work conducted by different research entities was hard to compare when the research was done on different oil shale samples. It would be helpful to have a reference shale for each to calibrate their data.

Lesson 2: Some site specific experiments could be enhanced with more sophisticated and/or additional data points so that the data might be of more value in basin wide models. For example, the task force could identify private R&D efforts that may lend themselves to additional R&D, paid for by the government, which has a basin wide focus rather than an individual lease focus.

Lesson 3: More effort should have been taken to coordinate private environmental research so that the “big picture” is at least considered in most circumstances.

Results: Revised Challenges, R&D Needs Prioritization

The results of the two parallel breakout groups' modification and prioritization of the list of R&D needs are summarized in Table 1.

The original R&D needs included six under the category of Air Quality, five under the category of Water Quality, and four under the category of Surface Impacts.

Breakout Group A added several additional R&D Needs:

- Under the Air Quality category: *Conduct a specific regional assessment of CO_2 end uses/disposition (i.e., Where can it go?)*

- Under the Water Quality category: *Perform a basin/regional climate variability/climate change assessment for water supply.*

- Under the Land Impact category: *Determine impacts to wildlife/habitats*

- Group A also added an overarching R&D Need that encompassed all of the categories: *Develop a regional energy/resource system model.*

Breakout Group B added two additional R&D Needs:

- Under the Air Quality category: *Perform a life-cycle assessment of air quality impacts from entire oil shale recovery process (power generation, production, processing, and fuel combustion).*

- Group B also added a new category: Solid Waste. Under this category the R&D Need added was: *Develop protocols for infrastructure evaluation; alternative land use; subsidence mitigation strategies; and spent shale by-product R&D.*

The two groups voted on their amended lists of R&D Needs. Each participant received three stickers and these were placed on the participants' top priority R&D Needs. All three could be voted for a single need if the individual determined that was appropriate. The results of that process are shown in Table 1.

There was a significant degree of congruency in the priority attached to the R&D Needs by the two breakout groups.

The top five highest priority R&D Needs identified by Group A were (in order):

- Developing an integrated basin/regional baseline for surface and groundwater data (quality and quantity) and customized GIS-based analytical tool.

- Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT.

- Develop a regional energy/resource system model. (*Added by group*)

- Develop accurate, predictive regional models for release, fate and transport of air emissions.

- Identify gaps, and conduct R&D to develop innovative technologies for reducing (high efficiency) or controlling (capture/separation) air emissions at any point; pre-process through post-process.

These five R&D needs received vote totals ranging from 15 to 7 votes. The next highest need garnered only four votes, with all of the remaining needs averaging about 1 vote per need. There was a clear distinction between the top-ranked needs and the rest of the list. Of the four R&D needs added by Group A, only "Develop a regional/resource system model" received significant votes.

The top five highest priority R&D Needs identified by Group B were (in order):

- Develop accurate, predictive regional models for release, fate and transport of air emissions.

- Develop an integrated basin/regional baseline for surface and groundwater data (quality and quantity) and GIS-based analytical tool.

- Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT.

- Integrate and coordinate with CO2 regional partnerships (CO2 sources and sinks/markets) for development of a CO2 management plan.

- Characterize spent shale and perform R&D related to alternative by-products.

These five R&D needs received vote totals ranging from 10 to 4 votes. The next highest need garnered four votes, but was ranked out of the top five based on the fact the Group A gave it a lower vote total (see Table 1). All of the remaining needs averaging about 2 votes per need. Again, there was a clear distinction between the top-ranked needs and the rest of the list, although not quite as clear as with Group A. Neither of the two R&D needs added by Group B received a significant number of votes. Three of the top five priorities for each group were shared.

When the results of the two groups' voting were combined, an overall priority could be assigned to the R&D Needs. The results, given in Table 1, show that the top five overall R&D Needs are:

Priority 1. Developing an integrated basin/regional baseline for surface and groundwater data (quality and quantity) and customized GIS-based analytical tool.

Priority 2. Develop accurate, predictive regional models for release, fate and transport of air emissions.

Priority 3. Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT.

Priority 4. Develop a regional energy/resource system model. (*Added by group*)

Priority 5-6 (tie). Characterize spent shale and perform R&D related to alternative by-products.

Priority 5-6 (tie). Identify gaps and conduct R&D to develop innovative technologies for reducing (high efficiency) or controlling (capture/separation) air emissions at any point; pre-process through post-process.

After voting, each of the Breakout Groups divided into sub-groups, loosely based on area of expertise, to develop detailed task lists for implementing the R&D Needs. Given the limited amount of time available in this one-day workshop, the highest priority R&D Needs were addressed first.

Table 1 identifies the R&D Needs for which the task statements were developed. Six of these were prepared by Group A and six were prepared by Group B. In the case of two of the high priority R&D Needs, task statements were prepared by both Breakout Groups.

Group A, in addition to preparing their task statements, recommended an overarching task that all R&D should be to involve the Regulatory Agencies from the beginning in any research plans and to let them know what the research plan is; what will be done to execute the research, and if appropriate, permit them to have representation on a technical committee established for each research area.

These proposed task statements are collected in the following pages.

Table 1: R&D Needs Prioritization Process Results

Area	R&D Need	Group A Votes	Group B Votes	Total Votes	Overall Priority	Group A Outline*	Group B Outline*
AIR	Develop a protocol for basin/regional emissions monitoring	0	0	0			
AIR	Develop accurate, predictive regional models for release, fate and transport of emissions	8	10	18	**2**		**yes**
AIR	Conduct process-/resource- specific emissions research and evaluate best available cleanup technology (BACT)	2	3	5	8		
AIR	Identify gaps, and conduct R&D to develop innovative technologies for reducing (high efficiency) or controlling (capture/separation) emissions at any point; pre-process through post-process	7	1	8	5 -6		
AIR	Integrate and coordinate with CO2 regional partnerships (CO2 sources and sinks/markets) for development of a CO2 Management Plan	2	4	6	**7**	**yes**	
AIR	Assess life-cycle emissions under various development scenarios, including full suite of infrastructure requirements	0	3	3			
AIR	Specific regional assessment of CO2 end uses. Where can it go?	0	na	0			
AIR	Perform life-cycle assessment	na	3	3			**yes**
WATER	Develop integrated basin/regional baseline for surface and groundwater data (quality and quantity) and GIS-based analytical tool	15	9	24	**1**	**yes**	**yes**
WATER	Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT	12	5	17	**3**	**yes**	**yes**
WATER	Conduct R&D to develop new, low water consumption processes; cost-effective water treatment and improved recycle/reuse options	1	4	5	9		**yes**
WATER	Conduct R&D to characterize and assess solutions to potential spent shale leachate	2	1	3			
WATER	Assess water requirements and potential effluents for multi-site oil shale development in conjunction with other regional water use planning efforts for the development of a Water Resource Management Plan	0	1	1			
WATER	Perform a basin/regional climate variability/climate change assessment for water supply	2	na	2			
LAND	Spent shale characterization and R&D for alternative by-products	4	4	8	**5-6**	**yes**	
LAND	Conduct research and analysis to reduce process/development foot print	2	2	4	10		
LAND	Conduct research on subsidence and potential mitigation strategies	1	2	3			
LAND	Coordinate infrastructure evaluation using GIS-based analysis tools; oil shale and alternative land use development scenarios (trade-off analysis) for the development of a Land Use Plan	1	2	3			
LAND	Determine impacts to wildlife/habitats	3	na	3		**yes**	
SOLID WASTE	Develop protocols for infrastructure evaluation; alternative land use; subsidence mitigation strategies; and spent shale by-product R&D	na	0	0			**yes**
GENERAL	Develop regional energy/resource system model	10	na	10	**4**	**yes**	

