EGI Energy & Geoscience Institute AT THE UNIVERSITY OF UTAH

Since 1972

In Development

Production & Economic Analysis of Tight Reservoirs

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Investment per Sponsor
$TBD (USD)

Duration
TBD

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Value

- Provide insight to multiphase flow behavior in hydraulically fractured reservoirs using analytical and numerical tools to determine the depletion conditions, completion parameters etc.
- Develop diagnostic tools to help determine the impact of reservoir rock, fluid, completion, and operational practices on liquid recovery.
- Apply acquired knowledge to increase liquid recovery through optimization of completion practices such as fracture and well spacing.

Key Deliverables

1. Provide semi-analytical tools that can capture complex multiphase flow behavior and their application to a robust production data base. Up to 6000 wells representing prolific liquid plays in the USA such as the Bakken, Niobrara, Eagle Ford, Woodford, and the Permian Basin will be used.
2. The development of reservoir evaluation tools to :
    a. Calculate fracture interference time
    b. Determine fracture conductivity
    c. Determine reservoir depletion
    d. Forecast fluid production
    e. Estimate EUR
3. Identify geological, fluid, rock-fluid, completion, and operational parameters and their degree of influence on production through semi-analytical and numerical multivariate analysis.
4. Based on the developed theoretical framework in this research, provide a universal fracture and well spacing optimization strategy that considers production and current economic trends such as oil prices.

Rationale & Significance

Conventional wisdom does not apply to the production of liquids from shales and tight formations due to the highly complex nature of multiphase flow in hydraulically fractures reservoirs. Developing a comprehensive understanding of the kind of impact that various geological, fluid, rock-fluid, completion, and operational parameters have on multiphase flow is essential to evaluate shale production evaluation. In addition to developing a theoretical framework, analytical and simulation tools will be applied to thousands of wells in prolific liquid plays in the USA. Conclusions from this comprehensive study will enhance the understanding of oil shale behavior and improve our ability to optimize production strategies.

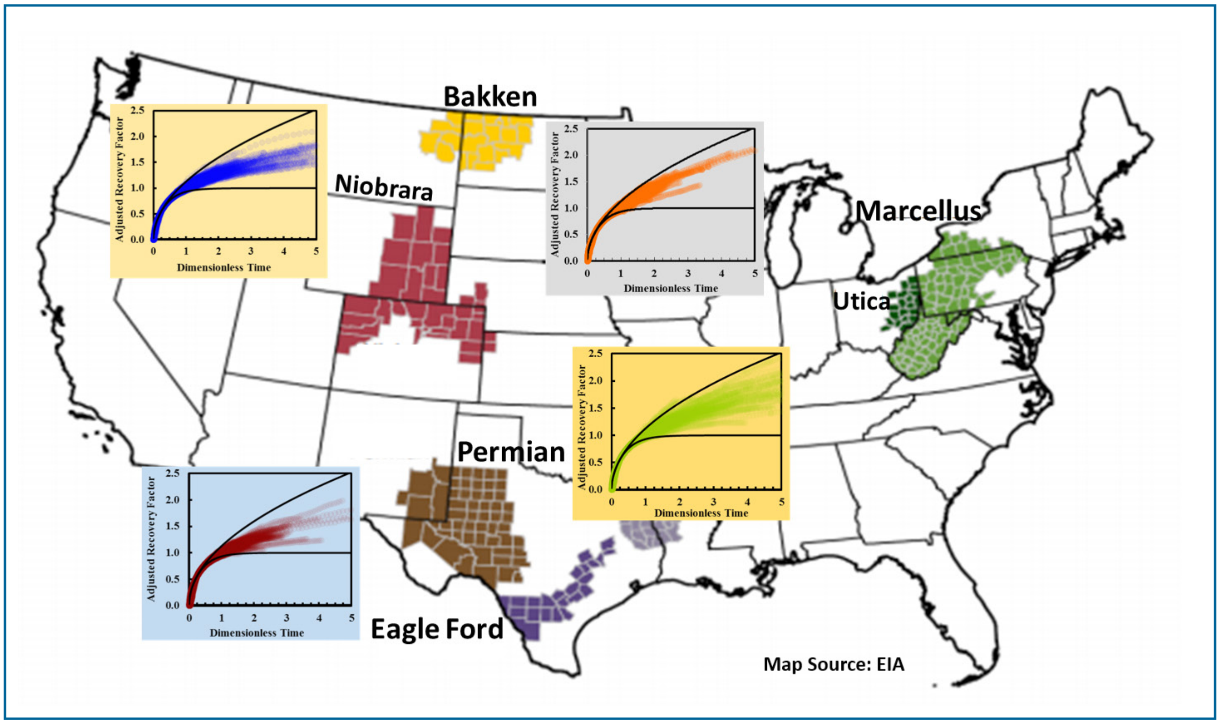

Figure 1: Prolific shales/tight formations in the USA.

