Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH

In Development

Principal Investigators:

Milind Deo, Ph.D.
EGI Affiliate Scientist, Professor, Department Chair for Chemical Engineering

Email: milind.deo@utah.edu

Palash Panja, Ph.D.
Post Doctoral Research Associate

Email: ppanja@egi.utah.edu

Investment per Sponsor
$75K (USD)

Duration
12 months

Project I 01284

EMAIL:
ContactEGI@egi.utah.edu

PHONE: (801) 585-3826

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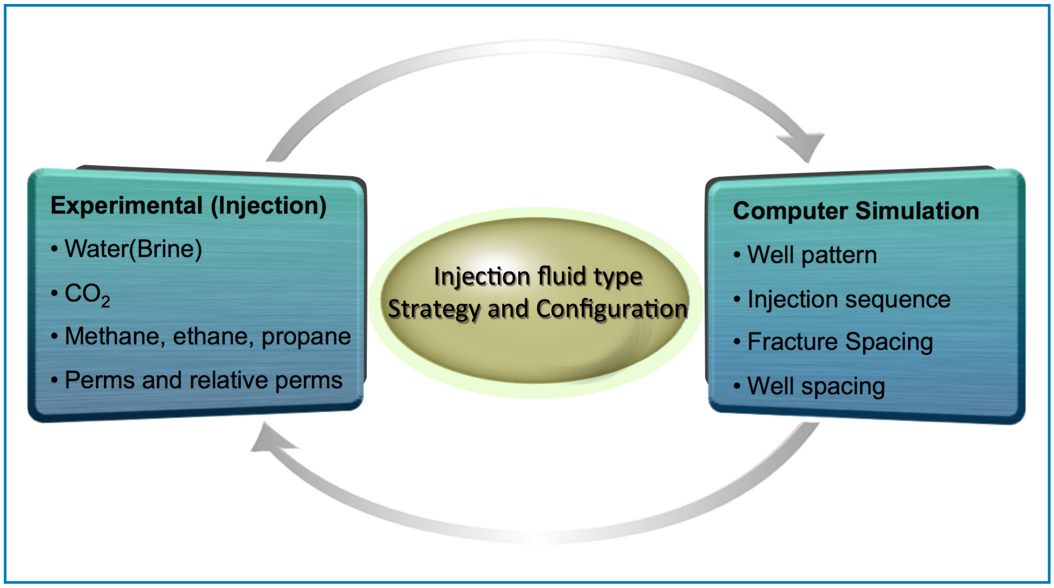
Enhanced Oil Recovery in Shales

Value

- Provide sound injection strategies for enhanced oil recovery in shales based on phase behavior and flow capacities.
- Provide optimized injection – production well configurations for field application.

Key Deliverables

1. Report on suitability of using water, CO_2, natural gas, ethane or propane for enhancing recovery from shales based on core flood recoveries.
2. Evaluation of the effect of rock type on the choice of the injection fluid.
3. Measurements of permeabilities of liquids and gases by performing flow-through experiments and relative permeabilities of selected pairs of fluids (water-oil; oil-CO_2; oil-gas).
4. Guidelines based on computer simulations for injection and production configurations – well locations, spacing, fracture spacing, etc.



Project activities at a glance.

Rationale & Significance

It is recognized that oil recoveries in plays producing liquids are low (5-10%), and that new technologies are necessary to unlock the enormous amount of stranded oil. Secondary recovery in the form of waterflooding is common in conventional reservoirs. Gas injection is used to enhance recoveries in a number of cases, with carbon dioxide (CO_2) being the most common injectant. Keys to the success of any injection strategy to enhance recoveries are the compositions and properties of the phases formed (phase behavior) and flow capacities (relative permeabilities) of the phases. Previous research conducted at the Energy & Geoscience Institute has revealed interesting permeability characteristics for organic and aqueous phases. Once the suitability of injection fluid is established based on phase behavior and flow considerations, an appropriate injection-production program must be designed to understand, how, where and when to inject and produce fluids. Experimental investigation of phase behavior and flow for various injectants and computer simulations of injection/production strategies will be undertaken in this project.