**** Indicates if an outline of the tasks needed to address the R&D Need was completed***

GROUP A - **Priority 1 - Developing an integrated basin/regional baseline for surface and groundwater data (quality and quantity) and GIS-based analytical tool.**

- Compile all data into a central repository
    - Single/combined model
    - Share models (individual) with USGS for incorporation into a larger regional model.
    - Provide incentive for operators to share data
    - Define data set of interest
    - Government funding/support for data collection
    - Identify gaps and ask industry to fill those gaps
    - Get a system in place for data collection that can be expanded into other areas (*i.e.* Utah, WY)
    - Get operators to allow access to well data/property for pump test etc…
    - Data validation/QC under controlled environment
    - List of water quality parameters/potentiometric data/age dating
    - Formalize the process
- Provide leadership for industry going forward

GROUP B - Priority 1 - Developing an integrated basin/regional baseline for surface and ground water data (quality and quantity) and GIS-based analytical tool.

- Web-based system anyone can access
- Coordinate existing efforts (USGS, BLM, industry, etc.)
- Define study area(s)
- Define stakeholders (Fed, local, state, water districts, lease holders including oil and gas leases, water rights holders, etc.)
- Develop a protocol for basin/region water monitoring (surface and ground water)
    - Identify parameters and sites that are important.
    - Identify existing data (temporal and geographically)
    - Identify data gaps
    - Fund program to collect data and fill gaps
    - Geologic characterization of ground water/surface water system

Priority 2 - Develop accurate, predictive regional models for release, fate and transport of air emissions.

- Quantify Emissions of Criteria and Hazardous Pollutants
    - In Situ
    - Retorting Industry
    - Upgrading
    - Entire Site
    - Oil & Gas & other – Colorado APCD and other state agencies
- Meteorology – Colorado APCD and other state agencies
- Baseline Air Quality Data –current & projection – state agencies
- DOE-funded and oversight – DOE
- Protect Ambient Air (National Ambient Air Quality Standards)
- Look at existing models – EPA
- Contact current lease holder….Gordon Pierce at Colorado APCO & other state agency counterparts
- Secure agreements
- Secure meteorological data needs for modeling – state agencies
- Evaluate existing models (perhaps only gap-filing is needed)
- Consult with air shed
- Note any gaps
- Gaining agreements from federal government
- Gaining agreements from industry
- Estimate emissions of criteria pollutants and HAPs - industry (oil shale), state agencies (oil and gas and other) – define scenarios (plant-size, region)
- Deliverable $\Rightarrow$ baseline model for use by stakeholders.

Group A - Priority 3 - Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT.

Evaluate Generated Contaminants

- Literature review of existing information
    - Perform quality checks and reliability of existing data
    - Separate ex-situ from in-situ
    - Identify data gaps
        - because of different or new reporting processes
        - temperature
        - duration
- New work/research to address the knowledge gaps
    - Perform bench scale laboratory studies covering range of relevant retorting conditions
        - what is generated and into what phase does it go.
    - Look for opportunities to work with ongoing demonstration projects to obtain field data on generated contaminants.

Evaluate process-specific water consumption

- Literature review and sourcing of information from ongoing demonstration projects.
    - Identify data gaps
- For each retort process/technology (including both ex-situ and in-situ)
    - Identify how much water is to be consumed per unit of production (this research can be achieved only by working with ongoing demonstration projects)
- Investigate water re-use opportunities under each retort process
    - Determine if process produces water from formation
    - Identify what treatment would be necessary for water re-use (process and cost)

Group B - Priority 3 - Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT.

- Identify processes
- For each process identify:
    - Constituents which will leach
    - Changes in flow regimes (quality & quantity, hydraulic characteristics)
    - Project water use
- Identify other studies w/useful data
- Basin-wide model for water balance/water consumption/water quantity & quality impacts

Model needs to tie back to data collection in **Group B Priority 1 - Developing an integrated basin/regional baseline for surface and ground water data (quality and quantity) and GIS-based analytical tool.**

Priority 4 - Develop a regional energy/resource system model. (*Added by group*)

Energy Resource Development Systems Model: A Framework for Decision Assessment

This will be an overarching model that will use output from more specific existing complex models (air dispersion models, water supply, solute transport, economic/social, wildlife models) to examine implications of potential oil shale development scenarios.

1. Identify resource development activities (power, oil shale, tight gas, oil coal, etc) to be considered.
2. Define geographic extent of region to be modeled. Develop data and models (local and regional) for air, water, wildlife, etc. predictions related to development to use as input for systems models.
3. Define critical environmental issues/impacts to be assessed (air quality, water supply and demand, water quality, wildlife, population, etc.).
4. Develop criteria to be met, i.e. what regulations or public perceptions or desires will drive/impede/impact the rate or amount of development in basin? (CO2, salinity, other air quality/water quality parameters, in-stream flows, etc.).
5. Prioritize impacts that are most important to assess (We may be limited by $ and/or time to address all issues).
6. Define baseline and future scenarios (define a base set of scenarios) to investigate (e.g, low, medium and high development scenarios).

Cross-cut

Make sure that models address geographic specifics as well as basin wide outcomes.

Predictive Regional Models for Release, Fate and Transport of Air Emissions

(a submodel of the overarching model)

1. Get stakeholder to buy into need, output, and use of air dispersion models for basin. Determine air values of concern and interests (visibility, CO2, etc.).
2. Choose appropriate modeling frameworks.
3. Determine geographic domain of model, i.e., at what scales do we need output?
4. Determine data requirements for modeling and obtain data. Establish appropriate monitoring strategy to populated model and framework to monitor trends.
5. Define baseline growth scenarios to evaluate modeling.
6. Carry out modeling runs and associated emissions reduction options.

Identify gaps and conduct R&D to develop innovative tech for reducing (high efficiency) or controlling (capture/separation) emissions at any point; pre-process thru post-process.

1. Identify key emissions that need to be addressed.
2. Develop a regulatory framework for CO2.
3. Implement an incentive program for CO2 and other emissions.
4. Enable industry to partner with research institutions to develop technologies

Priority 5-6 (tie) - Characterize spent shale and perform R&D related to alternative by-products.

There are two clear cases to be considered: ex-situ and in-situ. Each is addressed.

Ex-Situ

- Literature review – research done in the 1970s and 1980s.
    - Mineral composition of Green River spent shale (depends on specific retort process, mostly highest temperature and atmosphere)
    - Check reliability of existing data; is the methodology okay?
    - Identify data gaps needed to cover all relevant retort conditions
    - Perform research to fill the data gaps (laboratory studies)

In-Situ

- Characterizing how the retorting process has affected the physical and chemical properties of the rock.
    - Flow properties (permeability, porosity, fracturing)
    - Geomechanical properties (consolidation, potential for subsidence/uplift)
    - Reference work done on generated contaminants under **Group B - Priority 3 - Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT**

Priority 7 - Integrate and coordinate with CO_2 regional partnerships (CO_2 sources and sinks/markets) for development of a CO_2 management plan.

- Quantify CO_2 generated from different technologies/processes
- Identify regional potential sinks/reservoirs into which CO_2 could be sequestered
- Follow closely developments on CO_2 sequestration
- What are the challenges associated with doing this?
- Develop cost estimates for basin-wide infrastructure requirements to do this.