Scope of Work

Understanding the production behavior of liquids from shales involves multi-faceted research. We will analyze production data from thousands of wells across North America in order to develop a semi-analytical model for unification of production trends. Simulations will be designed for multi-variate analysis to investigate the effects of various fluid, operational, and geological parameters. The combined understanding of field data and simulation will provide context for an economic study aimed to maximize profits based on production and oil price trends.

Field Data Analysis

Production data from prolific plays in USA such as Bakken, Niobrara, Eagle Ford, Permian, Woodford, etc., will be analyzed. We plan to evaluate as many as 6000 wells for this robust analysis. Based on findings of previous projects at EGI, Liquids from Shales Phases 1 and 2 (EGI Reports I 00973 and I 00973_2), each play is unique in geologic settings, PVT properties, and initial reservoir conditions. Well and fracture spacing as well as operational parameters vary from well to well. This research project will include various plays in order to account for variability in terms of operational and geological parameters. Many well established decline curve or type curve methods such as Arp's empirical method (1945), Fetvikovich method (1980), Palacio-Blasingame method (1993), Agarwal-Gardner method (1998), Wattenbarger-Elbanbi (1998) type curves assume constant flowing bottom hole pressure or boundary dominated or transient flow of single phase etc. A universal type curve will be constructed considering the two-phase flow in transient state and boundary dominated flow conditions. Variable operating conditions, completions, and geologic parameters are accounted for in our analysis of liquid production from tight formations or shales. A semi-analytical solution of the production of two-phase flow in transient state will be presented using proper dimensionless recovery factor and dimensionless time. The developed tool will be straightforward to integrate in to production data.

