

# Technical Reviewers' Rating Summary

Proposal Number G-026-060 Application Title Enhanced Bakken Recove Submitted By  
 Energy & Environmental R Request For \$450,000.00 Total Project Costs  
 \$1,350,000.00

## Section A. Scoring

Statement	Weighting Factor	G-026-01	G-026-01	G-026-03	Average Weighted Score
1. Objectives	9	4	3	4	27
2. Achievability	7	3	4	3	21
3. Methodology	8	3	3	4	24
4. Contribution	8	4	4	5	32
5. Awareness / Background	5	4	5	4	20
6. Project Management	3	4	4	4	12
7. Equipment / Facilities	2	5	5	4	8
8. Value / Industry - Budget	4	4	4	4	16
9. Financial Match - Budget	4	4	5	4	16
<b>Average Weighted Score</b>		<b>187</b>	<b>194</b>	<b>201</b>	<b>194</b>

Total: 50

**250 possible points**

## OVERALL RECOMMENDATION

FUND X X X  
 FUNDING TO BE  
 CONSIDERED  
 DO NOT FUND

## Section B. Ratings and Comments

- The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Oil and Gas Research Council goals are:

The goal of the project is to evaluate the benefits of CO2 EOR in the Bakken play. If proved beneficial EOR can increase Bakken production by billions of barrels.

- Reviewer: G-026-01

- Rating: 4

While the ultimate goal of the endeavor is pretty clear, the actual project goal is less so. The goal to "generate knowledge enabling informed decisions regarding CO2 EOR for Bakken" is pretty broad/vague. The tasks don't support such a broad goal. A clearer goal would be one that captures the essence of what questions will be addressed by the tasks performed during these 15 months. This project will be a first step in a long process to evaluate the viability of CO2 EOR potential. What is the goal of this first step?...this would be a clearer project goal. For example "build static and dynamic phase equilibrium models to enable estimation of theoretical oil recovery from CO2 EOR processes."

- Reviewer: G-026-01

- Rating: 3

The objective of the project is clearly defined as determining the viability of CO2 for enhanced oil recovery in the Bakken formation by using new and existing reservoir characterization, laboratory data integrated with reservoir modeling.

- Reviewer: G-026-03

- Rating: 4

The goal of the proposed project is to predict the performance of CO2 EOR based on the results of laboratory experiments and modeling activities. Those activities will be conducted to quantify phase behavior and fluid properties under reservoir conditions. Data from three Bakken pools will be compiled and used to evaluate potential CO2 EOR schemes in both thermally mature and thermally immature portions of the Bakken. Lab analyses will include petrographic analysis of rock samples and pressure-volume-temperature (PVT) and vanishing interfacial tension (VIT) studies of Bakken oil samples. Modeling will include the integration of well file data and new experimentally-derived data to generate static reservoir models and conduct dynamic simulation modeling.

- Applicant

2. With the approach suggested and time and budget available, the objectives are:

The suggested approach seems to be well justified. However, the proposal does not discuss a couple of important issues. 1) The reservoirs most of the times are naturally overpressured. Thus enhancement can be mostly due to miscibility. With the given type of Bakken oil it is not quite clear whether the miscibility will provide significant benefits; 2) the proposal does not intend to investigate the possibility of shale swelling in response to gas injection, while swelling of an organically rich rock can have significant negative effect on permeability; 3) the paper on the technique for the evaluation of miscibility enclosed with the project specifically discusses the use of 99.9% pure CO2. How this relates to lower purities of CO2 is not quite clear, while using high purity CO2 may appear uneconomic.

- Reviewer: G-026-01

- Rating: 3

Given the Investigator's experience, facilities and access to core and fluids, the tasks look achievable within the time and budget allotted. The main concern is that the investigators will dive too deeply into one specific activity, as problems and new questions arise, which will derail the overall schedule. For example, Relative Permeability Testing of Core is likely to be

extremely challenging. It is critical to force each activity to provide "best technical estimates and hi/lo ranges" if a deterministic answer isn't found within the allotted time.

- Reviewer: G-026-01

- Rating: 4

The data acquisition listed in Task I and Task II is both related to the success of the experiments and the quality and uniqueness of the experimental results. Since it is highly difficult to conduct experiments using nano darcy permeability rock such as generation of CO<sub>2</sub>/water/oil relative permeability curves, the time component of the project may be extended or re-evaluated.