Priority 9 - Conduct R&D to develop new, low water consumption processes, cost effective water treatment and improved recycle-reuse options

- Include recycle of O&G produced water.
- Take water balance (from **Group B - Priority 3 - Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT**) and evaluate opportunities for reduction, recycle-reuse.
- Provide incentives for efficient water use (i.e. modify state water law).
- Identify opportunities for National Labs to work with industry on water efficiencies.

Lower Priority (3 votes) – Determine Impacts to wildlife/habitats

- Determine suitable habitat preservation with biologist input
- Responsible surface management
- Encourage carpooling
- Make ManCamp regulation and permitting less restrictive
- Identify migration routes and avoid habitat fragmentation

Lower Priority (3 votes) – Perform life-cycle assessment

Conduct comparative assessment of environmental & economic tradeoffs for oil shale development utilizing full life-cycle methodologies

- Define goal, scope and boundary conditions
- Collaborate with industry and stakeholders for best available data
- Evaluate environmental and economic tradeoffs
    - Identify data gaps
    - Determine significant drivers and areas of technology improvement
- Develop plausible industry development scenarios including resource screening
- Evaluate range of cumulative environmental impacts to determine growth constraints (exclusive of other industry)
- Define other resources and evaluate range of cumulative environmental impacts to determine growth constraints (inclusive of other unconventional and conventional resources)
- Create regional resource development strategy and complement with socioeconomic and acceptance drivers
- Make data publicly available for decision makers and interested stakeholders

Lower Priority (0 votes) – Solid Waste - Develop protocols for infrastructure evaluation; alternative land use; subsidence mitigation strategies; and spent shale by-product R&D

1. Develop protocol for coordination of infrastructure evaluation using GIS-based analysis tools, oil shale and alternative land use (beneficial) development scenarios for a land use plan.

- Conduct a geospatial analysis of infrastructure needs (assuming an above-ground retort) for mine and adjacent neighbors
    - Compatibility of mine site for beneficial use
        - Landfilling (mix of garbage with spent shale – adsorption)
        - Wildlife habitat
        - Recreational activities
- Regulation Evaluation

2. Develop protocol for R&D on subsidence and potential mitigation strategies (surface retort only, not applicable to in situ processes)

- Evaluate physical properties (of various types of natural oil shales)
- Bench scale physical testing of oil shale samples after heating
- Rock mechanics - modeling

3. Develop protocol for R&D on spent shale management and beneficial use of by-products)

- Describe applied technologies (retort, oil shale inputs)
- Describe waste management plan
    - Disposal site location
    - Potential for hydraulic transport of pollutants via ground water or surface water
    - Identify potential pollutants and release mechanism
    - Identify applicable regulations
- Treatment schemes
    - Available technologies
    - Applicability
    - Select technology for pilot tests or lab-scale tests
    - Evaluate and address post-treatment wastes

- Beneficial Use
    - Evaluate potential uses
        - Filler material
        - Fertilizer
        - Organic adsorbent (e.g., landfill … drill and estimate effects)
- Cement
- Bricks (ceramics)

Summary of Key Comments by Participants

This section includes representative comments made by each participant prior to the breakout sessions (related to key challenges) and within each breakout session (related to R&D needs). These are not *verbatim* (being compiled from edited notes) and **are not attributed**. Each bullet does however relate to an individual speaker.

Question: What do you see as additional key challenges that you don't see listed from the past year:

- So much other activity is going on related to oil and gas activity, efforts by governments and stakeholders to address issues … so much of this will be well underway before oil shale is ready, and you need to consider the entire picture … you can't do what we are doing here … considering the environmental challenges facing oil shale development in a vacuum … without considering the entire energy development picture.

- It would be so helpful if there could be some sort of memorandum of understanding between the EPA and the State of Colorado … that would make our lives as energy developers and your lives as researchers much easier. I would also urge you to publish the results of whatever R&D is carried out in a format that the public can understand.

- It will be important to have clear standards for water quality and injection that people can understand, so that developers can plan accordingly. There are problems even now with unclear standards and with oil shale it will become even more difficult, without an effort to be clear.

- Another issue … although it may not be strictly environmental, but it could impact environmental issues … is the question of primacy in the development of oil shale in areas where oil and gas development is underway. This will need to be addressed.

- A big challenge will be finding a way for the industries that are in a sense competing for the right to develop their resource in the basin (oil, gas, coal, oil shale, recreational), given the limited amount of environmental impacts (air, water, land) that can be permitted, to collaborate in dealing with environmental challenges. Collaboration and integration across the various industries should be a goal.

- I am concerned about mercury emissions to the atmosphere. Emissions from surface retorting similar to those seen in the 1980s would be totally unacceptable today … adequate controls will be very expensive … emissions from in situ retorting are completely unknown … this is an issue which is not addressed specifically in the list of challenges.

- We need to devise a process that is collaborative and transparent, where all stakeholders can play a role and have access to the information. Regular, open meetings are important. While companies understandably want to protect themselves from competitors by keeping their data secret, in the end, a collaborative effort will lead to more progress and be less expensive … more efficient. If people don't know what is going on they tend to fabricate stories.

- We need to recognize that perhaps the biggest challenge here is going to be the volume of carbon dioxide generated by the various processes for producing oil from oil shale … and finding ways to deal with this problem through capture and sequestration … we can't assume that we can just inject the carbon dioxide and sequester it. This will be a big issue and we need to look carefully at the data surrounding carbon dioxide generated by various processes and what we can realistically do with it, early on.

- We need to look at what kind of predictive models we have to work with. We have to have good tools to look forward at various development scenarios.

- There is a lack of trust in the information that is being put forth … an example is water … one group says there is enough … another says there isn't … people don't know who to trust. There is no body of knowledge that people can go to as a point of departure that all agree on. We need a single set of data that paint a real picture of the current field of play, and the boundaries of what we know and don't know. Uncertainty is OK, given the state of where the industry is, but giving people a sense of what we know and what the boundaries of our knowledge are is important.

Break out Session A (in main auditorium)
Question: What are key R&D needs/issues you believe need to be addressed?

- Before we can determine which R&D needs to address first, we need to know what we want to achieve in the end, and this requires that we know what the emissions limits will be … for example, how much Hg can we emit … how much particulates … and Yucca Mountain can be a useful model of how to make these decisions. There, a predictive model was used to determine the intersection between high priority emissions and the uncertainty in characterizing them … as a way to decide where the most important R&D should be focused.

- All of these R&D needs are good goals. In regard to water in particular … and the data needs for groundwater in the basin … there is a lot of data out there, and we need to come up with a way of allowing that data to be brought forth to a group like this in a manner such that proprietary information concerns are met. There are ways to do this and we need to find them.

- My company sensed last year that CO_2 was a terrible problem … perhaps a showstopper … so we spent the last year trying to come up with a way to eliminate

CO_2 from the process. This is a paper idea at the moment … we need funding to demonstrate it … but we think that, unless people do something like this approach, given the climate trends related to CO_2, there will never be a commercial oil shale industry … or at least certainly not a surface retorting industry. So, finding a way to deal with generated CO_2 is the biggest issue.

- We need to develop a regional energy/resource systems analysis model. This model would enable us to evaluate the impact of the whole suite of energy development in the basin and the region … including the impact of the timing and intensity of different energy development alternatives. The model should also be able to evaluate the impact of the insertion of different technologies and or regulation designed to solve environmental problems, considering the tradeoffs between costs and benefits. It would enable us to evaluate the risks associated with various emissions, groundwater pathways, water supply issues … and allow us to quantify the tradeoffs. Don't forget that such models will need to be validated, and that requires data from companies.

