Oil & Natural Gas Technology

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Quarterly Progress Report
With Summaries of Center-sponsored Research
(July - September 2008)

UTAH HEAVY OIL PROGRAM

Submitted by:
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Quarterly Progress Report
Utah Heavy Oil Program
University of Utah
DE-FC26-06NT15569
Quarter Ended September 30, 2008

Philip J. Smith, Principal Investigator
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EXECUTIVE SUMMARY

The mission of the Utah Heavy Oil Program (UHOP) is to provide research support to federal and state constituents for addressing the wide-ranging issues surrounding the creation of an industry for unconventional oil production in the United States. While work continued in this quarter on the repository for information, data, and software and on the five UHOP-sponsored research projects, progress was hampered by the departure of three key personnel (the repository computer technician, a PI on two projects, and a graduate student) involved in several of the projects. In addition, the timeline for the project related to commercial oil shale leasing has been extended due to delays in the release of the Final Programmatic Environmental Impact Statement and the moratorium on finalizing regulations that was only recently lifted. Due to these delays, a request has been made for a no-cost extension so that the original project deliverables can be achieved. As projects are completed in the next 3-12 months, final reports will be prepared and distributed. The redesigned repository was rolled out in a meeting with Robert Vagnetti on September 18, 2008. Several hundred documents have been uploaded to the repository in this quarter, but most are awaiting approval by a soon-to-be-hired librarian before being released to the public.

PROJECT MILESTONES/PROGRESS PERFORMANCE

A. Progress in Program-Sponsored Projects

Brief summaries are provided below for ongoing work in the five UHOP-sponsored projects.

1. Detailed Study of Shale Pyrolysis for Oil Production

Milind Deo, Eric Eddings, Terry Ring

The kinetics of shale pyrolysis were studied in detail, and the data was presented at the 28th Oil Shale Symposium at the Colorado School of Mines. Based on the discussions and feedback at the meeting, it was determined that the single-rate methods were inappropriate for deducing activation energies for shale conversion. The Friedman method was used to obtain activation energies as a function of conversion (x). The

activation energies obtained are listed in Table 1. These values are in the range of values obtained previously by other methods.

Table 1. Activation energies for shale pyrolysis using the Friedman method.

N_2_Nonisothemal_Friedman						
α	Slope	Intercept	R^2	Ea kJ/mol	A	LnA
0.05	12767	16.49	0.983	106.14	1.5E+07	16.54
0.1	14197	18.57	0.981	118.08	1.3E+08	18.68
0.2	16912	22.46	0.983	140.60	7.1E+09	22.68
0.3	19417	25.93	0.982	161.43	2.62E+11	26.29
0.4	21671	28.99	0.989	180.17	6.55E+12	29.50
0.5	24326	32.55	0.997	202.24	2.75E+14	33.24
0.6	26110	34.82	0.998	217.07	3.34E+15	35.74
0.7	28020	37.10	0.996	232.95	4.33E+16	38.30
0.8	27740	36.16	0.990	230.63	2.53E+16	37.77
0.9	25843	32.35	0.986	214.85	1.13E+15	34.65
0.95	27102	33.17	0.991	225.32	5.09E+15	36.16

A 2D multi-physics model for the *in situ* extraction of oil shale has been developed. The model accounts for the heating of the deposit from one well and the production of oil and gas from another well. The wells are drilled in an equilateral triangular pattern, allowing half of the equilateral triangle to be used for a model of the deposit with the heating well at the apex with the 60º angle and the production well at the apex with the 30º angle. The apex with the 90º angle is a point of symmetry for the model. The heating is done by conduction in the deposit with the heating well hole being the heat source. Once heated, the kerogen decomposes to bitumen, oil and gas. The kinetics of the multi-step decomposition are modeled. The oil and gas flow via D'Arcy's law in the deposit due to an increase in the gas pressure when the kerogen is decomposed by the high temperatures in the deposit. Physical properties of the kerogen, bitumen, oil and gas are modeled as a function of temperature and pressure. The multi-physics model has been solved using Comsol, a finite element solver. Recently, modeling work has run into convergence problems at a simulation time of ~100 days. The heat transfer equation has been identified as the equation that does not converge. To date, researchers have decreased the size of the grid elements, decreased the time step and varied other parameters without

success. Researchers are considering other approaches, including a re-analysis of the thermal conductivity from first principles, to solve the convergence problem and obtain results from *in situ* extraction of oil shale after 1 year of simulation time.