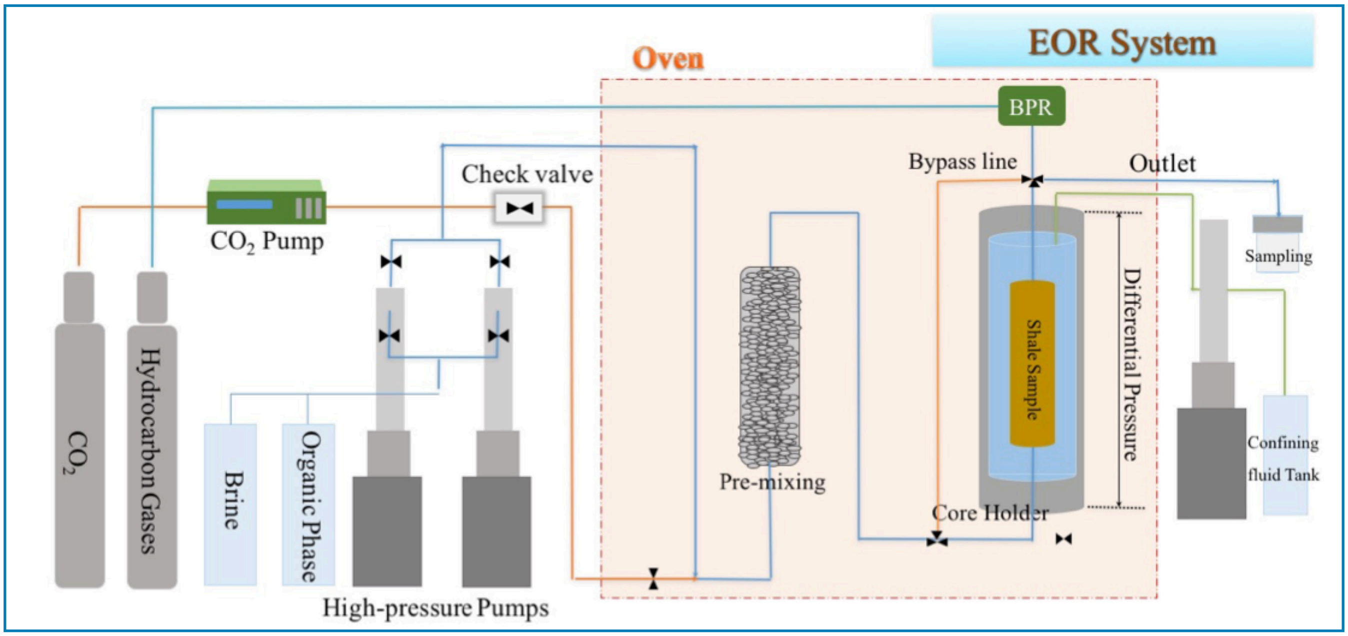


Figure 1. Thermodynamics and Flow Measurements Equipment at the University of Utah.

Project Activities

The project will consist of experimental activities of the assessment of the use of several injectants – water, CO_2, methane, ethane, propane and gas mixtures in cores from the Eagle Ford, Permian Basin and the Bakken. Initially, decane will be used as the organic phase, followed by a representative oil. Core floods will be conducted to determine additional oil recoverable by use of the specific injectant. Phase behavior and phase permeabilities will be assessed during the flood. The core flooding system shown in Figure 1 was used to measure single-phase liquid permeabilities in an organic-rich shale, and surprisingly fluid dependent permeabilities were observed (Figure 2). These measurements conducted as part of the recently concluded Flow in Nanoporous Rocks project highlight the need to conduct flow measurements in cores.