- Most of the people here are talking about models that will look at the big picture … who should we be sending our very site/process specific data to if we are willing to publish it? There needs to be some sort of group to collect this information until we define who will be using it in models.

- I don't understand why oil shale developers need to be so proprietary about their information. There is a lot more data out there than is being shared … if it is public data reported to the EPA of other regulators, it needs to be made available. All companies should have an overriding interest in making data available if it will help to enable an oil shale industry to grow.

- There is about 100 ppm Hg in oil shale on average and surface retorting methods will release most of it … with in situ methods we don't know how much of that will be released. This issue is a big gap in the R&D lists from last year that needs to be addressed.

- An important part of the R&D process is to be able to have people from the outside (e.g., academic researchers) be able to do calculations and crosscheck results reported by oil shale developers. The lack of public information on oil shale recovery process data isn't helpful in the long run.

- There needs to be a parallel effort going on, to bring together the regulators and industry players, so that we know what the standards are going to be and what needs to be protected and what doesn't. For example, in the case of groundwater models, which aquifers need to be protected and which ones don't? We don't even know this yet.

- Speaking as a member of the oil shale development industry, our biggest problem is unknowns. If we can identify a problem, we generally can gather the expertise and

address it. One unknown that clearly is close to the top of my list is CO_2. It's not that we can't handle it. The problem is: I don't know what I've got to do with it … what are the rules going to be? We can develop solutions if we know what the rules are going to be and know that they won't be changed. Consistency in the regulatory framework is important to those making these investments in R&D and development. Today's energy developers are responsible and want to do this the right way. This comment applies to all issues … air, water, land … not just CO_2, which is really a much bigger issue than as it relates to oil shale.

- There is a lot of excellent baseline data out there, resident in the former EIS documents for the prototype leasing program in the 1980s, and other than some obvious differences, the ecosystem hasn't changed that much. There are only two problems with this old data, you can't find it and if you do find it it's not in a digital form. One important functions of an environmentally focused group could be to locate and process old data into a format that will allow it to be widely disseminated.

- To truly assess the R&D needs we have listed here, we need to get on the ground and develop the data, but to do this we need to have the various regulatory agencies work together to develop a streamlined regulatory framework. Is has been such a slow painful process. The Federal, state and local governments need to get together and decide to work together. They have promised this but nothing has happened yet.

- The one common aspect here is that there will be uncertainty associated with the data and with the models that are developed to use the data as far as how well they represent reality. We need to make an early effort to better understand the potential consequences of that uncertainty, in order to make certain that we don't waste out efforts.

- The focus here is about individual waste streams and impacts, but what R&D research do we feel is needed to help facilitate the development of oil shale technologies? How can we take a positive approach to make this work, rather than, how do we deal with the negatives. The studies and R&D may be the same, but the perspective would be more positive: how can we make this work in an environmentally safe way, rather than what are the negatives we need to measure.

- The overall progress of the industry would be helped by more companies getting involved in developing new oil shale technologies, but the regulatory environment doesn't foster this. We have a whole suite of environmental issues that could potentially be problems; however, the new technologies being developed to produce oil from oil shale could address these issues before they become problems. If we can work on developing low emission technologies, we lessen the need to model and deal with impacts.

- We need to consider the potential for groundwater contamination similar to the MTBE problem, from VOCs related to oil shale development. Also, the Western

Slope needs to be recognized as a complex system of micro-climates that can have different reactions to emissions, particularly during the wintertime.

- The Colorado School of Mines (Heather Whitehead in the library) is currently working to gather historical material, both technical data and other information, related to oil shale. One participant suggested that Frank Weldon, and other "oldtimers" in Meeker, have a wealth of hard copy data that is not available anywhere else. One part of an organized effort might be to visit with such individuals to capture data that might otherwise be lost.

- We need to perform a basin-wide or regional climate variability/climate change assessment, so that we can have a better idea of the long time supply of water in the upper Colorado River basin for energy development.

- Given that the expected timetable for regulations to be put in place for commercial development of oil shale could be as long as seven years (a statement from the earlier days symposium speaker was quoted), it will be important to get results form these R&D efforts within the next 2 to 3 years … integrated results that overlay air, water, land and biology … so that whatever models are developed can be useful in terms of helping to shape the regulations. If we want these efforts to create some public confidence in what the regulators are doing, we have a constrained time frame within which to work.

- One question that is not addressed in these R&D needs is: What are the impacts on wildlife from oil shale development, and what controls need to be in place versus what might need to be considered, so that we can deal with things like surface occupancy requirements? Studies done historically need to be captured, and current studies focused on natural gas development impacts can also be used.

- We need to do some basic assessments as to what can be done with CO_2 captured from oil shale processes … how much can reasonably be stored in the region and where is it going to go… as well as how much might be generated … before we simply assume that we can sequester it**.**

Break out Session B (in other building classroom)
Question: What are key R&D needs/issues you believe need to be addressed?

- Based on the example of tar sands in Canada, this approach presents some opportunities for research alliances, including alliance between government and industry consortia. This approach is a good way to spread the risk of early high risk R&D money. There are ways to manage intellectual property protection, which is an industry concern. Industry/government collaborative R&D works. The dramatic change in operating costs and increase in production in the case of Canadian tar

sands was a result of the harvesting of the fruits of early technology R&D collaborative efforts.

- Trying to look at processes that don't consume water is important. R&D devoted to developing low water use technologies is also an environmental technology.

- What can we do to synergize oil and gas development with oil shale development? There must be a way to plan for oil shale development in a manner which accounts for all of the current and future activity related to oil and gas that will have been done by the time oil shale is commercially viable.

- A life cycle assessment could be carried out to address the question of exactly what data is most important to the environmental issues surrounding oil shale. This can be particularly important when it comes to oil shale because some of the contaminants impact different areas (air, water, land) over the life of a project (e.g., solid sulfur starts as a land issue but becomes a water and air issue with time).

- We don't know what processes will be used, so the R&D we conduct should be general enough to be of use whatever processes are ultimately chosen. One example would be to move past the notion that the issue of CO_2 sequestration can be dealt with later. We need to evaluate local options for CO_2 sequestration … where do you put it and how much can you put away …early on in the process.

- Quantification of the hazardous air pollutants that will be generated during the in situ process is an important unknown that needs to be determined. Also, quantifying the contribution of oil shale development to ambient ozone levels is important. As ozone becomes more closely monitored in rural areas, high levels will become a problem.

- The importance of fractures and fracture flow in the Piceance Basin's hydrologic system is not well understood, but needs to be researched if whatever models that are developed are to be accurate.

- We need a regional water supply and use model. Optimizing the use of water in the region is very important and we need to be able to understand how different development options will impact the system.

- Getting public buy in is absolutely critical. To successfully do this you have got to fund and support and continue monitoring outside the areas that are going to be leased. This may be the government's job, perhaps with some industry support. It is necessary to show that activities in one area are not impacting water quality or air quality in another.

- The national labs should already have in place at the various oil shale R&D leases, subsurface sampling and monitoring wells and surface elevation monitoring capabilities, as well as continuous air monitoring equipment.

- Research needs to be done to make certain that we understand the wildlife habitats in the basin and the degree to which current regulation related to wildlife behavior will impact operations of potential oil shale operations.

- We need to not be so concerned with mitigating the impacts of oil shale development, but rather look at what we believe the target environmental impacts should be and design the technology accordingly. Because commercial production is relatively far off, and because the size of the resources means it could go on for quite some time beyond that, we need to have a forward-looking approach.