2. **New Approaches to Treat Produced Water and to Perform Water Availability Impact Assessments for Oil Shale Development**

   Steve Burian, Ramesh Goel, Andy Hong, Brian McPherson

Water Resources Sustainability: The water management project task focused on developing a water management model for the Uinta Basin to assess the impacts of estimated water demands on regional water resources, including streamflow and groundwater reserves. Daily streamflow data were acquired for all gages within the Uinta Basin boundary. Missing flow data were estimated using nearby records and the watmodel system. Using their GIS database, the researchers input the hydrologic network into the MODSIMM water management model. The MODSIMM Uinta Basin model was then populated with the streamflow records. The Uinta Basin MODSIMM model is now ready to be combined with the project's previous energy development water demand estimates to analyze water resources management alternatives to support energy resources development in the basin.

Integrated Treatment Approach: The produced water treatment research focused on degradation of naphthalene under more refined conditions. Efforts were made to set up a contract with GE water systems to purchase membrane modules. Chemical, electrolytic and biological degradation of naphthalene has been completed and a manuscript is being prepared for publication.

In the ozonation work, researchers refined the pressure cycles-assisted ozonation system and successfully removed suspended oil that was prone to sheen formation. Waters with several hundred mg/L of suspended and dissolved Rangely crude oil were treated for oil removal. After treatment, degradability of compounds remaining in the treated water was tested. The treated water contained no suspended oil that would cause sheen and it contained only trace levels of dissolved organic acids that were readily biodegradable. The treated water appeared to be suitable for recycle and reuse. The new method is superior to the best available technologies for improving produced water quality. A manuscript will be completed and sent out for review and publication shortly. Funding for this work has not been continued; the PI is presently seeking funding for additional optimization, pilot testing, and site implementation on the new technology for produced water treatment and reuse.

3. **In Situ Production of Utah Oil Sands**

   Pete Rose, Royhan Gani, Jack Hamilton and Milind Deo

No report received.

4. **Depositional heterogeneity and fluid flow modeling of the oil shale interval of the upper Green River Formation, eastern Uinta Basin, Utah**

   Royhan Gani and Milind Deo

Geological characterization: Using gamma and density logs, the correlation was done for both stratigraphic picks and oil-shale zone picks across the study area and tied to core U059. In addition, each horizon in the study area was mapped and isopach (i.e. same oil shale interval thickness) maps for key stratigraphic and oil-shale intervals were produced. The lithology of core U059 was divided into a number of facies, which were then interpreted in terms of depositional environments. The entire geological results of this project were integrated to characterize the oil-shale interval of Green River Shale in detail and to formulate a model for the deposition of oil-shale rich intervals, particularly in terms of fluctuations in lake levels.

The complete core log is shown in Figure 1. Most of the shale is classified calcareous mud and appears fairly homogeneous in the rich sections of the deposit.

Fluid flow modeling: The geologic description was incorporated into a reservoir simulator and the oil production process was studied. A hexagonal pattern of heaters at about 50 feet spacing was used to pyrolyze the organic matter. The complex reaction set shown below was used to describe the process.

- Kerogen → Heavy Oil + Light Oil + Gas + CH_4 + char
- Heavy Oil → Light Oil + Gas + CH_4 + char
- Light Oil → Gas + CH_4 + char
- Gas → CH_4 + char
- Char → CH_4 + Gas + coke

The base production results are shown in Figure 2. A significant amount of gas is produced in the process. Process variations and energy balances will be reported in the next report.