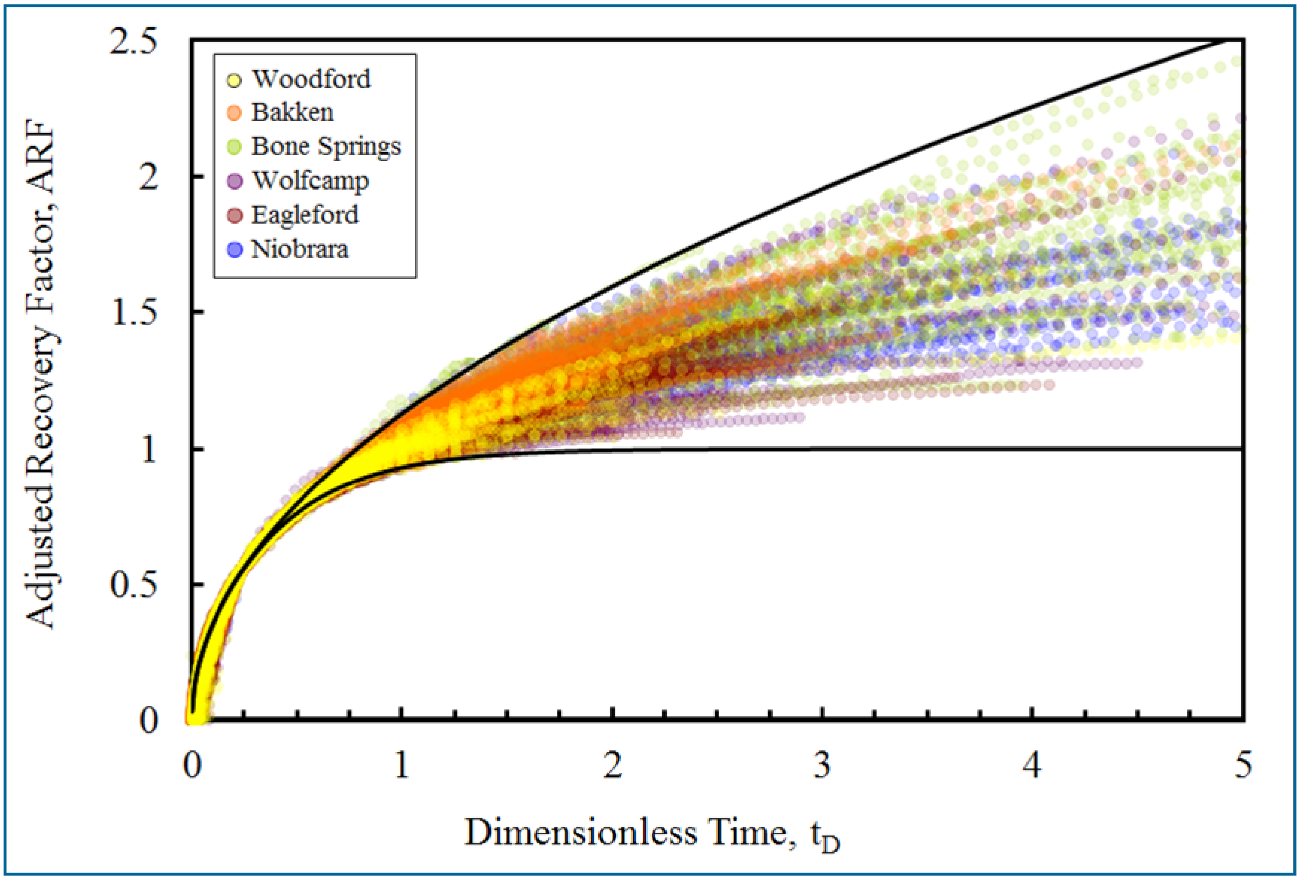

Figure 2: Universal behavior of U.S. tight oil production.

Multivariate Analysis

To better understand the impact of various parameters numerical simulations are required. The simulation experiments will be designed by varying fracture conductivity, fracture flow area, flowing bottom hole pressure, initial reservoir pressure, relative permeability curves, saturations, PVT, etc. Surrogate reservoir models for recovery factors will be developed using polynomial response surface, least square support vector machine (LSSVM), and artificial neural network (ANN). The developed surrogate models will be used for production forecasts and sensitivity analysis, uncertainty analysis, hierarchy determination and optimization.

Reservoir Description & Diagnosis

In transient flow conditions, reservoir characterization is essential in order to evaluate production performance. Analysis of field data and results from numerical simulation will provide a great understanding of the two-phase flow behavior in the subsurface. Using this knowledge, we will develop simple tools to estimate fracture interference time, reservoir depletion, forecast fluid production, ultimate recoveries, etc. Other important completion parameters can be estimated such as fracture effective conductivity and surface area.

Economic Analysis

In order to keep unconventional wells profitable, current reservoir characterization and evaluation is not sufficient. Well spacing and fracture spacing are the most important parameters for successful field development. The profitability is not directly proportional to the number of wells in a field and number of fractures in each well due to the drainage interference. Adding more wells and fractures increase the completion cost. The profitability is also strongly dependent on the amount of production and the oil prices. In this project, a comprehensive economic study will be conducted considering the cost of drilling, completion, land acquisition, royalty, fixed operating cost, future oil price etc. Various economic measurements such as Net present value (NPV), internal rate of return (IRR), discounted profitability index (DPI), discounted return on investment (DROI) will be calculated. This analysis will provide optimized scenarios for any given production conditions and oil prices.