- An R&D effort is needed to categorize the technologies that are currently available to deal with current air quality issues, and then develop options for new technologies to meet current air quality issues.

Conclusions and Next Steps

In general, the results of the 2007 workshop confirmed the results of the 2006 workshop in terms of the need for R&D related to the environmental issues surrounding potential oil shale.

One central theme was that potential oil shale development should be evaluated in concert with the ongoing and future development of all natural resources region-wide. Thus, strategies to manage the environmental aspects of air, water, solid waste, and carbon should be addressed on a regional basis taking into account all natural resource development, not just oil shale.

A second general theme was that information and data should be shared publicly as much as possible, and a set of baseline environmental data should be established for air, land and water as a starting point for modeling and forecasting.

There was general support for a Federal government role in four areas. It was recommended that the government could:

- Facilitate communication among industry, state and federal regulators, and other stakeholders,

- Provide funding and direction for a data gathering and regional systems modeling efforts that can be used to determine the costs and benefits of various resource development scenarios taking into account the cumulative impacts of the entire spectrum of land use options.

- Collect/develop an objective “baseline” data set and make this data available to the largest possible number of users while preserving the intellectual property rights of technology developers, and

- Identify, collect and publicly disseminate historical data and information from oil shale development that occurred during the 1970s and 1980s.

There was general support for re-establishment of a collaborative effort similar to that of the Oil Shale Environmental Task Force, active from 1978 to 1984. The previous Task Force organized an umbrella organization of oil shale researchers that included National Labs, universities, and others.

This approach, or something similar, could be beneficial in that it would:

- Provide a framework for organizations to contribute data and expertise in a transparent and collaborative manner,

- Act as an aggregator of data and a developer of regional/basin level assessments, work that no individual technology or resource developer has an economic motivation to pursue,

- Provide a mechanism for strengthening the interaction among state and local governments, the public, various federal agencies, the industry, environmental groups, and others interested in ensuring that any oil shale industry is developed in an environmentally sound manner, and

- Provide input to DOE for its management of R&D opportunities funded by the Office of Fossil Energy

Two environmental challenges that were highlighted by the attendees that had not been so prominent in the challenges identified during previous workshops were:

- The challenge of quantifying the level of mercury emissions that might accompany either surface retorting or in situ recovery of oil from oil shale. The concern was that this challenge was not specifically identified and the levels of mercury emissions associated with 1980s technologies would be unacceptable today.

- The challenge of dealing with the large volumes of carbon dioxide that could be generated by either surface or *in situ* processes, and the notion that underground sequestration is a possible solution that needs evaluated comprehensively -- both the volume to be generated and the potential places to store it.

More than 60 professionals attended the 2007 workshop and represented a cross section of stakeholders involved in oil shale development activity. The group's top priorities identified at the workshop include:

- An integrated basin/regional baseline for surface and groundwater data (both quality and quantity) and customized GIS-based analytical tools for analyzing and working with the data.

- Accurate, predictive regional models for release, fate and transport of air emissions from oil shale operations and other activities.

- Research to evaluate generated contaminants and water consumption, and evaluation of Best Available Control Technology.

- Regional energy/resource system model that will enable cost/benefit analysis of a large variety of resource development and land use alternatives in a comprehensive way.

While the participants provided many thoughts and perspectives on a wide variety of issues and concerns, these four elements appeared to form common threads through much of the discussion.

Finally, the Next Steps outlined at the conclusion of the Workshop included:

- Preparation of a draft report on the proceedings of the workshop, distribution of the draft report for comments, and preparation of a final report.

- Integration of the findings from the Workshop into NETL's planning of its future R&D portfolio.

- Engagement of the wider oil shale community to ascertain the level of interest in forming a collaborative effort similar to the previous Oil Shale Environmental Task Force to assist in further developing an oil shale environmental R&D strategy.

Appendices

A. 2007 Oil Shale Environmental Workshop Attendees

Last	First	Company
Ackman	Terry	U.S. DOE NETL
Adenekan	Adeyinka	ExxonMobil Upstream Research Co
Al-Harahsheh	Adnan	Al-Bayt University
Al-Harahsheh	Mohammad	Al-Hussein Bin Talal University
Alleman	David	U.S. DOE NETL
Baldridge	Anne	Norwest Corp
Barkmann	Peter	Colorado Geological Survey
Boak	Jeremy	Colorado Energy Research Institute CSM
Brandt	Adam	U of California, Berkeley
Butler	Roland	Altius Minerals Corporation
Byrns	Cindi	Natural Soda, Inc.
Capson	Craig	Excalibur Industries, Inc
Carroll	Joe	Bloomberg News
Cong	Lianzhu	PetroChina Co Limited Expl. & Prod.
Covell	James	EG&G Technical Services Inc.
Crawford	Peter	Intek Inc
Dammer	Anton	U.S.DOE Naval Petroleum Reserve
Dweirj	Mohammad K.	Alhussein Bin Talal University
Gallagher	Brian	Ecotonics Environmental Scientists
Grigsby	Bryan	S.S. Papadopulos & Associates, Inc.
Habicht	Jaan	Tartu University
Hale	Arthur	Shell E&P Inc.
Harstein	Art	Technology & Management Services, Inc.
Hatfield	Kent	Combustion Resources
Herron	Michael	Schlumberger-Doll Research
Hill	Robert	S.M. Stoller Corp.
Hogle	Dave	Environmental Protection Agency
Housman	Van	National Program for Mining, EPA
Johnson	Thomas L.	U.S. DOI Bureau Land Management
Justus	Julie	Chevron U.S.A Inc.
Kasper	David	ExxonMobil
Kay	Cathy	Western Colorado Congress
Klusman	Ron	Colorado School of Mines
Krenkel	Harold	Alberta Research Council
Lang	Karl	Technology & Management Services, Inc.
McMahon	Peter	U.S. Geological Survey
Nelson	Laura	Red Leaf Resources
Norris	Sean	Chevron U.S.A. Inc.
Nummedal	Dag	Colorado Energy Research Institute, CSM
Ogunsola	Olayinka	U.S DOE FE HQ
Olsen	David	Technology & Management Services, Inc.

Onyskiw	Denise	Colorado DPHE, Air Pollution Control Div
Palmer	Carl D.	U.S. DOE Idaho National Laboratory
Pelham	Jim	ConocoPhillips
Porto Alegre	Henrique	Petrobras
Randall	Bob	Western Resource Advocates
Rogers	John D.	Houston Advanced Research Center
Ross	Douglas	Technology & Management Services, Inc.
Sabanov	Sergei	Tallinn University of Technology
Sarathi	Ramesh	Northwestern University
Skone	Tim	SAIC
Svoboda	Larry	Environmental Protection Agency
Symington	Bill	ExxonMobil Upstream Research Co
Thomas	Michele	ExxonMobil Upstream Research Co
Thompson	Sherri	U.S. DOI Bureau Land Management
Tomer	Brad	U.S. DOE NETL
Vagnetti	Robert V.	U.S. DOE NETL
Vawter	Glenn	ATP Services
Von Guerard	Paul	U.S. Geological Survey
Wilson	Cathy	U.S. DOE LANL Earth & Env. Sciences Div
Wood	Tom	U.S DOE Idaho National Laboratory
Zukor	Steve	Technology & Management Services, Inc.