- Reviewer: G-026-03

- Rating: 3

Regarding the first reviewer comments, the investigators' responses are enumerated as follows: 1) The investigators recognize the typically overpressured nature of the Bakken and understand the importance of taking this into account when considering the effects of a miscible flood in the context of Bakken oil types. The EERC team intends to address those questions over the course of the experimental activities. This aspect of the work was not described or discussed in the proposal because of the mandated 15-page limit on the proposal. 2) The investigators recognize that swelling of shales or other organic rich rocks may have a negative effect on CO<sub>2</sub> EOR efforts. While understanding those effects is important to predicting the effectiveness of EOR schemes in the Bakken, the resources that are currently available to this project are not sufficient to include swelling experiments. Such efforts could be part of a separately funded future project, a separately funded complementary but parallel project, or even a later add-on to the proposed project should more funding become available from current partners. 3) The EERC has the capability and experience to work with CO<sub>2</sub> streams that contain a wide variety of impurities, including H<sub>2</sub>S, in a broad range of concentrations. The use of high purity CO<sub>2</sub> will minimize the number of variables that must be taken into account when designing the experiments and evaluating results. While the investigators recognize the effects that impurities can have on miscibility, etc., since the proposed work is considered to be pioneering in nature the investigators currently plan to use high purity CO<sub>2</sub>. However, the investigators are familiar with the nature of impurities in CO<sub>2</sub> streams from sources that might be used in North Dakota, such as the Great Plains Gasification plant, local gas processing plants, and even coal-fired power plants in the region and we will consult with the participating industry sponsors to determine if the experimental design should be modified to include an impure CO<sub>2</sub> stream. Based on the EERC's experience working with impure CO<sub>2</sub> streams it is anticipated that such modification of the experimental design would not cause a change in the overall budget. Regarding the second reviewer's comments about the project schedule being derailed by investigators diving too deeply into any one specific activity, we believe that our experience conducting similar projects will enable us to avoid such pitfalls. Our experience indicates that the best way to avoid getting off schedule is to maintain frequent and effective communication between all key project participants (technical team, management team, partners, and funding agencies). High levels of communication allow for the participants to assess challenges to the project in a timely manner and provide the technical team with input regarding potential solutions to those challenges. In addition to the quarterly reports shown

on the proposal timeline, EERC personnel will interact frequently (typically monthly, sometimes weekly if necessary) with key personnel from the various partner organizations. The reviewer comment also mentions providing "best technical estimates and hi/lo ranges" if a deterministic answer isn't found in the allotted time. This is an approach that the investigators certainly agree with, have used when appropriate in other projects, and are comfortable with using if necessary in this project. Regarding the second and third reviewers' comments about the challenges related to relative permeability testing of low permeability rocks, it is worth noting that the EERC's Plains CO2 Reduction (PCOR) Partnership program has included relative permeability testing of a variety of rock types, including low permeability rocks. The challenges related to working with low permeability rocks are recognized by the investigators and based on past experiences we are confident that the proposed activities can be completed according to the proposed schedule.

- Applicant

3. The quality of the methodology displayed in the proposal is:

Please see the issues discussed in Question 2.

- Reviewer: G-026-01

- Rating: 3

While this Reviewer is recommending the goal be tightened up (in order to better match expectations to the actual planned tasks), one area to consider modifying is the overall methodology. The study appears to be following a conventional "laboratory work, modeling and documentation" approach. While much of the application talks about the 'big' uncertainties of EOR in tight fractured reservoirs, the tasks don't really target these. Instead they seem to follow convention. The concern here is the study will result in some good technical work, but won't provide a clear next step to answer the ultimate question...will CO2 EOR work in the Bakken. It is recommended to consider a methodology that focuses this foundation work toward setting up the next step of "field data collection and field trials." That is, look at each activity through the lens of next steps...that is, how would this parameter be confirmed at a reservoir level? While the actual activities might remain the same, they would be performed in the context of next steps.

- Reviewer: G-026-01

- Rating: 3

The methodology to determine the viability of CO2 for EOR includes very comprehensive method from rock scale (thin sections, core plug analysis) to reservoir model (numerical simulation). The data integration from different scales will be challenging due to the characteristic of the Bakken formation but it will be achievable with the plan in place (Task I and Task II). In addition, most of the experiments are related to characterize the Bakken formation, rock and fluid properties. It will be essential to conduct special core analysis experiments to test CO2 recovery in the laboratory (maybe using centrifuge).

- Reviewer: G-026-03

- Rating: 4

Regarding the first comment, the investigators agree that in order for the project to be

considered a success the results must provide clear guidance with respect to future laboratory- and/or field-based activities. The philosophy of the EERC is to conduct research activities that provide practical results that can be directly applied to the real world. With this in mind the experimental and modeling activities described in the proposal will be performed in the context of next steps, particularly with respect to potential field-based work. The results of the project will also be evaluated in the context of next steps and the final report will include a section that discusses the results in terms of recommended paths forward.