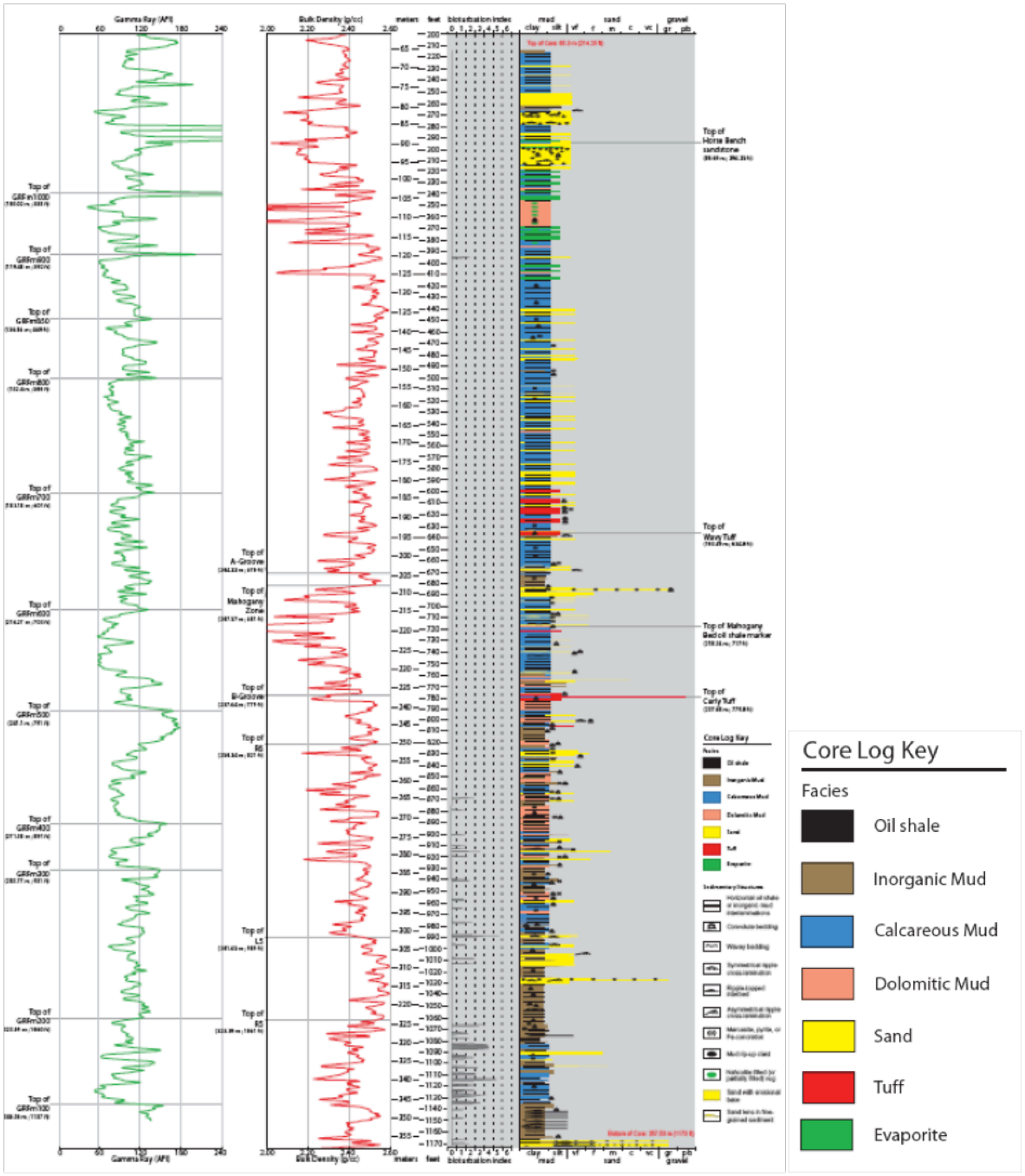

Figure 1: The complete core log with legend. Density and gamma-ray logs are superimposed to show lower density sections coinciding with high organic content.