B. Ongoing Activities in Support of Oil Shale Development

Efforts to commercialize oil shale in response to the 1970s and 80s oil crisis were attempted by a number of major oil firms including Exxon, Shell, Mobil, Occidental, Atlantic Richfield, Chevron, and Unocal; however, the last effort of these commercialization efforts was terminated by Unocal in 1991.

The Bureau of Land Management (BLM) has leased government land in Colorado and Utah to private industry entities to conduct six research and development (R&D) projects, possibly to be followed by a commercial leasing program. **Shell Oil** has been awarded three of these R&D leases to test three different variations of their in situ technology to prove technical, environmental, and commercial viability. Shell's In situ Conversion Process (ICP) eliminates fracturing in favor of slowly heating isolated shale strata over an extended period of time. This technology utilizes extensive drilling of numerous heating, production, and isolation wells. The process protects local ground water by constructing a freeze wall around the in situ retort. The thermal conduction of heat generates slower heat-up rates and results in lower process temperatures, reducing oil losses from thermal cracking and coking reactions, as well as decomposition of carbonate rock. Pressure from the production of gases and vapors creates permeability and allows transport of oil vapors to the production wells.

One of the three Shell projects will explore the possibility of co-producing the nacholite mineral found in some oil shale deposits. In 2005 a Shell spokesperson[1] indicated that a decision to move forward commercially could be expected from Shell by 2010.

Chevron Oil has been awarded an R&D lease to further develop an in situ process which has historic ties to the Equity Oil Company technology tested in the 1970's. This approach uses conventional drilling technologies and modified fracturing techniques designed to control and contain the process underground. It entails drilling wells into the oil shale formation and applying a series of controlled horizontal fractures within the target interval to prepare the production zone for heating and in-situ combustion. Additional fracturing of the shale would be facilitated by subjecting the formation to thermal cycles. Hot CO_2 gas would be introduced into the fractured formation and would flow between connected fracture test wells to further rubblize the process interval. If necessary, propellants and/or explosives may be used to facilitate further rubblization in the production zone. The heating and in-situ combustion phases of the process include the generation of hot CO_2 gas that would be circulated in the target zone to create the heat needed to decompose the kerogen into producible hydrocarbons.

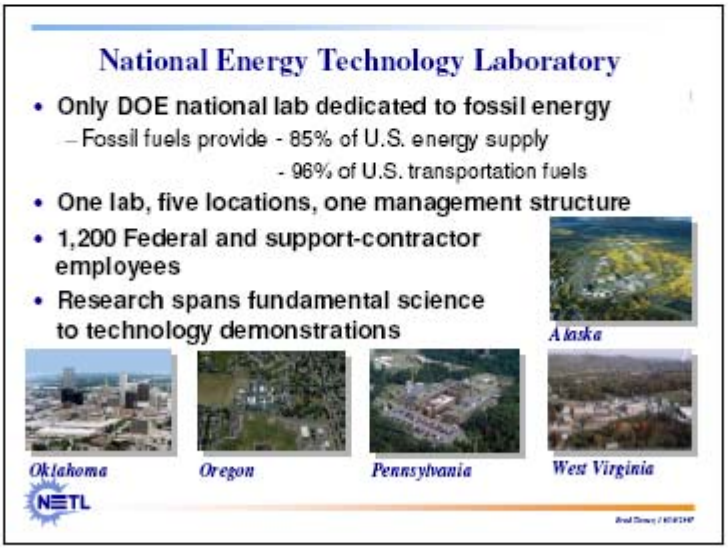
EGL Resources, Inc., also an R&D lease holder, is developing another *in situ* technology. The technology involves drilling five cased wells that would vertically penetrate nearly the full length of the oil shale deposit. Once near the bottom of the oil shale zone, the wells would be drilled horizontally for a distance of about 1,000 feet to the opposite side of the pattern. The wells would then be drilled vertically to connect

[1] Terry O'Connor, Shell Vice President of External Affairs, Associated Press article, "Shell Oil Hopes to Begin Shale Oil Production by 2010," April 8, 2005

with the surface. Fracture stimulation would be used to ensure that these parallel, lateral heat transfer holes along the bottom of the shale column are in communication with each other for delivery of the heating fluid. The heating fluid (a variety of fluids could be used) would then be circulated to bring the oil shale to retorting temperature (350-380 °C). Heating would start at the top and move downward and finally horizontally. A dewatered zone would be established in the retorting zone in order to reduce groundwater infiltration. This would be accomplished with 4-8 pumping wells surrounding the subsurface retort area. Extracted water would be re-injected down gradient.

White River Mine Co. is the lone Utah lease holder and the only surface retorting project. The project will utilize the Alberta Taciuk Process (ATP) retort. Phase 1 involves the collection of about 1,000 tons of oil shale from an existing stockpile within the White River Mine for initial processing through a retort in Calgary, Alberta, Canada. The oil shale will be processed in a 4-ton/hour ATP pilot plant. Phase 2 will move the pilot plant to Utah; reopen the mine, and mine and retort approximately 10,000 tons of new oil shale producing about 6,000 bbl of shale oil. Phase 3 will involve the design, permitting, and construction of a 250 ton/hour ATP demonstration plant. The mine will be sufficient to support the mining of 1.5 million tons/year of oil shale. The ATP plant is planned to retort 2.7 million tons of oil shale and produce about 1.8 million bbl of raw shale oil over a two year operational test period.

C. Speaker Presentations



1

Strategic Center for Natural Gas & Oil

Implement science and technology programs that resolve the environmental, supply and reliability constraints of oil and natural gas resources and enhance our energy security

- **Create public benefits by investing in research that industry would not conduct itself**
- **Deliver a balanced portfolio of technology to:**
  - Enable Independents to efficiently produce discovered resources
  - Conduct Long-term/High risk, high potential payoff R&D - develop entirely new sources of supply
  - Minimize environmental impact

A Multi-discipline, Long-Term, High-Risk, and High-Reward endeavor that will only occur through Federal involvement.

Energy Policy Act of 2005

Oil Shale RD&D Items

- **Sec 965 - DOE Traditional Oil and Gas Program**
  - DOE conduct a program of Oil & Gas RD&D
    - E&P; RLE; T&D; oil shale; environmental
- **Sec 969 – Strategic Unconventional Fuels Task Force**
  - Recommends that government define and implement an Oil Shale R&D Plan focused on mitigation of environmental impacts
- **Sec 999 – Ultra-deepwater & Unconventional Program**
  - Royalty trust fund ($50 million/year for 10 years)
  - Consortium for ultra-deep water; unconventional; small producers
  - Complementary research at NETL

2

Purpose of Workshop

- Build upon last year's workshop results and the findings of the Strategic Unconventional Fuels Task Force
- Develop the framework for an Oil Shale Environmental R&D Roadmap
  - Major environmental challenges
  - R&D needs to address challenges
  - Actions necessary to achieve R&D success
- Identify next steps

Today's Agenda

- Review results of last year's Workshop
- Speakers to provide perspective on environmental challenges
- General session to review and refine major environmental challenges associated with oil shale development (air, water and surface impacts)
- Breakout sessions to identify R&D needs and key tasks necessary to address challenges
- Summarize Results
- Plan Next Steps

3

Intended Workshop Product

- **Draft framework for an Oil Shale Environmental R&D Roadmap**
  - Clear set of challenges and prioritized R&D needs
  - Proposed tasks for achieving these needs
  - Clear path forward for implementing an Oil Shale Environmental R&D Roadmap