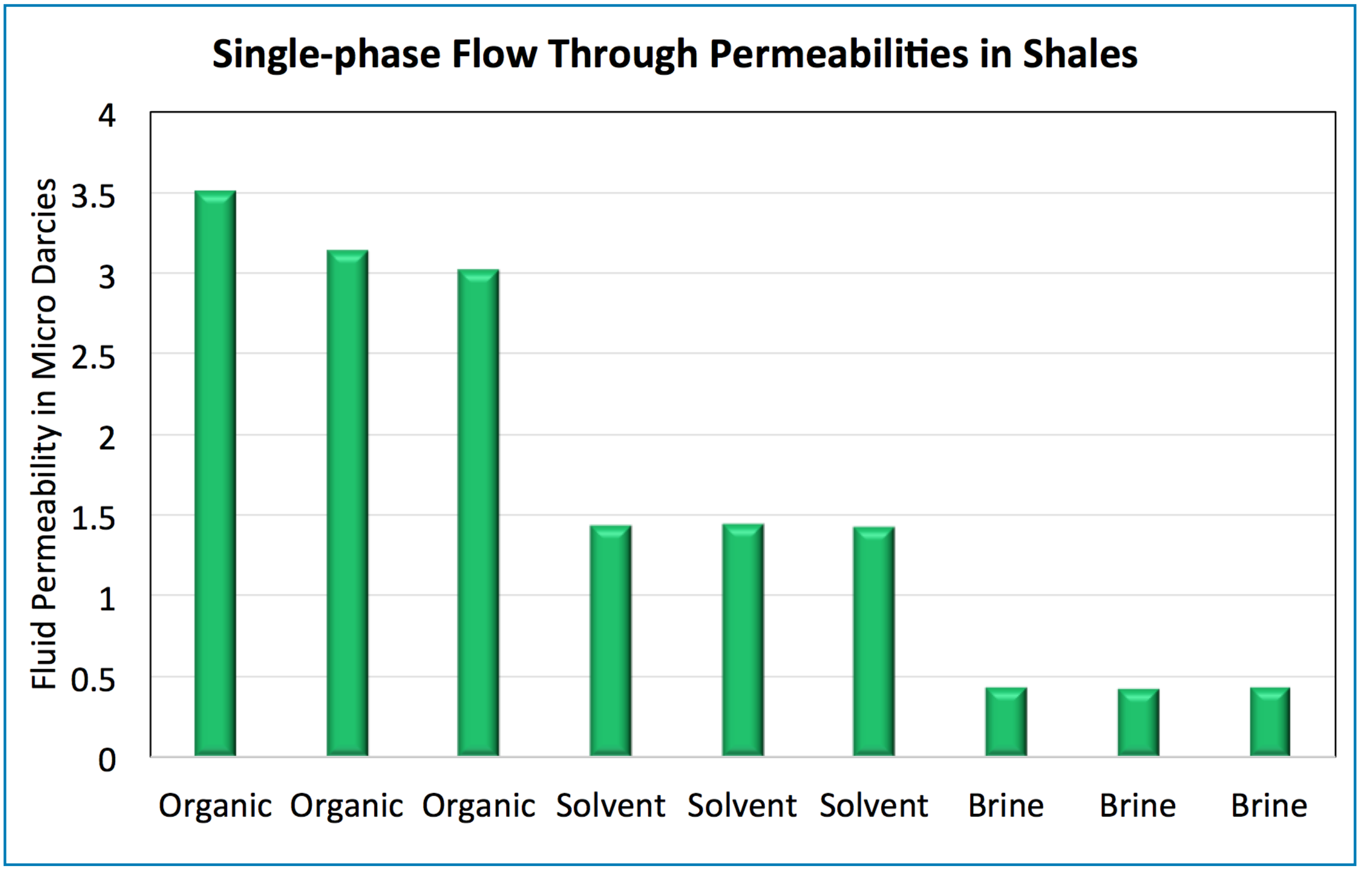


Figure 2. Figure showing fluid-dependent absolute permeability

The experimental research will be complemented by how, where and when to inject and produce fluids. Results of pilots in the Bakken show that enhanced oil recovery efforts using water, natural gas and CO_2 have not been very successful. It is important to configure the fractures, wells and all the other design variables to get the most out of each enhanced oil recovery operation.

Different injection strategies within a well and between wells will be examined using realistic geologic models in the Bakken, Eagle Ford and the Permian. Injection and production horizons (where to land the wells), continuous or cyclic injection, well and fracture spacing, etc., will be investigated to design the best possible configuration for an EOR operation.

Project Timeline, Report & Investment

The duration of the first phase of the project is one year. Updates and interim data uploads will be announced during the project cycle and provided to all sponsors. A final report will be prepared and delivered following the final meeting.

The investment per sponsor is $75,000.

Research Team

Staff	Expertise/ Affiliation
Milind Deo, Ph.D. **Chair, Department of Chemical Engineering** **University of Utah**	Principal Investigator Reservoir Simulation & Engineering, Enhanced Oil Recovery
Raymond Levey, Ph.D., **Director & Research Professor**	EGI Director & Project Advisor
Palash Panja, Ph.D. **Post Doctoral Research Associate (EGI)**	Production, Process Engineering & Simulation
Raul Velasco **Post Doctoral Research Associate (EGI)**	Reservoir Numerical Simulation

EGI Technical Contacts

Milind Deo, Ph.D. | Chair, Department of Chemical Engineering, University of Utah
Energy & Geoscience Institute at the University of Utah
423 Wakara Way, Suite 300, Salt Lake City Utah 84108
Tel. 801-581-7629 | Email: milind.deo@utah.edu

Raymond Levey, Ph.D. | EGI Director and Research Professor
Energy & Geoscience Institute at the University of Utah
Tel. 801-585-3826 | Email: rlevey@egi.utah.edu

EGI Sponsorship & Contract Information

Raymond Levey, Ph.D., EGI Director & Research Professor – College of Engineering
Tel. (801) 585-3826 | Fax (801) 585-3540 | Email: EGIDirector@egi.utah.edu

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Email
milind.deo@utah.edu

Phone
801-581-7629

Research Interests

- Production of fluids from shales
- Reservoir engineering
- Enhanced oil recovery

Milind Deo, PhD

PROFESSOR CHEMICAL ENGINEERING

Milind Deo is a Professor and Chairman of the Department of Chemical Engineering at the University of Utah and Director of the Petroleum Research Center where he has supervised over 20 Ph.D. students and six Masters students.