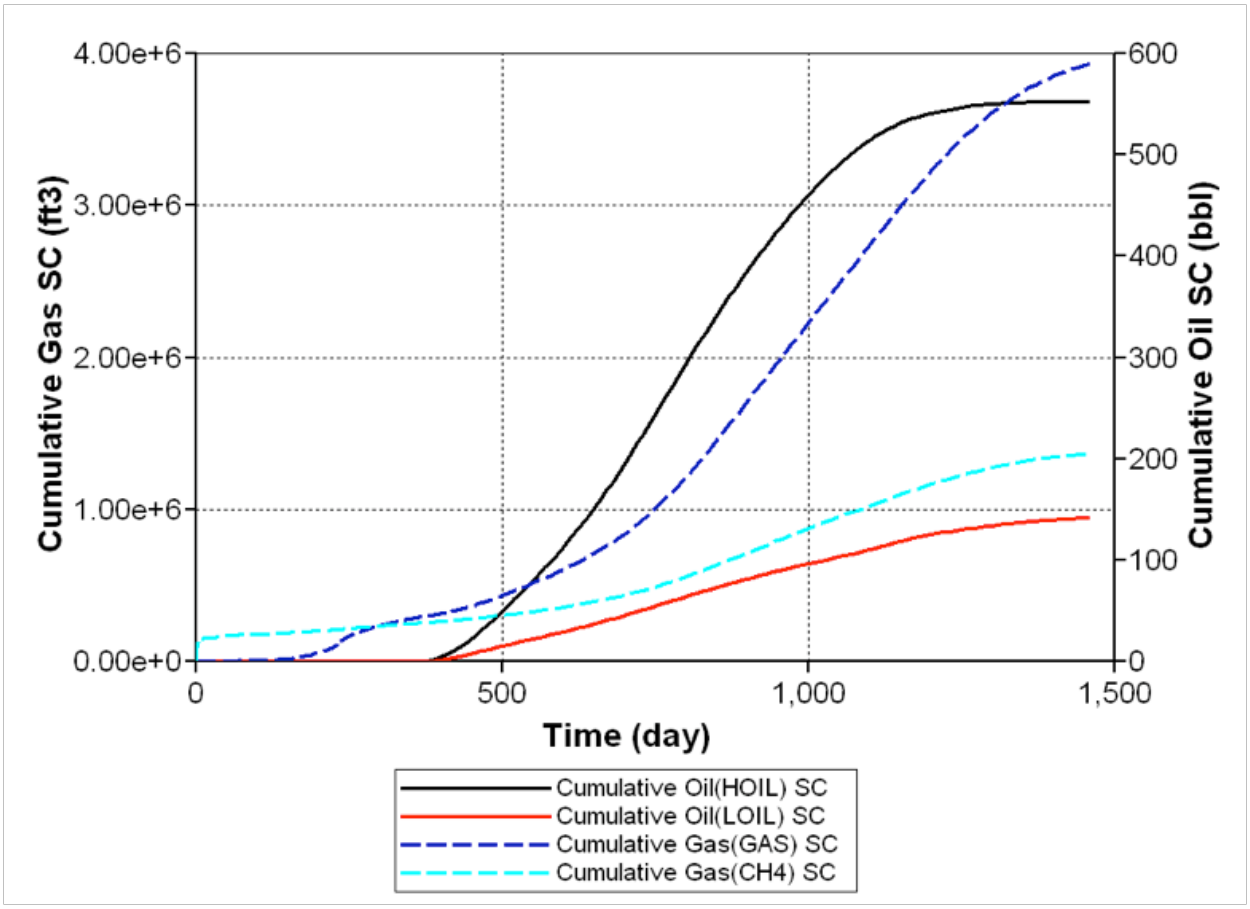

Figure 2: Base production results showing cumulative production of the various components.

5. **Analysis of Environmental, Legal, Socioeconomic and Policy Issues Critical to the Development of Commercial Oil Shale Leasing on the Public Lands in Colorado, Utah, and Wyoming under the Mandates of the Energy Policy Act of 2005**

   Robert Keiter, Kirsten Uchitel

Researchers continued their review and analysis of the Bureau of Land Management's PEIS on Oil Shale Leasing as well as the public, non-governmental organization, and industry comments on the leasing options outlined in the PEIS. Additionally, they began their review of the draft oil shale regulations released by the Bureau of Land Management and interviewed and discussed the impacts of the regulations on various oil shale leasing issues and commercial oil shale development models with individuals with commercial leasing experience on the public lands. Finally, researchers continued to review, draft and edit preliminary sections of the report on commercial oil shale leasing.