- Applicant

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Oil and Gas Research Council goals will likely be:

Production from the Bakken Formation is one of the key contributors to the ND economics. Any attempt to enhance the production potentially has strong positive impact on ND industry. Thus, the intended project strongly supports NDIC and GRC goals.

- Reviewer: G-026-01

- Rating: 4

As stated in the Application, this technical work will build an essential foundation of knowledge to begin to understand how an EOR process may work in a tight fractured oil system like the Bakken. It will, however, be just a first step, and will require considerable followup technical and field experimentation before it is understood how well these processes will work technically, let alone economically. The NDIC expectations should be aligned with this fact, that the conclusions from this effort will be qualitative and directional, not conclusive and decision making, in nature.

- Reviewer: G-026-01

- Rating: 4

In the case of meeting the objective of the project: using CO<sub>2</sub> for EOR in the Bakken will result in increased ultimate recovery which is not only crucial as a technical and scientific contribution but also huge economic impact to North America oil and gas production from unconventional reservoirs which can be also applied to other unconventional plays in US.

- Reviewer: G-026-03

- Rating: 5

The investigators have no comments.

- Applicant

5. The background of the principal investigator and the awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is:

The PI has a strong research record. The discussion presented in the proposal provides the evidence that the PI has extensive experience with and excellent understanding of the Bakken. The literature review is adequate.

- Reviewer: G-026-01

- Rating: 4

The investigators in this project have an excellent combination of capabilities in reservoir characterization, EOR processes and CO<sub>2</sub> sequestration, all of which will be important to tackling this complex problem.

- Reviewer: G-026-01
- Rating: 5

The background of the principal participants is highly aligned with the objective of the project since their expertise area has been focused on Bakken through their previous studies. In addition, EERC has in-house capability for experimental studies and also team with skill sets for numerical modeling and experimental studies. Published literature in this area is very limited and this is why this project is challenging. However, EERC seems to follow the new experimental techniques which are already included in their laboratory plan such as VIT technique.

- Reviewer: G-026-03
- Rating: 4

The investigators have no comments.

- Applicant

6. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is:

The plan is very good. However, more detailed description of the milestones can further improve the proposal.

- Reviewer: G-026-01
- Rating: 4

The timetable and budget look well sequenced and include additional time and expense for the supporting activities for a multi-discipline project like this. As mentioned previously, the extremely tight and complex rock facies will tend to make these characterization activities difficult to finalize and move on to the next phase of the study. The tendency will be to keep reworking each activity beyond the original timeframe, which will delay the final integration and modeling efforts. It will be key to the project managers to recognize this issue and set expectations with each activity leader up front before each task.

- Reviewer: G-026-01
- Rating: 4

The details about timetable, budget and plan for required technologies are clearly stated. The only recommendation is to have additional time for economic analysis of the project at the end of the technical and laboratory studies and include time for any possible delays because of inter-dependent milestones such as not receiving lab results on time and couldn't perform simulation work as planned.

- Reviewer: G-026-03
- Rating: 4

The timetable on page 14 of the proposal lists the various subtasks of the project and the anticipated schedule associated with each. The initiation and completion dates for those

subtasks can each be considered to be a project milestone. More detailed descriptions of these subtasks are presented in Tables 1 and 2 of the proposal. Additional discussion of the subtasks and their relationships as milestones was not included in the proposal in order to keep the proposal within the 15-page limit. Frequent communication between project managers and the technical staff will ensure that each task is conducted in a timely manner and that results from each activity are integrated effectively and efficiently. The EERC's laboratory team and modeling team have a history of working together and have established strong professional relationships. Some key personnel have experience conducting both laboratory work and modeling, which will facilitate the development of experimental data that can be smoothly integrated into the modeling activities. While the investigators recognize the importance of economic analysis when considering the selection and implementation of an EOR scheme, the resources currently available to the project do not allow for any detailed, robust economic analysis. In the event that more resources should become available for the project then the investigators, in consultation with the industry partners, will consider adding an economic analysis component to the project.

- Applicant

7. The proposed purchase of equipment and the facilities available is:

No equipment to be purchased.

- Reviewer: G-026-01

- Rating: 5

The EERC equipment and facilities are excellent and should not be a hinderance to successful completion of the project.

- Reviewer: G-026-01

- Rating: 5

The capability in the Relevant Geology Laboratory, Natural Materials and Analytical Research Laboratory at EERC is well justified. With this capability and in-house experts, new set up or modifications required to work with very low permeability core plugs will be achieved. The HPHTOC apparatus need and its importance to the project success is also clearly emphasized.