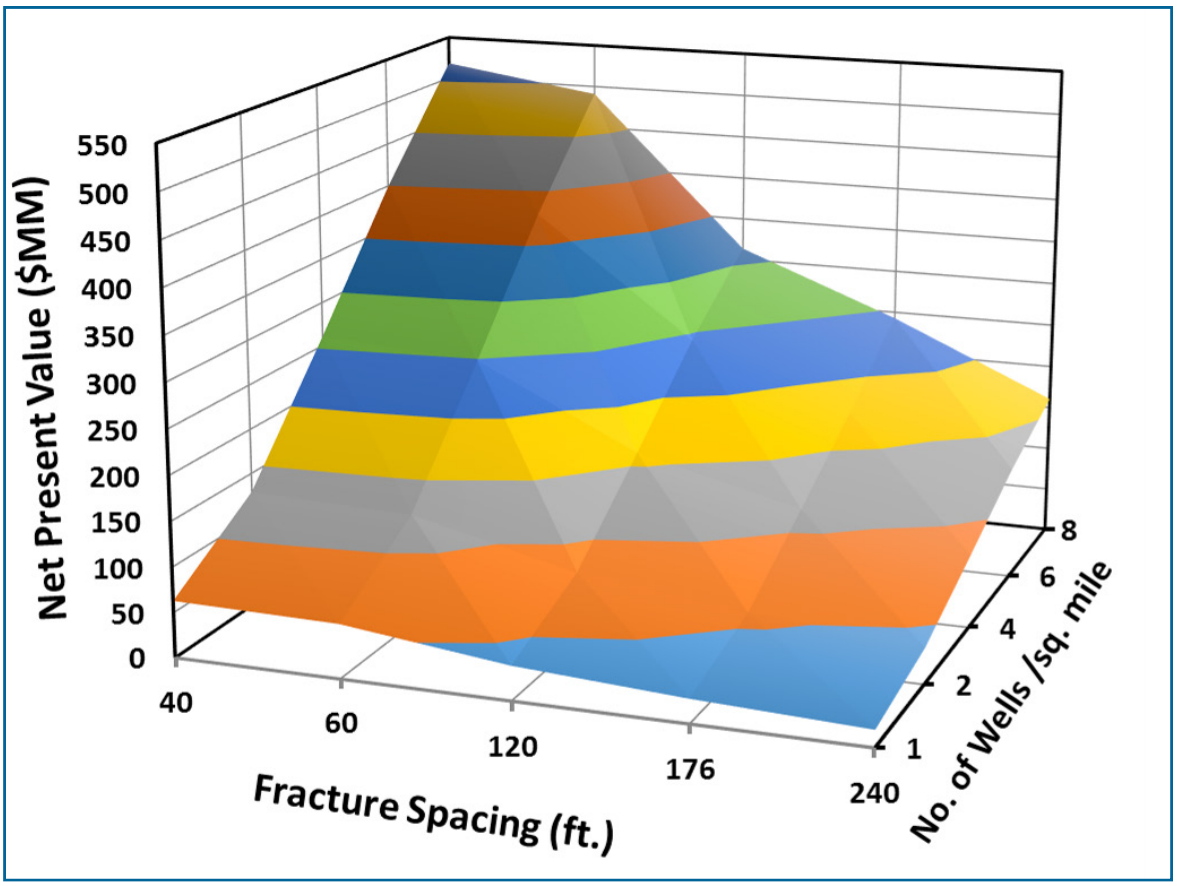

Figure 3: Maximizing profit by optimizing the completion job.

Research Team

Staff	Expertise/ Affiliation
Palash Panja, Ph.D. **Post Doctoral Research Associate (EGI)**	Co-Principal Investigator Production, Process Engineering & Simulation
Raul Velasco, Ph.D. **Post Doctoral Research Associate (EGI)**	Co-Principal Investigator Production Analysis, Reservoir Engineering & Numerical Simulation Development
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

Project Timeline, Report & Investment

The duration of the project will be determined by sponsors. 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.

Sponsor participation: We encourage sponsors to provide production, completion, and PVT data. Using these data, we will provide sponsors a rapid and dynamic characterization and diagnosis of the reservoir in order to increase confidence in business decisions.

The investment per sponsor is dependant on the number of sponsors.

EGI Technical Contacts

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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.

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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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

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Research Interests

- Conventional and unconventional reservoir engineering
- Reservoir simulation development
- Tight oil and gas production analysis
- Molecular Dynamics
- Artificial Intelligence

Affiliate Scientist Raul Velasco originally joined EGI as Postdoctoral Research Fellow in 2016, where he worked closely with EGI Affiliate Scientist, Professor, and Chair of the Department of Chemical Engineering at the University Utah, Dr. Milind Deo. As a research fellow, Raul developed novel semi-analytical and numerical techniques to help understand, model, and predict the behavior of unconventional reservoirs. Raul also taught the theory and development of reservoir simulation as well as the application of commercial simulators, to Petroleum Engineering Masters students at the University of Utah.

As a Petroleum Engineering and Mathematics undergraduate student, Raul worked at the Physics & Astronomy Department designing and building antennas for the IceCube neutrino detection project in Antarctica. This experience was formative in developing a career in science and engineering research. He later obtained his Ph.D. in Chemical Engineering at the University of Utah, where he focused on the reservoir engineering study of unconventional reservoirs. As a research assistant, Raul contributed to EGI's Liquids from Shales, Phase 1 and 2 projects where he developed tools to help evaluate tight formation potential. After working with Schlumberger as a reservoir engineering intern, Raul developed a new discrete fracture representation framework designed to facilitate the modeling of complex hydraulic and natural fracture networks. As an active member of the Society of Petroleum Engineers (SPE), Raul has presented his work at workshops and conferences and served as vice-president of the University of Utah student chapter. He was also recipient of EGI and ConocoPhillips fellowships as well as the John Zink graduate scholarship award.

Research Experience & Focus:

- Developed semi-analytical methods for the multiphase production analysis, evaluation, and prediction of unconventional reservoirs.
- Contributed to research projects that involved reservoir engineering studies of the Eagleford, Niobrara, and Bakken.
- Studied tight oil decline rates and proposed optimal fracture and well spacing based on well production, completion, and economic trends.
- Developed reservoir simulation programs with novel discrete fracture representations for simple and complex fracture network models.
- Implemented machine learning methods to forecast oil and gas production from hydraulically fractured reservoirs.
- Experimentally verified bubble point shift in confined fluids.
- Currently exploring the effects of nano-scale transport in shale porous media by use of molecular dynamics.

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Milind Deo, PhD

PROFESSOR CHEMICAL ENGINEERING

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Research Interests

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

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.

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