He received his B.S. from the Indian Institute of Technology in Chennai, India and his Ph.D. from the University of Houston in Houston, TX, in Chemical Engineering. His Ph.D. research concentrated on the development of methods for determining residual fluid saturations after a carbon dioxide flood.

After a short stay at the Schlumberger Perforating Center in Houston where he worked on under-balanced perforating technology, followed by two years of post-doctoral work at Stanford University, he joined the University of Utah in December 1989. At Stanford, his main areas of interest included detailed petroleum characterization and phase behavior of oil, gas, and carbon dioxide mixtures. His main areas of research at the University of Utah have been reservoir engineering and enhanced oil recovery. He is widely published in the field with numerous papers and articles, and has authored several EGI reports.

Research Highlights

Dr. Deo's research group was involved in two highly successful U.S. Department of Energy (DOE) Class I and Class III Reservoir Projects. The Class I Reservoir Project with Lomax Exploration Company led to the revitalization of waterfloods in the Uinta Basin, while the Class III Project reactivated an idle lease in the Midway Sunset Field, resulting in over two million barrels of additional oil produced.

His research group has also developed a new generation of reactive-transport, multiphase reservoir simulators that are also capable of modeling fractures as discrete networks. He is conducting a comprehensive multifaceted study on Liquids from Shales that includes production analysis, development of rapid analysis and forecasting tools, material and geologic characterization, reservoir simulation, and geomechanics.

Currently, he and his students are engaged in research related to production of oil from oil shale, carbon dioxide enhanced oil recovery and sequestration, heavy oil production, and flow assurance apart from unconventional gas production.

Dr. Deo has developed a strong oil and gas enhanced oil recovery and reservoir engineering research program at the University of Utah. An important milestone in this program was the establishment of the Petroleum Research Center as one of the State Centers of Excellence. He has also established a computational component with focus on fractured reservoirs and discrete-fracture models, including a series of multi-phase, finite element discrete-fracture models as an alternative to dual-porosity models to help better understand and manage fractured reservoirs.

DEPARTMENT OF Chemical Engineering COLLEGE OF ENGINEERING | THE UNIVERSITY OF UTAH

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Palash Panja, PhD

Research Scientist

Palash Panja joined EGI in 2015 as a Post-Doctoral Research Associate. He is an instructor in the Department of Chemical Engineering teaching courses for BS in Chemical Engineering and MS in Petroleum Engineering. He is working closely with EGI Affiliate Scientist Dr. Milind Deo on the Improved Liquid Recovery in Shales project, Palash is examining various reservoir engineering aspects of conventional and unconventional reservoirs as well as working on existing EGI projects and developing new projects in collaboration with EGI staff and Corporate Associates.

After receiving his Master's degree from the Indian Institute of Technology, Bombay, Palash earned his Ph.D. in Chemical Engineering from the University of Utah, specializing in petroleum and reservoir engineering.

Palash has worked 5 years with a variety of companies ranging from downstream companies to upstream production companies to University research. He worked for three years for ONGC, India's largest public E&P Company, serving as a production engineer on an offshore gas and condensate production platform.

As a graduate research assistant at the University of Utah, Palash worked on EGI's Liquids from Shales Phase 1 and 2 projects, enhancing his global oil and gas understanding through direct experience with a variety of unconventional plays throughout the United States, including the Bakken, Barnett, Eagle Ford and Niobrara.

Panja's current interests include production optimization from unconventional reservoirs while minimizing the environmental impacts, improved hydrocarbon recovery, CO_2 capture and injection, geothermal field development, interactions between flow and thermodynamics, surrogate model development, data analysis using machine learning etc. He has published more than 20 articles in journals and conferences.

Email
ppanja@egi.utah.edu

Phone
801-585-9829

Research Interests

- Improved liquid recovery from shale
- Enhanced Geothermal System (EGS)
- CO_2 capture & injection
- Machine learning
- Molecular dynamics in nanopores
- Rock on a chip
- Food, Energy & Water nexus

Research Experience & Focus:

- Generate surrogate models for black oil and condensates in shales for quick production forecast, sensitivity study, and to assess the uncertainties in recoveries.
- Understand the flow and thermodynamic behaviors of hydrocarbons in nano-pores through molecular dynamics simulation.
- Develop model for completion and production from fractured basement reservoirs.
- Study the importance of petrophysical and other parameters on production and recovery from shales.
- Design an efficient system to extract heat from an enhanced geothermal system (EGS)
- Apply machine learning in various aspects of reservoir characterization, field development, completion, production and completion operational strategies.
- Develop and improve modules of University developed in-house reservoir simulator A.R.T.S.

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