- Reviewer: G-026-03

- Rating: 4

The investigators have no comments.

- Applicant

8. The proposed budget "value"<sup>1</sup> relative to the outlined work and the commitment from other sources is of

EERC requires NDIC to cover only 33% of the project cost. Some of the cost shate will come in the form of in-kind contributions.

- Reviewer: G-026-01

- Rating: 4

The project budget appears to be well detailed and includes other costs beyond labor. To

improve the quality of the budget a breakdown by each subtask, along with FTEs of each, would give more confidence. However, with good cost controls the project manager can track the costs and make adjustments along the way.

- Reviewer: G-026-01
- Rating: 4

Having the commitment of support from Bakken producers is notably good to show the value of the project and in the event of success of the project; today's investment will pay out more than its budget with the improved oil recovery in the Bakken. Even if the economic viability of CO<sub>2</sub> was not supported with the project, this would save so much time and investment for individual companies to do the same effort and would bring value to the industry for other possible innovative solutions.

- Reviewer: G-026-03
- Rating: 4

The investigators have no comments.

- Applicant

9. The “financial commitment”<sup>2</sup> from other sources in terms of “match funding” have been identified:

Please refer to Question 8.

- Reviewer: G-026-01
- Rating: 4

The other sources of funding, the EERC and the three producers are very strong partners. These producers are very strong technical companies and are leaders in advanced petroleum and/or EOR processes.

- Reviewer: G-026-01
- Rating: 5

No comment

- Reviewer: G-026-03
- Rating: 4

The investigators have no comments.

- Applicant

1 “value” – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar. A commitment of support from industry partners equates to a higher value.

2 “financial commitment” from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Support less than 50% from Industrial Commission sources should be evaluated as favorable to the application; industry partnerships equates to increased favorability.

## General Comments



The project is of good quality. However, the issues discussed in Question 2 seem to be significant. It might be suggested that the proposer include investment of the issues into the workplan. Since the proposer is creating a consortium, it could be beneficial to include ND Geological Survey and UND into the consortium.

- Reviewer: G-026-01

The proposed project is a significant first step in evaluating the potential of CO<sub>2</sub> EOR for increased oil recovery from the Bakken. This technology is probably one of the most likely methods to significantly improve the productivity of this resource. It is important to assess the potential of EOR early in the development of this resource, before infill drilling especially, because it will likely require different well and facilities designs. As stated previously, it is recommended to temper expectations about this study leading to "decision making" on CO<sub>2</sub> EOR viability. It will just be a first step, one that focuses on basic parameters at the laboratory and core level. A real home run will be if this project sets the stage for data gathering and field trials at the well and reservoir level. That is, if the lab work says: "it could work under these conditions" and the analysis says: "here are the data and field trials needed to confirm technical viability...", then the next step could rapidly follow-on this initial study and perhaps some full pilots could come in just a few years time. One specific suggestion to the investigators is to consider evaluating MMP for oil with not only 99.9% pure CO<sub>2</sub>, but also with CO<sub>2</sub> from the ND Gasification pipeline. This is a logical source of nearby CO<sub>2</sub>, but it has impurities that may negatively affect miscibility or other parameters. Would be good to know whether this supply is a non-starter for any reason. Overall, this project fits extremely well with the NDIC Oil and Gas Research Program. It begins the technical work on a process that could have a huge impact on the already significant Bakken resource. Funding is supported.

- Reviewer: G-026-01

Considering low recovery factor in the Bakken with primary production from hydraulically fractured horizontal wells, this project and its results may open a new era in unconventional plays by providing increased oil recovery even with a small improvement in ultimate recovery. Having a focused area based on the participating operators is very essential to the success since the learnings as well as readily available data through operators may be shared which will accelerate the project life. In addition, considering the heterogeneity in the Bakken reservoir in terms of reservoir and fluid properties, the three Bakken study areas will enable to test the viability of CO<sub>2</sub> in the different part of the Bakken. Although the use of CO<sub>2</sub> is widely applied in conventional reservoirs, it should be realized that this is a new technology in terms of application to very low permeability oil reservoirs so through the project, there may be changes in the plans due to the available technology and time required to complete the project such as experimental studies and very detailed reservoir modeling. In other words, we are still in the learning curve to produce from unconventional reservoirs with a primary recovery so possible changes in the scope of EOR project should be expected and understood while the new learnings will be integrated to the project during the life of the project.

- Reviewer: G-026-03