Overview of Last Year's Workshop

- **Identified challenges and recommended actions in four areas:**
  - Water quality and quantity
  - Air quality
  - Surface and ecosystem impact
  - Social and economic impacts
- **Challenges were classified as *in situ*, surface operations or both, and whether they were:**
  - Near-term (needing to be addressed by 2010),
  - Mid-term (by 2015), or
  - Long-term (beyond 2020)
- **Identified, where possible, who should lead recommended action**

4

Challenges and Recommended Actions
Air Quality

- **Challenges**
  - Need for long-term, basin/regional air quality monitoring & measurement
  - Insufficient process-specific emissions data; e.g., no data for CO_2
  - Need for a coordinated strategy for addressing CO_2 emissions, capture and use/storage
- **R&D Needs**
  - Develop a protocol for basin/regional emissions monitoring
  - Develop accurate, predictive regional models for release, fate and transport of emissions
  - Conduct process-/resource- specific emissions research and evaluate best available cleanup technology (BACT)
  - Identify gaps, and conduct R&D to develop innovative technologies for reducing (high efficiency) or controlling (capture/separation) emissions at any point; pre-process through post-process
  - Integrate and coordinate with CO_2 regional partnerships (CO_2 sources and sinks/markets) for development of a CO_2 Management Plan
  - Assess life-cycle emissions under various development scenarios, including full suite of infrastructure requirements

Challenges and Recommended Actions
Water Quality & Availability

- **Challenges**
  - Cumulative impacts on surface and groundwater quality and availability unknown
  - Data needed for process-specific water use/consumption and waste water contaminants
  - Need for coordinated strategy for addressing water needs and produced waters from multi-resource/alternative land use development efforts
- **R&D Needs**
  - Develop integrated basin/regional baseline for surface and groundwater data (quality and quantity) and GIS-based analytical tool
  - Conduct process-specific research to evaluate generated contaminants and water consumption; evaluate BACT
  - Conduct R&D to develop new, low water consumption processes; cost-effective water treatment and improved recycle/reuse options
  - Conduct R&D to characterize and assess solutions to potential spent shale leachate
  - Assess water requirements and potential effluents for multi-site oil shale development in conjunction with other regional water use planning efforts for the development of a Water Resource Management Plan

5

Challenges and Recommended Actions
Surface Impacts

- **Challenges**
  - Need process-specific data on solid and liquid wastes (waste constituents and volumes)
  - Cumulative impacts on land, habitats and ecosystems unknown
  - Information on land requirements (spatial/temporal) for oil shale development and associated infrastructure needed
  - Need for of integrated multi-resource land use planning

- **R&D Needs**
  - Spent shale characterization and R&D for alternative by-products
  - Conduct research and analysis to reduce process/development foot print
  - Conduct research on subsidence and potential mitigation strategies
  - Coordinate infrastructure evaluation using GIS-based analysis tools; oil shale and alternative land use development scenarios (trade-off analysis) for the development of a Land Use Plan

NETL

Cross-cutting Themes

- Loss of institutional knowledge from 1970/80s R&D era
- Need for central repository of past and ongoing research and development efforts
- Multiple competing interests for best use of federal lands
- Multiple layers of oversight at all levels; federal, state and local
- Need for a coordinated approach to addressing environmental challenges

NETL

6

Participants Will Be Asked To…

- **Review and refine recommended research needs for air, water and land**
  - Are there missing or incomplete R&D needs?
  - What are the two or three most critical needs that must be addressed?
  - Are there any potential "show stoppers" that may foreclose the development of oil shale?
  - What tasks need to be achieved to meet R&D objectives?
  - What is relative timeframe for achieving objectives?
  - Who should be involved?
- **Help define the necessary steps to:**
  - Establish and implement an oil shale environmental R&D roadmap

How to Approach Your Session

- **Consider technology pathways for solving environmental issues**
- **Consider all phases of the shale oil product value chain**
- **Willingly contribute the benefit of your insights and knowledge regarding ongoing activities that could contribute to solving oil shale environmental challenges**

7

Naval Petroleum and Oil Shale Reserves

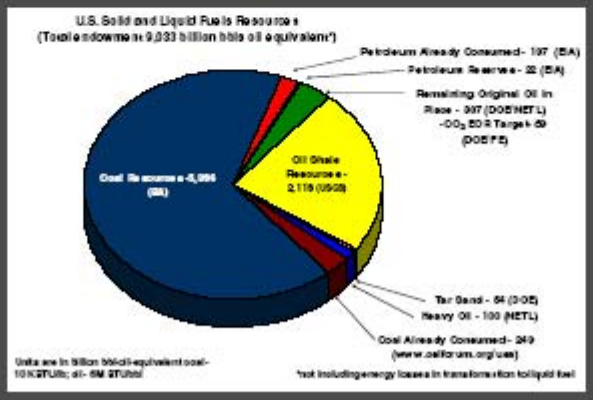
Strategic Unconventional Fuels Task Force

October 18, 2007

Tony Dammer
Director, Office of Petroleum Reserves
United States Department of Energy

27th Oil Shale Symposium
The Colorado Energy Research Institute & The Colorado School of Mines
October 15 – 18, 2007

The Opportunity: America's Endowment of Solid and Liquid Fuels Resources



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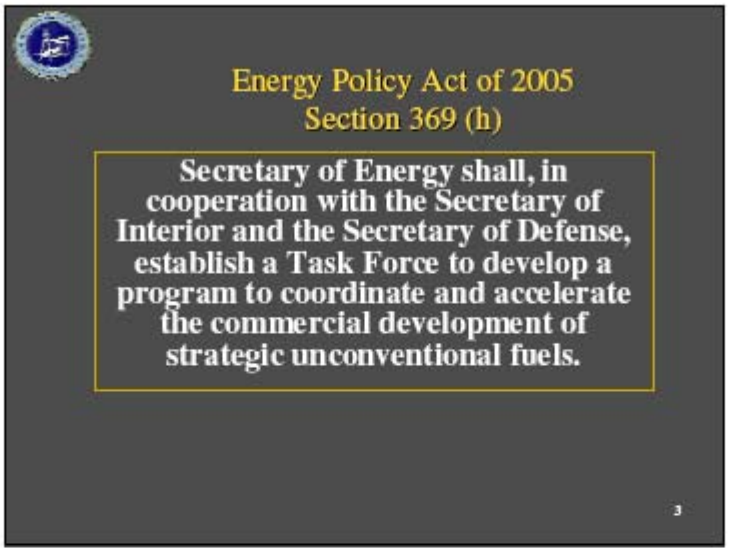
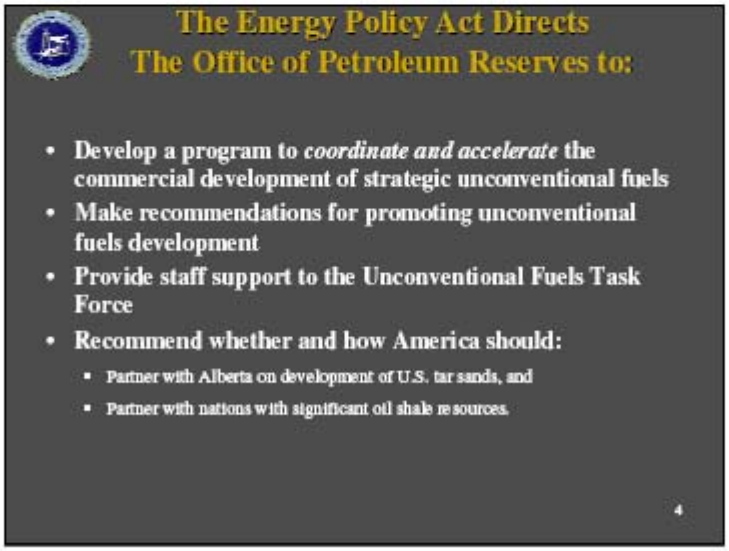
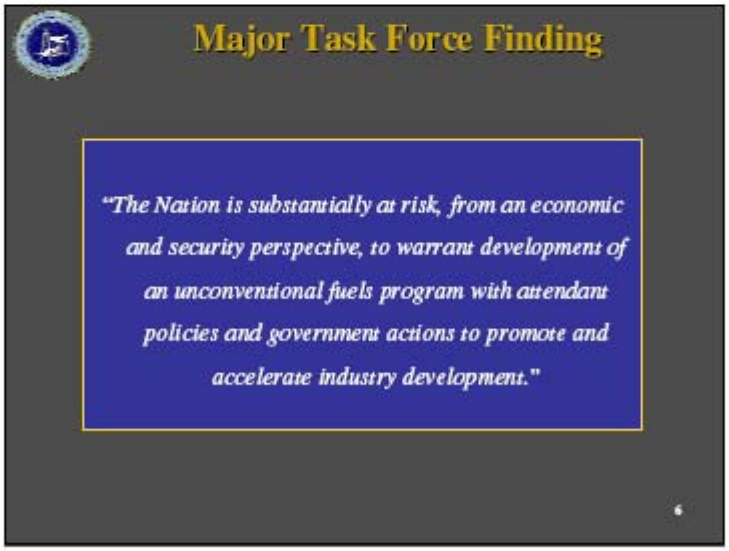