B. On-line Repository

The undergraduate student who was hired to upload documents to the repository has been working steadily the entire quarter. While some documents are now available for full-text searching and for downloading at http://ds.heavyoil.utah.edu/dspace/index.jsp, the majority of the several hundred documents that have been uploaded await approval of a librarian before being made publicly accessible. A staff member of UHOP has been approving documents when time is available, but a full-time librarian is necessary to remove the backlog and bring all documents online. A search is currently underway to hire a librarian. In addition, the part-time computer technician responsible for maintaining DSpace left for a full-time position at the beginning of August 2008. Recent hardware and software problems have highlighted the need for a full time computer professional to maintain the repository (based on the DSpace platform) and the GIS-based map server interface to the repository and to resolve the backlog of issues that have arisen since early August. The job has been posted and interviews will be conducted in the next several weeks. A request for a no-cost extension has been in order to use available funds to cover the cost of hiring these two new employees.

CONCLUSIONS

Several UHOP projects have been hampered this quarter by key personnel for other jobs and by the late release of federal documents related to oil shale leasing. For this reason, a no cost extension request is being made in order to complete the original deliverables on each of the projects. As projects as completed over the next few months, researchers will provide final reports. The UHOP repository with its map server interface is viewed as an important outreach and information dissemination tool. To insure its current and future utility, we are hiring both a computer professional and a librarian to replace the expertise we lost when employees at Energy and Geoscience Institute at the University of Utah (where we outsourced the work) left for other jobs.

COST PLAN/STATUS

Baseline Reporting Quarter	Year 1							
	Q1		Q2		Q3		Q4	
	6/21/06 - 9/30/06		10/1/06 - 12/31/06		1/1/07 - 3/31/07		4/1/07 - 6/30/07	
	Q1	**Total**	Q2	**Total**	Q3	**Total**	Q4	**Total**
Baseline Cost Plan								
Federal Share	126,295	**126,295**	239,349	**365,644**	41,357	**407,001**	147,911	**554,912**
Non-Federal Share	31,574	**31,574**	34,342	**65,916**	25,969	**91,885**	38,387	**130,272**
Total Planned	157,869	**157,869**	273,691	**431,560**	67,326	**498,886**	186,298	**685,184**
Actual Incurred Cost								
Federal Share	126,295	**126,295**	239,349	**365,644**	41,357	**407,001**	164,491	**571,492**
Non-Federal Share	31,574	**31,574**	34,342	**65,916**	25,969	**91,885**	30,841	**122,726**
Total Incurred Costs	157,869	**157,869**	273,691	**431,560**	67,326	**498,886**	195,332	**694,218**
Variance								
Federal Share	0	**0**	0	**0**	0	**0**	16,580	**16,580**
Non-Federal Share	0	**0**	0	**0**	0	**0**	(7,546)	**(7,546)**
Total Variance	0	**0**	0	**0**	0	**0**	9,034	**9,034**

Baseline Reporting Quarter	Year 2							
	Q5		Q6		Q7		Q8	
	7/1/07 - 9/30/07		10/1/07 - 12/31/07		1/1/08 - 3/31/08		4/1/08 - 6/30/08	
	Q5	**Total**	Q6	**Total**	Q7	Total	Q8	Total
Baseline Cost Plan								
Federal Share	147,911	**702,823**	147,911	**850,734**	147,911	**998,645**	147,911	**1,146,556**
Non-Federal Share	38,620	**168,892**	38,620	**207,512**	38,620	**246,132**	38,620	**284,752**
Total Planned	186,531	**871,715**	186,531	**1,058,246**	186,531	**1,244,777**	186,531	**1,431,308**
Actual Incurred Cost								
Federal Share	161,343	**732,835**	178,570	**911,405**	165,243	**1,076,648**	114,429	**1,191,077**
Non-Federal Share	29,299	**152,025**	10,038	**162,063**	36,285	**198,348**	19,020	**217,368**
Total Incurred Costs	190,642	**884,860**	188,608	**1,073,468**	201,528	**1,274,996**	133,449	**1,408,445**
Variance								
Federal Share	13,432	**30,012**	30,659	**60,671**	17,332	**78,003**	(33,482)	**44,521**
Non-Federal Share	(9,321)	**(16,867)**	(28,582)	**(45,449)**	(2,335)	**(47,784)**	(19,600)	**(67,384)**
Total Variance	4,111	**13,145**	2,077	**15,222**	14,997	**30,219**	(53,082)	**(22,863)**

Baseline Reporting Quarter	Year 3							
	Q9		Q10					
	7/1/08 - 9/30/08		10/1/08 - 12/31/08					
	Q9	Total	Q10	Total				
Baseline Cost Plan								
Federal Share	147,911	**1,294,467**	147,909	**1,442,376**				
Non-Federal Share	38,620	**323,372**	37,222	**360,594**				
Total Planned	186,531	**1,617,839**	185,131	**1,802,970**				
Actual Incurred Cost								
Federal Share	144,808	**1,342,302**						
Non-Federal Share	37,868	**255,236**						
Total Incurred Costs	182,676	**1,597,538**						
Variance								
Federal Share	(3,103)	**47,835**						
Non-Federal Share	(752)	**(68,136)**						
Total Variance	(3,855)	**(20,301)**						

MILESTONE COMPLETION CHART

Task	Critical Path Project Milestone Description	Project Duration Start: End:										Planned Start Date	Planned End Date	Actual Start Date	Actual End Date	Comments (notes, explanation of deviation from baseline)
		Project Year 1				Project Year 2				Project Year 3						
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10					
1.1	Identify resources on unconvention-al oil in North America	X										June, 2006	Sept., 2006	June, 2006	Sept., 2006	
1.2	Prepare draft update report on domestic unconvention-al oil resources	X	X									June, 2006	Sept., 2006	June, 2006	Feb. 2007	Identifying personnel & surveying available sources took longer than expected. Added value from the report will be from analysis, which also takes more time.
1.3	Release draft update to public & request input from unconvention-al oil community		X									Sept., 2006	Sept., 2006	Oct., 2006	March 2007	Preliminary draft was released on March 21, 2007 Release delayed by Task 1.2 delay and by problems with report quality from company hired to do page layout.
1.4	Attend the CERI Oil Shale Symposium & provide a summary		X				X					Oct., 2006	Oct., 2006	Oct., 2006	Oct., 2006	
1.5	Develop on-line repository for all types of material pertaining to unconvention-al oil resources in North America	X	X	X								June, 2006	June, 2008	June, 2006		The repository is being repopulated with the original 1400 documents that were included; expected completion date for this set of documents is Sept. 2008

1.6	Update and release enhanced version of report developed under 1.3, integrating comments received			X								Jan., 2007	Aug., 2007	April, 2007	Sept., 2007	
1.7	Release on-line repository to unconvention-al oil community			X								Jan., 2007	Jan., 2007	Jan., 2007	Feb, 2007	Release date was Feb. 15, 2007.
1.8	Refine repository, incorporating information provided by user community			X	X	X	X			X	X	Jan., 2007	Oct., 2008	Jan., 2007		
2.1	Identify Center-sponsored research projects areas in consultation with DOE	X				X						Sept., 2006	Sept., 2006	Sept., 2006	Oct., 2006	
2.2	Issue internal RFP to support project areas identified in 2.1		X			X						Sept., 2006	Sept., 2006	Oct., 2006	Nov., 2006	RFP was released on Nov. 20, 2006. Proposals were due Dec. 15, 2006.
2.3	Select 2-3 Center-sponsored research projects		X			X						Oct., 2006	April, 2007	Jan., 2007	April, 2007	Selection of research projects completed in March 2007. Researchers were not notified of project selection before end of quarter three.
2.4	Complete technical reports for Center-based research projects					X						Oct., 2008	Oct., 2008			

2.5	Provide priority listing of research & demonstration needs for domestic production from unconventional oil resources				X	X						June, 2007	Sept., 2007	Nov. 2007		Will address this milestone in the first quarter of 2008

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