Energy Policy Act of 2005
Section 369 (h)
Secretary of Energy shall, in cooperation with the Secretary of Interior and the Secretary of Defense, establish a Task Force to develop a program to coordinate and accelerate the commercial development of strategic unconventional fuels.
3


The Energy Policy Act Directs
The Office of Petroleum Reserves to:
• Develop a program to coordinate and accelerate the commercial development of strategic unconventional fuels
• Make recommendations for promoting unconventional fuels development
• Provide staff support to the Unconventional Fuels Task Force
• Recommend whether and how America should:
▪ Partner with Alberta on development of U.S. tar sands, and
▪ Partner with nations with significant oil shale resources.
4

2


Strategic Unconventional Fuels Program Goals
• Accelerate development of domestic unconventional fuels
• Promote effective environmental stewardship and impact mitigation
• Mitigate potential adverse socio-economic impacts on states and localities
• Generate substantial public benefits while ensuring government fiscal responsibility
5


Major Task Force Finding
"The Nation is substantially at risk, from an economic and security perspective, to warrant development of an unconventional fuels program with attendant policies and government actions to promote and accelerate industry development."
6

3

Major Program Strategies

- Assure access to resources on public lands by commercial leasing
- Coordinate and streamline regulatory and permitting processes
- Create a fiscal regime of tax, royalty, and purchase incentives to stimulate investment
- Support and share risks for technology development and demonstration
- Prepare an integrated local / regional infrastructure plan
- Support local planning and education and vo-tech training to meet development needs, mitigate impacts, maximize jobs, and foster growth.
- Evaluate potential government structures that can promote and accelerate efficient industry development.
- Partner with Alberta on U.S. tar sands development
- Partner with other countries on oil shale development.

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Technology Introduction

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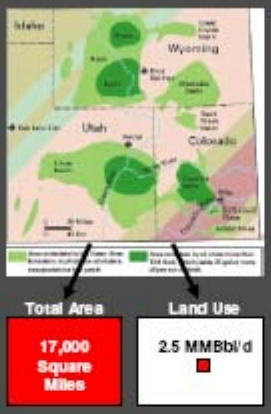
Oil Shale Environmental Impacts



- **Land Use**
  - Disturbance depends on process
  - 31 square miles per 1 MMBbl/d capacity (surface)
  - 21 square miles per 1.5 MMBbl/d capacity (in-situ)
  - Less than 0.5% for a 2.5 MMBbl/d industry
  - For 40 years
  - Green River Formation totals 17,000 square miles

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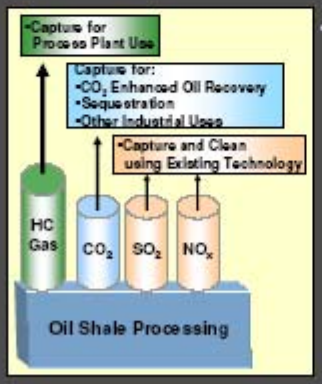
Oil Shale Environmental Impacts



- **Air Quality**
  - Heating shale can generate gases including CO_2, NOx, SO_2, particulates, and water vapor
  - Technology exists to control / reduce / sequester emissions

10

5

Oil Shale Environmental Impacts

- **Water Impacts**
  - Estimates range from 1-3 barrels of water per barrel of shale oil
  - Colorado river systems flow: 10-22 million acre feet/yr
- **2.5 MMBbl/d oil shale industry:**
  - Requires 0.2-0.4 million acre feet/yr
- **Challenge**
  - Water runoffs (surface)
  - Ground water protection (in-situ)

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Summary

- **Over 2 trillion barrels of in place resource**
- **The most concentrated hydrocarbon deposits on Earth**
- **Conversion technologies are advancing rapidly**
- **A unique opportunity to provide long term sustained domestic production**
- **Substantial economic benefits to the Nation**
- **Requires concerted effort by the private sector, Federal & State governments, and local communities to design practical environmental mitigation and remediation practices.**

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6

ENVIRONMENTAL CHALLENGES AN INDUSTRY PERSPECTIVE

R. Glenn Vawter
EGL Oil Shale, LLC
October 18, 2007

INTRODUCTION

- Representing EGL Oil Shale, LLC – Lessee of a BLM R,D/D Lease in Rio Blanco County.
- In agreement with the conclusions reached by the 2006 workshop. Congratulations due the sponsors and participants of that event.
- Have little to add to the major challenges and recommendations reached in 2006.

EGL PERSPECTIVE

- Insitu technology approach
- Conducting initial site investigations, laboratory testing and modeling work.
- Will not have information about a commercial project until further along with field testing and demonstration.
- However EGL like other developers have identified the key environmental challenges and are working on solutions.
- Transparency and collaboration

MAJOR ENVIRONMENTAL CHALLENGES

- **Water – Water and Water**
  - **Ground Water**
  - **Surface water**
- Carbon management
  - Sequestration
  - Disposition
- Multiple use
  - Wildlife
  - Other


RESEARCH NEEDS
Industry – Industry & Gov't – Gov't
Site – Area – Basin – Regional scales
Ideas for Industry and Gov't Collaboration
Baseline and long term monitoring
Ground water transport and quality
Surface water flow and quality
Carbon sequestration and disposition
Site monitoring for specific purposes
Air and water quality
Tomography to determine hydrologic character


CROSS CUTTING AREA NEEDS
Central repository and clearing house for environmental and socioeconomic data
Collaboration between all parties – state, federal, local and industry
Continuity of environmental policy and regulations that gives industry a sustainable roadmap of expectations

NON-INSITU SUGGESTIONS

- Even though emphasis is on insitu processes, extensive reserves are in private hands that are amenable to mining and surface retorting.
- Obtain literature data on reclamation of spent shale disposal from Unocal project and others.
- Assemble the extensive date available from past projects.

CONCLUSIONS AND RECOMMENDATIONS

- Keep up the good work and keep communications open and candid between all parties.